THE PITTSBURGH ORTHOPAEDIC JOURNAL

VOLUME 35, 2024

UNIVERSITY OF PITTSBURGH

Published by the residents and staff of the
Department of Orthopaedic Surgery,
University of Pittsburgh School of Medicine
orthonet.pitt.edu

University of Pittsburgh

THE PITTSBURGH ORTHOPAEDIC JOURNAL

2024 • Volume 35

ON THE COVER

Large photo: Human chondrocytes stained with lysosome-associated membrane proteins 1 and 2 (LAMP-1, -2) from the Joint Tissue Biology, Pathology, and Engineering Laboratory, led by department research faculty Dr. Hang Lin

Right photos (top to bottom):
Dr. Joon Lee and Orland Bethel celebrating their collaborative efforts to launch the Bethel Musculoskeletal Research Center

Dr. Anna Miller, visiting professor from Washington University School of Medicine in St. Louis, and Dr. George Russell, newly appointed chief of orthopaedic trauma at UPMC, standing in front of the bust of Dr. Ferguson

Dr. Boris Zelle, UPMC residency and trauma fellowship alumnus, receiving the American Academy of Orthopaedic Surgery 2024 Diversity Award

Mount Sinai Professor and Orthopaedic Department Chair Dr. Leesa Galatz in front of the bust of Dr. Fu during Resident Research Day

Dr. Hogan receiving the 2024 Chuck Cooper Foundation Leadership Award

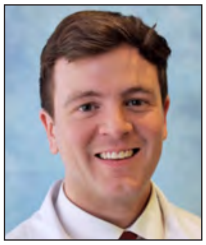
Instructions for Authors

The *Pittsburgh Orthopaedic Journal* is an annual publication by the Department of Orthopaedic Surgery at the University of Pittsburgh School of Medicine. The journal aims to serve as a vehicle for education and communication for those affiliated with the Pittsburgh orthopaedic community.

The journal welcomes submission by current residents, fellows, and faculty, as well as alumni and visiting students, fellows, and staff. Articles for consideration for the 2025 volume should be submitted to the *Pittsburgh Orthopaedic Journal* by March 1, 2025, at the address below. Specific formatting instructions for the text and figures of submitted articles will be announced by the journal editor in January 2025. The journal is distributed annually in June.

Please direct all inquiries and submissions to:
Editor, *Pittsburgh Orthopaedic Journal*
Department of Orthopaedic Surgery
University of Pittsburgh School of Medicine
3471 Fifth Avenue
Kaufmann Building Suite 1011
Pittsburgh, PA 15213

EDITOR'S NOTE



Jonathan Dalton, MD
Editor-in-Chief
2024 *Pittsburgh Orthopaedic Journal*

It is my privilege to present to you the 2024 edition of the *Pittsburgh Orthopaedic Journal* (*POJ*)! Following the tradition laid forth by previous editions, *POJ* represents the efforts of our department to contribute to the evolution of the field of orthopaedic surgery. Within these pages, we present the scientific endeavors, academic achievements, alumni community, altruism, camaraderie, and diligent work ethic of our orthopaedic team under the leadership of Chairman MaCalus V. Hogan, MD, MBA.

The cover of the journal again showcases highlights of the past year: Dr. Joon Lee and Orland Bethel celebrating their collaborative efforts to launch the Bethel Musculoskeletal Research Center; Dr. Anna Miller, visiting professor from Washington University School of Medicine in St. Louis, and newly appointed Chief of Orthopaedic Trauma at UPMC Dr. George Russell standing in front of the bust of Dr. Ferguson; Dr. Boris Zelle, UPMC residency and trauma fellowship alumnus, receiving the American Academy of Orthopaedic Surgeons 2024 Diversity Award; Mount Sinai Professor and Orthopaedic Department Chair Dr. Leesa Galatz in front of the bust of Dr. Fu during Resident Research Day; and Dr. Hogan receiving the 2024 Chuck Cooper Foundation Leadership Award. The main cover photo features human chondrocytes, illustrative of some of the incredible research work that truly sets the Department of Orthopaedic Surgery at the University of Pittsburgh apart.

Dr. Hogan's Chair's Corner kicks off the 2024 edition of *POJ*, highlighting many of the most substantial events from the past year. Building on that theme, the Special Reports section delves into greater detail on a litany of the most impactful events from the past year. This includes the announcement of the Bethel Musculoskeletal Research Center; the hiring of Dr. Russell as the new chief of the orthopaedic trauma division; and numerous impressive research grants, appointments to prestigious societies, and leadership positions.

POJ proceeds with a detailed update on the state of the residency program from directors Albert Lin and John Fowler. After what seemed like an eternity of virtual meetings and events during and after the COVID pandemic, the department continues to have in-person grand rounds, maintaining the strong Pitt Ortho tradition of dedication to resident education, research, and leadership. Along the lines of that theme, we were honored to have many extraordinary visiting professors, culminating with our 2024 Resident Research Day lecture from Professor Leesa Galatz, chair of the Department of Orthopaedic Surgery at Mount Sinai in New York. As in previous years, Resident Research Day recognized the clinical and basic science research performed by our residents currently engaged in their dedicated research year, as well as the graduating resident class with whom I have been privileged to work during my residency.

The Division Reports section displays the impressive breadth of surgical volume and clinical research being performed in each of our specialties within the orthopaedic department. One of the strengths of the Pitt Ortho residency is certainly the great clinical leaders who are recognized both within the City of Pittsburgh and nationally for their surgical acumen and orthopaedic expertise. In the Laboratory Reports section of *POJ*, Dr. James H-C Wang delivers the Orthopaedic Research Update, which details the scope and productivity of our basic science research laboratories. The following laboratory reports represent the diverse and truly incredible amount of scientific research that is done within the orthopaedic department.

POJ concludes with a Photo Gallery of our Pittsburgh orthopaedic family. We follow Dr. Hogan around the country, as he continues to devote his time to research, teaching, and international collaboration. Our department's commitment to excellence is again exhibited in a slew of orthopaedic meetings, conferences, and clinical settings. We try, however, to represent our faculty, trainees, and alumni in their lives outside the medical realm, as well—depicting and celebrating weddings, engagements, new additions to families (Young Orthopods!), and friendships that have formed over the past year and will endure for a lifetime.

Publication of the *POJ* would be impossible without the team behind the pages. I would like to personally thank the research staff, clinical faculty, fellows, and residents who dedicate so much time, energy, and effort to their craft and to the betterment of the orthopaedic academic community at large. I would like to specifically extend a thank-you to my predecessor Rick Wawrose, as well as Andrea Badway, Barbara Moore, Lisa Arrisher-Brown, Katie Morris, Noreen Corcoran, Amanda Sites, and the design and production team, led by Keightley Amen. Additionally, I would like to thank the medical students Jay Kashyap, Christian Cisneros, and Matt Como for their tireless work in helping make *POJ* a reality this year.

I would like to extend a special thank-you to my mother, Suzanne Dalton Kearins, who has supported me tirelessly through pre-med, medical school, and certainly throughout residency from afar in St. Louis, Missouri. I would not be in the position I am without her guidance and support. My passion for orthopaedic surgery began after I witnessed my father, Jon Dalton, sustain a devastating, limb-threatening orthopaedic injury when I was 12 years old. Over the subsequent months after that accident, I witnessed firsthand not only the power that orthopaedic surgery can have to improve a patient's life in a time of crisis, but also the importance of perseverance and tenacity in the face of hardship. I credit both my parents for fostering these values in me, and I am thankful every day for their presence in my life. I would also like to thank my loving and hard-working significant other, Dr. Ruby Hollinger, MD, MSc. It has been such an incredible experience to watch her accomplish so much in medical school and in her master's degree in London. I am thrilled about starting the next phase of our academic careers in Philadelphia together.

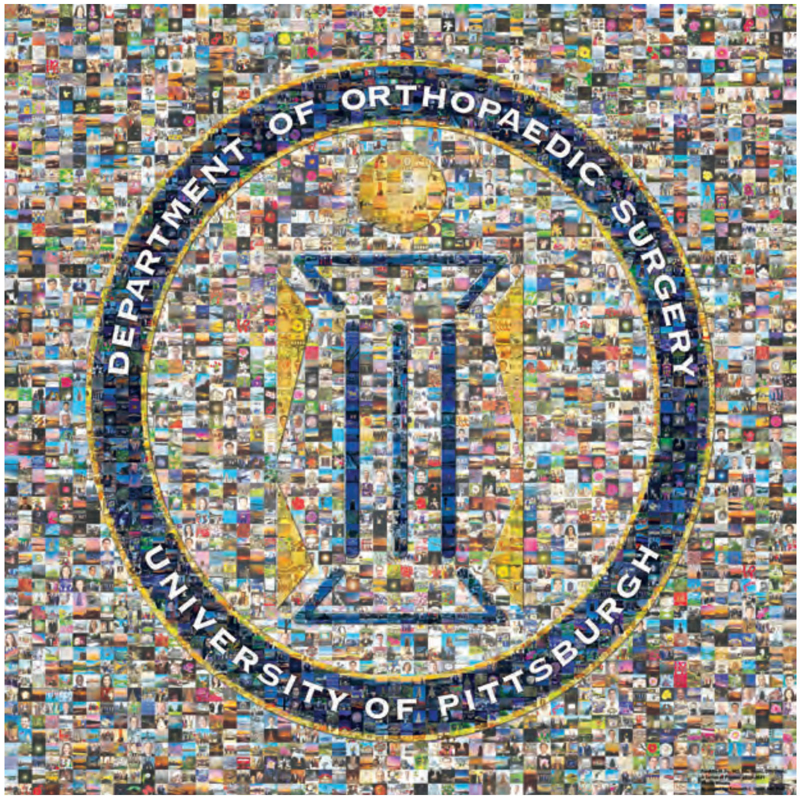
I would also like to thank Dr. Lee, Dr. Donaldson, Dr. Shaw, Dr. DeGroot, Dr. Smith, Dr. Silvaggio, Dr. Dede, Dr. Mendelson, and Dr. Ward. It has been an absolute honor to be able to train under your tutelage, and I credit you all with igniting not only my passion for spine surgery but also my dedication to spine research.

Lastly, I would like to extend a very heartfelt thank you to Dr. Hogan. Thank you for your support and guidance over the years, both as program director and as chair. It has been an honor living and working in Pittsburgh, and I hope that I have upheld the values instilled by Dr. Fu and continued under your leadership. Finally, I would like to thank my co-residents for being undeniably the best part of every workday and for making Pittsburgh feel like home over the past five years.

I hope that you enjoy the 2024 edition of the *Pittsburgh Orthopaedic Journal*!

Sincerely,

Jonathan Dalton



Kenneth L. Urish, MD, PhD, created this steel I-Beam collage by organizing more than 3,600 pictures from Chairman Freddie Fu that he saved since he started his faculty position within Pitt Ortho.

The steel I-Beam.
Since the turn of the century, this structural device has changed the way the world builds.

Today, the I-Beam stands as a symbol of strength and support
Reflecting the mission of the Orthopaedics Department:
To provide a structurally solid framework for the delivery of orthopaedic care,
To allow for the continued pursuit of excellence in resident education, and
To accept the ongoing challenge of developing new treatments in orthopaedics.

The steel I-Beam.
Since the turn of the century, this Pittsburgh creation has changed
The landscape of the world.
Today, it stands as our symbol of commitment to change
The landscape of orthopaedic care.

University of Pittsburgh Department of Orthopaedic Surgery
3471 Fifth Avenue, 1011 Kaufmann Building
Pittsburgh, PA 15213
412-605-3203

TABLE OF CONTENTS

University of Pittsburgh Department of Orthopaedic Surgery

2023–2024 – by the Numbers

Faculty and Trainees:

207

62 Clinical faculty
9 Research faculty
44 Residents
19 Fellows
39 Affiliated faculty
34 Joint/adjunct faculty

Fellowship Programs:

Adult Reconstruction
Hand
Pediatric Orthopaedics
Spine
Sports Medicine
Trauma
Shoulder and Elbow

Visiting Learners:

57

32 Visiting medical students
25 Visiting research fellows

Research:

101 active awards
$11,423,494 in federal and foundation funds
$544,049 in corporate support
$119,182 in other support
$12,086,726 in total
$2,388,973 in New Awards FY24

Surgical Case Volume:

9,368 ambulatory cases	**5,548** inpatient cases	**14,916** in total

12 Divisions:

- Adult Reconstruction
- Concussion
- Foot and Ankle
- General Orthopaedics
- Hand and Upper Extremity
- Musculoskeletal Oncology
- Pediatric Orthopaedics
- Podiatry
- Primary Care Sports Medicine
- Spine Surgery
- Sports Medicine
- Trauma

16 Research Centers and Labs:

- Anatomic Anterior Cruciate Ligament Reconstruction Group
- Arthroplasty Design & Outcomes Laboratory
- Biodynamics Laboratory
- Concussion Program Laboratory
- Ferguson Laboratory for Ortho and Spine Research
- Foot and Ankle Injury Research [F.A.I.R.] Group
- MechanoBiology Laboratory
- Musculoskeletal Oncology Laboratory
- Neuromuscular Research Laboratory
- Ortho Engineering Laboratory
- Orthopaedic Robotics Laboratory
- Outcome Research
- Shoulder and Elbow Mechanics Laboratory
- Tissue Engineering and Osteoarthritis Research Laboratory
- Surreality Lab
- Bethel Musculoskeletal Research Center

Interdisciplinary Department Collaborations:

- Anesthesiology
- Bioengineering
- Biostatistics
- Clinical and Translational Science
- McGowan Institute for Regenerative Medicine
- Mechanical Engineering and Materials Science
- Medicine
- Neurobiology
- Neurology
- Neurosurgery
- Pathology
- Pharmacology and Chemical Biology
- Physical Medicine and Rehabilitation
- Physical Therapy
- Plastic Surgery
- Rehabilitation Science and Technology
- Sports Medicine and Nutrition
- Surgery
- Surgery/Plastics

Sports Medicine Coverage:

2 professional teams
2 semi-professional/adult teams
1 professional ballet company
14 college/university teams and club sports
78 high schools
numerous tournament and youth sporting events
1 marathon and numerous races
1 Rush to Crush cycling event
1 Tier 1 junior level hockey
100s of injury-prevention programs

doximity

Doximity Orthopaedic Residency:

#10 in Reputation

#7 in Research

BEST HOSPITALS U.S.News & WORLD REPORT HONOR ROLL

US News & World Report Ranking:

High Performing

in adult orthopaedics

2024 CHAIR'S CORNER

MaCalus V. Hogan, MD, MBA
Professor and Chair, Department of Orthopaedic Surgery
University of Pittsburgh School of Medicine, UPMC

I am pleased to welcome you to this year's edition of the *Pittsburgh Orthopaedic Journal* (*POJ*), a testament to our commitment to excellence in orthopaedic care, education, and research. As chair of the Department of Orthopaedic Surgery at the University of Pittsburgh and UPMC, it is my honor to present this journal, which encapsulates our guiding principles and embodies our collective vision for the future of this department.

In my second year as chair, I am pleased to see that the themes and missions I chose for the department are coming to light. As Drs. Fu and Ferguson said before me, respecting the past is foundational to our identity. We stand on the shoulders of giants who have paved the way for advancements in orthopaedic medicine. Their legacy inspires us to embrace our future as a world-class orthopaedic department, push the boundaries of what is possible, and continually strive for excellence in patient care, education, and innovation.

Jim Grant, chief executive officer of Elizur, and Dr. Hogan congratulate the resident winners of the inaugural Freddie Fu Leadership Award for High School Community Service.

Speaking of that future, residents and fellows are the heart of our legacy. As educators, mentors, and colleagues, we are currently shaping the future of orthopaedic surgery through our residency and fellowship education programs. We understand the importance of nurturing the next generation of orthopaedic leaders, instilling in them not only clinical expertise but also the values of compassion, integrity, and lifelong learning.

To celebrate our residents who go above and beyond, this year marked the founding of the Freddie Fu Leadership Award for High School Community Service, graciously funded by Jim Grant, chief executive officer of Elizur, a musculoskeletal solutions industry leader. The award is given to residents who show a special affinity for their local high school sports group and who go the extra mile in patient care. Five residents were honored this year, and the Department of Orthopaedics, along with Jim Grant and Elizur, are proud to offer this award that highlights Dr. Fu's dedication to patient care and his willingness to always do something more.

We were pleased to once more have in-person residency interviews this year, our first since COVID-19. In all, we met with 88 outstanding applicants from 57 unique medical schools, including 35 women and 33 minorities who are underrepresented in medicine. We look forward to welcoming eight new residents this coming summer.

The graduating chiefs pose with Dr. Hogan and Dr. Galatz after Resident Research Day. H2P!

Residents and faculty attend a Pitt basketball game with Dr. Hogan.

Research is at the core of our identity. We know that scientific inquiry drives progress and innovation in orthopaedic care. We also know that early- to mid-career scientists are more increasingly faced with difficult choices regarding their ability to stay in academics.

With the founding of the Bethel Musculoskeletal Research Center (BMRC), we now can support those young and talented individuals in pursuit of translational research. You'll read more about how the BMRC will work to change how we approach the big questions and allow creativity to solve musculoskeletal problems with outside-the-box solutions.

Our relationships with patients, colleagues, alumni, and partners are paramount. We recognize the importance of trust, communication, and collaboration in providing exceptional orthopaedic care. Our commitment to amplify and project Pitt and UPMC orthopaedics forward extends beyond the confines of our institution, as we collaborate with community groups, alumni, and international partners. I am inspired by the connections we have made so far and the knowledge we've been able to gain and share.

We've worked hard this past year to strengthen our relationships with our Pitt Ortho alumni family and to share in their successes. Some notable accomplishments: C. Benjamin Ma, MD, was appointed chair of orthopaedic surgery at the University of California, San Francisco, and Boris Zelle, MD (residency '10, trauma fellowship '11) was awarded the 2024 American Academy of Orthopaedic Surgeons (AAOS) Diversity Award.

As we embark on this journey together, I am excited to see our reputation as one of the best orthopaedic departments in the world grow, guided by the dedication and integrity I have come to know and expect from the faculty and staff I am honored to lead. Together, we will continue to shape the future of orthopaedics, advancing patient care, education, and research for generations to come.

I send thanks to the editor of this year's edition, Jonathan Dalton, MD. His hard work has not gone unnoticed and has resulted in another amazing edition of our *POJ*. I extend my best wishes to all readers for an enriching experience while perusing this year's journal.

Education

Residents and fellows are our legacy. Our residency and fellowship programs continue to recruit and train a diverse group of talented men and women. Our residency program matches eight positions per year, for a current complement of 45 interns and residents.

Our faculty are committed to providing excellence in clinical care, a focused education in various subspecialties, and cooperative participation in innovative research. Continued expansion of the basic science faculty and development of a large facility for studying biomechanical and developmental aspects of musculoskeletal diseases have made our program one of the premier programs in the country.

The UPMC Orthopaedic Surgery Residency ranked in the top 10 of residency programs in the Northeast, according to Doximity Residency Navigator. The department also has 20 fellows pursuing specialty training in adult reconstruction, hand and upper extremity, pediatrics, primary care sports medicine, spine, sports medicine, and trauma.

We send congratulations to this year's medical students on successfully matching into programs across the country. Nicholas Aloi matched at UPMC Hamot Medical Center, Erie, Pennsylvania; Samantha Ashok matched at Temple University Hospital, Philadelphia, Pennsylvania; Noel Bien Carlos matched at University of Florida College of Medicine–Shands Hospitals, Gainesville, Florida; Confidence Njoku-Austin matched at University of Minnesota, Minneapolis, Minnesota; Gillian Kane and Elizabeth Plakseychuk matched at UPMC Medical Education, Pittsburgh, Pennsylvania; Rajiv Reddy matched at Hospital for Special Surgery, New York, New York; Dominic Ridolfi matched at Northwestern McGaw Medical Center, Chicago, Illinois; and Joshua Setliff matched at Virginia Commonwealth University Health Systems, Richmond, Virginia. Their dedication, hard work, and passion have led to this moment, and we couldn't be prouder of their achievements. We have no doubt that their skills, resilience, and enthusiasm will guide them to great success.

John Fowler, MD, with Shaquille Charles, MD, who received the Harold Henderson Sankey, MD, Award for excellence in orthopaedic surgery. Congratulations!

The 2023 Harold Henderson Sankey, MD, Orthopaedic Award was presented to Shaquille Charles, MD. This award was established in 1969 and is awarded to the outstanding senior medical student interested in the study of orthopaedic surgery. Harold Henderson Sankey, MD, for whom the Sankey Award is named, was one of the earliest orthopaedic surgeons to practice in Pittsburgh. In response to the growing poliomyelitis epidemic of the early 20th century, each county in Pennsylvania had its own children's clinic. Dr. Sankey ran a clinic northeast of the city and referred many patients to Pittsburgh's Children's Hospital. Dr. Sankey enjoyed working with the residents at Pitt and was passionate about education, and his students welcomed his lessons and insights. The H.H. Sankey Award has continued for more than 50 years as a testament to his interest in and commitment to orthopaedic education.

Research Activities

Research is at the core of our identity here at Pitt Ortho, and as we look back on the previous year's research, I am proud of what we have accomplished. Our active laboratories and research units have pushed boundaries and been celebrated in their respective disciplines, embodying our commitment to innovation and excellence in the wider realm of orthopaedics.

The Joint Tissue Biology, Pathology, and Engineering Lab (Hang Lin, PhD, director) fosters innovative and interdisciplinary research utilizing principles of life sciences and engineering to develop tools and techniques for studying the development, function, pathogenesis, and regeneration of musculoskeletal tissues. This past year, the lab was awarded a National Institutes of Health (NIH) R21 grant and published eight peer-reviewed articles, two of which published in journals with an impact factor greater than 10.

The Shoulder and Elbow Mechanical Research Lab (Christopher C. Schmidt, MD, director) published a landmark paper, "Relative Contributions of the Supraspinatus (SS) Cord and Strap Tendons to Shoulder Abduction and Translation" in the *Journal of Shoulder and Elbow Surgery* this year, showing that abduction force from a simulated SS cord tear can recover with full-load transfer to an intact SS strap tendon, and vice versa. Omar Rodriguez-Alejandro, MD, 2022–2023 fellow, presented the work at the annual meeting of the Orthopaedic Research Society (ORS) in February 2024.

The Arthritis and Arthroplasty Design Lab (Kenneth Urish, MD, PhD, director) was founded in 2016 with a mission to improve diagnosis and treatment of arthritis, focusing on joint arthroplasty. This year has been very productive for the lab, with more than 20 publications, 13 ORS abstracts, and a series of major grants. This includes a major CARB-X grant supporting the development of a new class of antibiotics that has recently moved into Food and Drug Administration phase 1b studies (#NCT05137314). Other new areas of support include a Small Business Innovation Research grant as well as a new R03 continuing our efforts in improving the diagnosis and treatment of osteoarthritis and outcomes after total knee arthroplasty. Finally, the group is very excited about its ongoing R01 support.

The Orthopaedic Robotics Laboratory (codirected by Volker Musahl, MD, and Richard E. Debski, PhD, both faculty in orthopaedic surgery and bioengineering) works to prevent degenerative joint disease by improving diagnostic, repair, and rehabilitation procedures for musculoskeletal injuries using state-of-the-art robotic technology. The lab received an R01 renewal from NIH for a longitudinal study titled "Predicting the Outcomes of Exercise Therapy for Treatment of Rotator Cuff Tears (POETT)." Dr. Musahl had a busy year, as he won the *Video Journal of Sports Medicine* Best Picture Award; joined the International Society of Arthroscopy, Knee Surgery, and Orthopaedic Sports Medicine Executive Committee; and entered the presidential line of the ACL Study Group. Congratulations to postdoctoral associate Luke Mattar, PhD, for receiving a 2024 New Investigator Recognition Award from ORS.

The MechanoBiology Laboratory (James H-C. Wang, PhD, director), supported by the Department of Defense (DoD), is working to identify HMGB1, a molecule known to be involved in tissue-damage signaling, as a crucial player in the onset of tendinopathy due to mechanical overuse. By blocking HMGB1 with metformin (Met), a common drug for the treatment of diabetes, we are developing a potential preventive and treatment strategy for tendinopathy. With DoD support, the lab is investigating the effects of a topical Met lotion on tendinopathy prevention and treatment in our established animal model of tendinopathy. Additionally, the lab is conducting a clinical trial to explore the use of Met for managing chronic tendinopathy through oral administration.

This was a productive year for the UPMC Sports Medicine Concussion Program and Concussion Research Lab (codirectors Amthony Kontos, PhD, and Michael Collins, PhD). Our faculty continue to lead the field of sport-related concussion, with Drs. Kontos and Collins being the first- and fourth-ranked researchers in the field (Tang et al., *World Neurosurgery*, 2022). In 2023, the lab was involved in 15 externally funded research projects, and our faculty and fellows published in numerous high-impact journals, including *Sports Medicine* (11.93) and *American Journal of Sports Medicine* (6.1). This was a banner year in research collaboration with our UPMC Concussion Network in Ireland, with three coauthored papers, including two studies on concussion in Ladies Gaelic Football Association players. A new joint PhD scholar resulted as the partnership among UPMC, the University of Limerick, and the Irish Rugby Injury Surveillance Program.

Our Orthopaedic Engineering and Sports Medicine Lab (Patrick Smolinski, PhD, director) has welcomed many new faces this past year, including students and seasoned researchers. The lab's main research area is the study of human joint and tissue behavior using mechanical engineering technologies to evaluate joint function, the effects of tissue injury, and surgical treatments. Matthieu Ollivier, MD, PhD, associate professor of orthopaedic surgery, Institute for Locomotion, Aix-Marseille University, Marseille, France, visited the lab to give a technical demonstration on tibial osteotomy.

The Ferguson Laboratory for Orthopaedic and Spine Research (codirected by Joon Lee, MD, Gwendolyn Sowa, MD, PhD, and Nam Vo, PhD) continues to expand the boundaries of basic and clinical spine research. The primary focus of the laboratory is to understand the biology of spine and other orthopaedic degeneration and to develop biological, biomechanical, and cell-based therapies for these pathological conditions. Drs. Vo, Lee, and Sowa were awarded an NIH R01 grant from the National Institute on Aging to study cellular senescence as a driver of disc aging. Postdoctoral fellow Prashanta Silwal, PhD, and Physician Scientist Training Program student James Kim continued the work on the mechanisms of disc cellular senescence and autophagy in age-associated intervertebral disc degeneration (IDD). In work funded by the NIH, Dr. Sowa investigates the correlation of biochemical and imaging biomarkers to IDD severity and pain. This work was selected for the International Society for the Study of the Lumbar Spine's 2022 Best Paper Award. The Ferguson Lab continues to carry out experiments in "LB3P: Low Back Pain Research Study, a Mechanistic Research Center," funded through a U19 award from the NIH HEAL (Helping to End Addiction Long-Term) Initiative.

Perhaps most exciting was the founding of the BMRC, which will promote transformative research to further study musculoskeletal disorders and will feature the core laboratories of the Ferguson Laboratory; the Joint Tissue Biology, Pathology, and Engineering Laboratory; Musculoskeletal Regenerative Rehabilitation Laboratory; Musculoskeletal Oncology Laboratory; Pittsburgh Orthopaedic Spine Research Group; Surgery of the Upper Extremity Research Group; Foot and Ankle Injury Research Group; Biodynamics Laboratory; and MechanoBiology Laboratory. Funding opportunities for early-career scientists to promote generation of critical preliminary data for breakthrough treatments will be awarded in fall of 2024. Renovation of BMRC core lab spaces in the Biomedical Science Towers has begun and will continue through 2026.

Tying research and education together, our talented researchers offer monthly seminars, spearheaded by Drs. Vo and Dr. Wang this year. We were pleased to host Yan Ma, PhD, chair and professor of the Department of Biostatistics at the University of Pittsburgh School of Public Health, to present a lecture on his group's statistical research interests in missing data imputation, machine learning, and meta-analysis, as well as the formation of collaborative research between his department and the Department of Orthopaedic Surgery.

As external grant funding continues to be highly competitive, our faculty continue to succeed in securing grant awards in support of their research efforts. For fiscal year 2024, our faculty have received grant awards totaling nearly $12 million from federal, foundation, state, industry, and other external sources.

This is just a small sample of our research achievements, and I invite you to investigate further into the journal this year for more detailed information on our labs and their work.

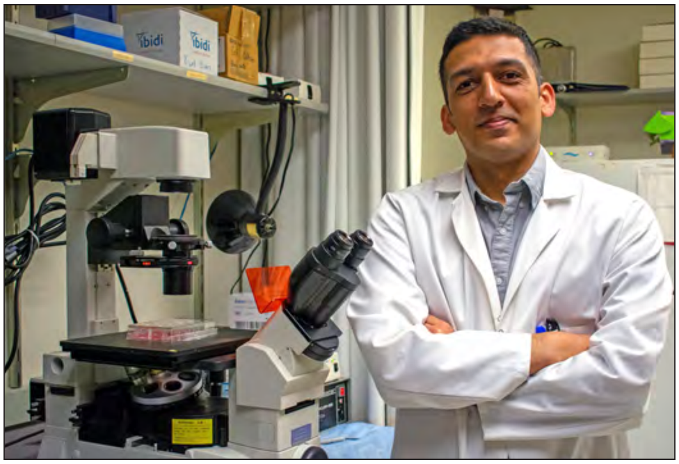
Other News and Events

Relationships are key to our success. As such, Pitt Ortho has continued our collaboration with local nonprofit AD99 Solutions. AD99's mission is to change the trajectory of under-resourced youth by providing education and resources in supportive and safe environments, so they are empowered academically, socially, and athletically. As valued partners, we eagerly anticipate the opportunities that lie ahead and the positive impact we can create together. One highlight from our collaboration in 2023 was the extraordinary Mental Flex Forum held in May. The event, hosted at the Freddie Fu Sports Complex, brought together a diverse community of student-athletes, coaches, and healthcare professionals.

UPMC Orthopaedic Care partnered with CNX Foundation to launch UPMC/CNX M.O.V.E.S. (Motivation, Opportunity, Value, Experience, Success) in 2023. The initiative aims to expand career opportunities for students from the CNX Mentorship Academy into the healthcare sector. Since the founding of the initiative, various UPMC facilities have hosted tours and discovery days for local high school students, including UPMC Magee-Womens Hospital and the UPMC Freddie Fu Sports Medicine Center.

Our commitment to improving diversity and inclusion of unrepresented portions of our community continued this year with our participation in the NFL Diversity in Sports Medicine Pipeline Initiative. The initiative aims to increase diversity in the pipeline of students interested in pursuing careers in sports medicine to help make a positive impact in the medical field and to help diversify NFL club medical staffs over time. Warren Austin, a third-year medical student and mentee of MaCalus V. Hogan, MD, MBA, was the first local participant in the program and divided his time between the training facility at St. Vincent College in Latrobe and the clinic at the UPMC Rooney Sports Complex.

The UPMC Sports Medicine Concussion Program and the University of Pittsburgh Concussion Research Laboratory hosted the Targeted Rehabilitation and Evidence-Based Active Treatments (TREAT) Sport-Related Concussion Conference.



Postdoctoral fellow Prashanta Silwal, PhD, works at the Ferguson Lab.

MaCalus Hogan, MD, MBA; Dean Anantha Shekhar, MD, PhD; Orland Bethel; and Joon Lee, MD, present the commemorative plaque introducing the Bethel Musculoskeletal Research Center.

We were thrilled to be able to bring back the in-person Department of Orthopaedic Surgery Welcome Picnic in 2023, hosted at Acrisure Stadium. Dr. Fu started the tradition of welcoming staff, faculty, and new residents and fellows each year for a casual get-together. This year marked our first welcoming picnic since the pandemic, and Dr. Hogan’s first as chair. There was delicious food, a caricature artist, face painting, and games for children and adults alike. The weather cooperated as well, with the rain stopping right as the party kicked off.

In November 2023, the University of Limerick (UL) and UPMC announced a new strategic research partnership to advance knowledge and understanding on the treatment of concussion. The Irish Rugby Injury Surveillance project, based at UL, ultimately aims to increase understanding of concussion and its treatment to enhance player health and welfare. The partnership will involve the appointment and full funding of a PhD scholar who will split research time between the Sport and Human Performance Research Centre in UL under the direction of Tom Comyns, PhD, OLY, Ian Kenny, PhD, and John Mulvihill, PhD, and UPMC Pittsburgh under the guidance of internationally renowned experts in sports-related concussions, Drs. Collins and Kontos.

Department Awards and Events

The department was well represented at the Arthroscopy Association of North America conference in New Orleans, May 4–6, 2023. Dr. Hogan served as the Diversity Lecturer with his presentation on “A M.A.P. … Messages and Pearls from an Unexpected-Unfinished Journey.” Stephanie Boden, MD, and Shaquille Charles, MD, won the Diversity Research Award, and Albert Lin, MD, received the Richard J. O’Connor Research Award for Best Overall Paper.

The Department of Orthopaedic Surgery and UPMC Sports Medicine were in full force for a phenomenal American Orthopaedic Society of Sports Medicine (AOSSM) meeting, held July 13–16, 2023. In addition to multiple posters, instructional course lectures, presentations, and moderated sessions, the team brought home several awards:

- Ting Cong, MD: Fellow Best Clinical Science Award
- Stephanie Boden, MD: Excellence in Research Award
- James P. Bradley, MD: George D. Rovere Education Award
- Dr. Musahl’s sports medicine team: the inaugural *Video Journal of Sports Medicine* Best Picture Award
- Jonathan Hughes, MD: Steven P. Arnoczky Young Investigator Grant, which provides $40,000 to support clinical and basic science research for early-career principal investigators

Fritz Steuer (MS4) took home the Best Fellow/Resident/Medical Student Award at the 2023 Orthopaedic Summit in Boston, held September 20–23. Steuer represented research performed by Dr. Cong, Dr. Charles, Mike Fox, MD, Gabrielle Fatora, MD, and the Pittsburgh Shoulder Institute. Dr. Lin was on hand to celebrate and represent a truly awesome group from the Department of Orthopaedic Surgery.

Kevin Colbert, former general manager of the Pittsburgh Steelers, provided an outstanding launch to our annual grand-rounds programming in September. A Pittsburgh native, Colbert spoke on his experience with the Pittsburgh Steelers from 2000 to 2021. Colbert is widely credited with building the recent Super Bowl–winning teams and was named the Steelers’ first-ever general manager in 2010.

Dr. Hogan was this year’s medical honoree at the Arthritis Foundation’s annual Bone Bash, held in October 2023. The Bone Bash Gala is one of the largest fundraising events of the year for the Arthritis Foundation. Attended by many members of Pittsburgh’s medical, professional, and social communities, the evening honors those living with arthritis and their medical providers.

Kurt Weiss, MD, was honored by the Jerome Bettis Bus Stops Here Foundation at the 16th annual Caring for Kids Gala. The foundation gifted a generous $10,000 to the Musculoskeletal Oncology Lab, which Dr. Weiss directs. The annual gala features a dinner and auctions, which help raise funds for the foundation’s work with underserved children in the City of Pittsburgh and across western Pennsylvania.

The American Academy of Orthopaedic Surgeons (AAOS) hosted its annual meeting February 12–16, 2024, in San Francisco, California. Numerous members of the UPMC Department of Orthopaedic Surgery attended and contributed to meaningful sessions, interactive lectures, courses, and workshops focused on the latest breakthroughs in orthopaedics across all specialties and career stages. We send a special congratulations to Dr. Zelle (Residency ’10, Trauma Fellowship ’11), who was awarded the AAOS Diversity Award, and Noreen Corcoran, academic manager, for her nomination as 2024 Coordinator of the Year.

UPMC Orthopaedic Care partners with the CNX Foundation to launch UPMC/CNX M.O.V.E.S. (Motivation, Opportunity, Values, Experience, Success). Shown here is an educational tour of UPMC Magee-Womens Hospital, aimed at expanding healthcare career exposure and opportunities for local high school students.

A joint grant partnership among the new BMRC, Department of Orthopaedic Surgery, and ORS was announced at the 70th Annual ORS meeting, held in Long Beach, California. The grants, equaling $50,000, will support early- and mid-phase clinician-scientists in pursuing and continuing careers in translational research. More than 100 applicants applied for the inaugural class of Bethel Fellows, which will be announced in fall 2024.

Dr. Mattar, a postdoctoral associate in the Department of Orthopaedic Surgery, was awarded a 2024 ORS New Investigator Recognition Award. Dr. Mattar's work focuses on predicting the outcome of exercise therapy for the treatment of rotator cuff tears, utilizing *in vivo* kinematic analyses and various other parameters.

Dr. Urish was selected as one of the University of Pittsburgh's Health Sciences Ascending Star awardees for 2024. This honor was established in 2022 to recognize highly productive, creative mid-career faculty members in the six schools of the health sciences. Dr. Urish is a fellowship-trained adult reconstruction and arthroplasty orthopaedic surgeon. As an associate medical director at the Magee Bone and Joint Center, his practice focuses on primary and revision hip and knee arthroplasty. He is also the director of the Arthritis and Arthroplasty Design Laboratory.

Congratulations to Gary Gruen, MD, on his retirement in December 2023. Dr. Gruen dedicated his life to healing and improving the lives of countless patients over his 34-year career. His commitment to excellence, compassionate care, and surgical expertise have left a mark on his colleagues in the department and the communities he served. Dr. Gruen will be greatly missed, but we wish him a retirement filled with relaxation and joy.

Dr. Hogan and Dr. Lin brought their families to the Department of Orthopaedic Surgery Welcome Picnic at Acrisure Stadium.

The UPMC Sports Medicine Concussion Program and University of Pittsburgh Concussion Research Laboratory hosted the Targeted Rehabilitation and Evidence-Based Active Treatments (TREAT) Sport-Related Concussion Conference on April 20–21, 2024. The conference provided cutting-edge advances in evidence-based clinical care and research from assessment to treatment for both sport-related concussion and brain health. Course directors included Dr. Collins, clinical and executive director of the UPMC Sports Medicine Concussion Program, and Dr. Kontos, research director, vice chair of clinical research, and professor, UPMC Sports Medicine Concussion Program.

New Faculty

George Russell, MD, MBA, joined the department as professor and chief of orthopaedic trauma, associate chief of surgical quality at UPMC, and executive vice chair in the Department of Orthopaedic Surgery in November 2023. He earned his medical degree at the University of Cincinnati and was part of the Department of Orthopaedic Surgery at University of Mississippi Medical Center, serving as chair from 2013–2022. He was later honored as the inaugural recipient of the James L. Hughes, MD, Endowed Chair and in 2021 assumed the role of chief executive officer of University Physicians. Dr. Russell is one of the nation's leading orthopaedic trauma surgeons, recognized as an expert on obesity in orthopaedics. His creation of the clamshell osteotomy has been widely used to correct malunions. He has authored and coauthored many publications, and he has presented both nationally and internationally on his specialty of orthopaedic trauma.

The University of Limerick and UPMC have partnered in a research capacity to investigate the pathophysiology and treatment of concussion.

Dr. Musahl attends a Keystone Theater event with Smith & Nephew at the American Orthopaedic Society for Sports Medicine annual meeting.

Tyler Petersen, DO, joined the department as a clinical assistant professor in the Division of Trauma Surgery in August 2023. Dr. Petersen earned his osteopathic medical degree at the Western University of the Health Sciences in 2017. He completed an orthopaedic surgery residency at Good Samaritan Regional Medical Center in June 2022 and recently completed fellowship training in trauma surgery at UPMC.

Dr. Kate Steklachich, DPM, joined the department as a clinical assistant professor in the Division of Podiatry, effective August 1, 2023. Dr. Steklachich earned her podiatric medical degree at Ohio College of Podiatric Medicine in 2008. She completed residency training in foot and ankle surgery at UPMC in 2011, as well as an Irvine Multi-Specialty Surgical Care (IMSC) sports medicine fellowship in 2014. She previously practiced as a podiatrist at Kaiser Permanente in San Diego, California.

Faculty Awards

Jeanne Doperak, DO, was awarded the distinction of American Medical Society for Sports Medicine (AMSSM) Fellow. AMSSM was formed in 1991 to provide a forum to foster professional relationships among sports medicine physicians to advance the discipline of sports medicine through education, research, advocacy, and excellence in patient care. The designation of Fellow of AMSSM (FAMSSM) was created in 2019 to recognize sports medicine physicians who have demonstrated an ongoing commitment to lifelong learning, advancement of the profession, service to AMSSM, and leadership in their communities. Conferred on sports medicine physicians who meet specific academic, practice, and service requirements, the FAMSSM designation can only be used by Fellows in good standing.

Dr. Cong and Fritz Steuer receive the Orthopaedic Summit award for best overall paper. Congrats!

Chief of Sports Medicine Dr. Musahl entered the presidential line of the ACL Study Group during the Biennial Meeting in Niseko, Japan. Dr. Hughes was inducted as a new member of this invitation-only group.

F. Johannes Plate, MD, PhD, a member of the American Association of Hip and Knee Surgeons (AAHKS) Research Committee, was selected as AAHKS Health Policy Fellow and invited to the Business of Joint Arthroplasty Course.

Adolph J. Yates Jr., MD, was recognized at the *Journal of Arthroplasty*'s Elite Reviewer Reception and received a Best Reviewer Award from the journal's editor-in-chief.

Kevin M. Bell, PhD, and Michael P. McClincy, MD, won a Pitt Innovation Challenge prize for their work on developing CuffLink, a telehealth rehabilitation platform that combines the safety of mechanical motion exercise equipment with motion tracking and remote monitoring. CuffLink provides a solution for the nearly 530,000 annual surgical shoulder patients who often exhaust their insurance-allotted outpatient physical therapy visits. The added remote monitoring capabilities allow early rehabilitation to move home, saving outpatient physical therapy visits for later in recovery, when hands-on treatment is most valuable.

Craig Mauro, MD, was appointed chair of the Fellowship Committee for the American Orthopaedic Society for Sports Medicine. Dr. Mauro will serve for two years, beginning in July 2024.

Visiting Professors

The Albert B. Ferguson Jr., MD, Resident Research Day marked yet another remarkable year of research for Pitt Ortho residents. For this year's presentations, we welcomed Leesa M. Galatz, MD, as keynote speaker. Dr. Galatz is professor and chair at the Leni and Peter May Department of Orthopaedic Surgery, Icahn School of Medicine, at Mount Sinai, in New York, New York. Dr. Galatz's talk was titled "Lessons in Leadership: Have It All, Just Not All at Once."

Our program is one of a few in the United States that offers the opportunity for residents to participate in one year of dedicated research during their residency training. Twelve residents (four junior and eight chief) gave presentations on their research work and were judged by Dr. Galatz. The following awards were given:

Best Junior Presentation

"Intraoperative Evaluation of Bone and Soft-Tissue Sarcoma Surgical Margins with Indocyanine Green Fluorescence Imaging"
Clark Roth, MD
Faculty advisors: Kurt Weiss, MD, and Ines Lohse, PhD

Best Senior Presentations

"Bariatric Surgery Results in Increased Failure Rates and Inferior Patient Reported Outcomes after Arthroscopic Rotator Cuff Repair"
Michael Fox, MD
Faculty advisors: Bryson Lesniak, MD, and Albert Lin, MD

"VEGF-Neutralized Platelet-Rich Plasma with Adipose-Derived Stromal Vascular Fraction Enhanced Osteochondral Repair in a Point-of-Care Goat Model"
Benjamin Rothrauff, MD, PhD
Faculty advisors: Rocky Tuan, PhD, and Freddie Fu, MD

Dr. Weiss celebrates with University of Notre Dame alumnus and Hall of Fame Steelers running back Jerome Bettis at the Bus Stops Here Foundation 16th annual Caring for Kids Gala. Dr. Weiss received a $10,000 award for the Musculoskeletal Oncology Lab.

Drs. Lee, Hogan, and Weiss join current research residents at the Orthopaedic Research Society annual meeting.

New Residents

Our tradition of attracting the best and brightest continued in 2024 as we matched eight outstanding medical students to our residency program. We are pleased to report that our incoming interns who matched on the clinical track are Sandra Catanzaro, State University of New York–Upstate; Elizabeth Clayton, University of Tennessee; Henson Destiné, University of Miami; and Gillian Kane, University of Pittsburgh. On the research track, we welcome John Bonamer, University of Cincinnati; Sahil Dadoo, University of North Carolina; Lawrence Garvin II, Howard University; and Elizabeth Plakseychuk, University of Pittsburgh.

In Memoriam

We extend our deepest sympathies to our orthopaedic family members who have lost loved ones over the past year. May they rest in peace.

Pitt Ortho alumnus Andy Wissinger, MD, passed away peacefully at his home on August 3, 2023. He was a month from his 93rd birthday. Dr. Wissinger was a great surgeon, leader, and mentor of orthopaedics. Many reflected on the difficult cases he would undertake and his multiple Golden Apple Awards as best educator to graduating classes.

Dr. Wissinger served as chair of orthopaedics at St. Francis and St. Margaret. He also served as the president of Oakland Orthopaedics (now Greater Pittsburgh Orthopaedic Association, or GPOA). He was a national leader in our field, serving on the boards of AAOS and American Orthopaedic Association, as well as editor of the *Journal of AAOS Global Research and Reviews* (the Blue Journal). His contributions to the field further led to the development of the Wissinger rod.

He was a legend and a reflection of the best of Pitt Orthopaedics. He is sorely missed.

Dr. Gruen at his retirement party. Congratulations, Dr. Gruen, and thank you for everything!

Personal Notes
The department enjoys sharing the news of success for both our current faculty and alumni. Please continue to keep us up to date on any exciting news. In turn, we'll continue to share that information throughout the year. It is a great way to keep us all connected from all corners of the country and world. We welcome ideas to improve our communication with all of you, so please keep your suggestions coming! Also, if your contact information changes over the year, please send us a note so we can update our alumni database.

Best wishes to you in the coming year. If your travel brings you through the Pittsburgh area, please be sure to say hi. We are always happy to welcome visitors.

Promotions
Dr. McClincy was promoted to associate professor of orthopaedic surgery in January 2024.

Jeremy Shaw, MD, was promoted to associate professor of orthopaedic surgery in February 2024.

Jianying Zhang, PhD, was promoted to research professor of orthopaedic surgery in March 2024.

Alumni Honors
Ronald A. Navarro, MD (Pitt sports medicine and shoulder surgery fellow '95–'96), has recently been installed as president of the American Association of Latino Orthopaedic Surgeons. Dr. Navarro's dedication to promoting care for the Hispanic population in the United States is commendable, and his appointment as director for clinical affairs at the Kaiser Permanente Bernard J. Tyson School of Medicine further underscores his commitment to advancing healthcare equity.

Brian Cole, MD, MBA (Pitt sports medicine fellow '96–'97), was recently named chair of the Department of Orthopaedic Surgery at RUSH University Medical Center in Chicago, Illinois. Dr. Cole has demonstrated remarkable leadership as a professor and managing partner of Midwest Orthopaedics at RUSH and at RUSH University Medical Center, where he has served as head of the Cartilage Restoration Center for nearly three decades. His leadership extends beyond academia, as evidenced by his presidency of the Arthroscopy Association of North America and his longstanding tenure as head team physician for the Chicago Bulls.

Visiting professor Dr. Galatz attends the welcome dinner prior to Resident Research Day.

The University of Pittsburgh Alumni Association would like to congratulate the graduating Class of 2024 for completing their residencies and would like to welcome them to the Alumni Association.

BETHEL MUSCULOSKELETAL RESEARCH CENTER at the University of Pittsburgh

GENEROUS DONATION FUNDS NEW MUSCULOSKELETAL RESEARCH CENTER

The Bethel Family Musculoskeletal Research Center (BMRC) was officially launched in January 2024 through the generosity of Mr. Orland Bethel, the founder of Hillandale Farms. Mr. Bethel is a patient of Joon Y. Lee, MD, professor of orthopaedic surgery in the University of Pittsburgh School of Medicine, clinical director of the Ferguson Laboratory, and executive director of the BMRC.

Mr. Bethel's generous donation was matched by the University of Pittsburgh School of Medicine, elevating its study of musculoskeletal disorders, including degenerative arthritis; fragility fractures; and cartilage, tendon, and spinal pathology. The center will attract and retain top scientists and advance leading-edge research, making musculoskeletal medicine a major focus at the University of Pittsburgh Health Sciences, alongside cancer and neuroscience.

What began as seeking care for incapacitating pain has become a transformative gift to benefit future patients, researchers, educators, and physicians. Suffering from severe spinal pain, Mr. Bethel's search for treatment led him to Dr. Lee. Mr. Bethel received relief after successful surgery and treatment, and he now enjoys restored function and motion.

Orland Bethel with Gwendolyn Sowa, MD, PhD, and Nam Vo, PhD

Orland Bethel with Afshan Rizvi, MD, and her husband; Joon Lee, MD, and his wife; and James Wang, PhD

Orland Bethel, founder of Hillandale Farms and benefactor of the Orland Bethel Family Musculoskeletal Research Center

MaCalus Hogan, MD, MBA, and his wife at the BMRC celebration

Dr. Lee with the Orthopaedic Research Society announcement poster

Dr. Lee with Orthopaedic Research Society Chief Executive Officer Sharon Smith-Terry, MBA, CDM

Gwendolyn Sowa, MD, PhD, Orland Bethel, and Nam Vo, PhD

BETHEL MUSCULOSKELETAL RESEARCH CENTER
at the University of Pittsburgh

"My family and I are pleased to offer our support to the spectacular work of Dr. Joon Lee and the other surgeons, physicians, and researchers within the department led by Dr. MaCalus V. Hogan through the creation of the Bethel Musculoskeletal Research Center," Bethel said. "I know how the University of Pittsburgh and UPMC changed my life and can only imagine how the lives of others—worse off than I was—will be improved thanks to the ongoing research at this new center."

The primary focus of the BMRC is to support early-career researchers and trainees so that their ideas and talents can produce breakthrough treatments for musculoskeletal ailments.

The BMRC's second focus is to support the education of young undergraduate, PhD, and medical students in pursuit of translational research. The center will provide funding for research interests in the early stages of education in the hopes of fostering and propagating future career scientists.

The third focus is the dissemination of knowledge. The first annual BMRC research symposium is currently being planned, along with other research seminars and meetings.

A reception at Alan Magee Scaife Hall on Oct. 27, 2023, celebrated the establishment of the BMRC in the School of Medicine. Speakers included Dean Anantha Shekhar, Dr. Hogan, Dr. Lee, and Mr. Bethel.

BMRC opened funding opportunities for Bethel Fellows in February 2024, along with the announcement of a joint partnership with the Orthopaedic Research Society (ORS) at its 70th annual meeting in Long Beach, California. The BMRC/ORS grants offer two levels of support: one for postdoctoral scholars or medical residents and one for junior faculty members. Initial application numbers were outstanding, and the level of interest from the community garnered more than 100 applicants from around the country.

Spring 2024 saw the first cohort of students for the BMRC Summer Student Research Program (BSSRP). BSSRP provides undergraduate and medical students from within and outside the University of Pittsburgh the opportunity to get hands-on laboratory experience with mentorship. Five students will receive training in research methods while in BMRC labs.

The BMRC core laboratory will be temporarily housed in the Riviera Building on Technology Drive. The permanent location, the 16th floor of the Biomedical Science Tower, will undergo extensive renovation and is scheduled to open in 2025.

BETHEL
MUSCULOSKELETAL
RESEARCH CENTER
at the University of Pittsburgh

Dr. Hogan and Dr. Lee with Orland Bethel, founder of Hillandale Farms, and the key benefactor of the Bethel Musculoskeletal Research Center

Dr. Lee, Orland Bethel, Dr. Hogan, and their spouses celebrating the announcement of the Bethel Musculoskeletal Research Center

Joon Lee, MD, and MaCalus Hogan, MD, MBA, at the entrance to the annual Orthopaedic Research Society meeting

Chair MaCalus Hogan, MD, MBA, delivering a speech at the Bethel Musculoskeletal Research Center welcome night

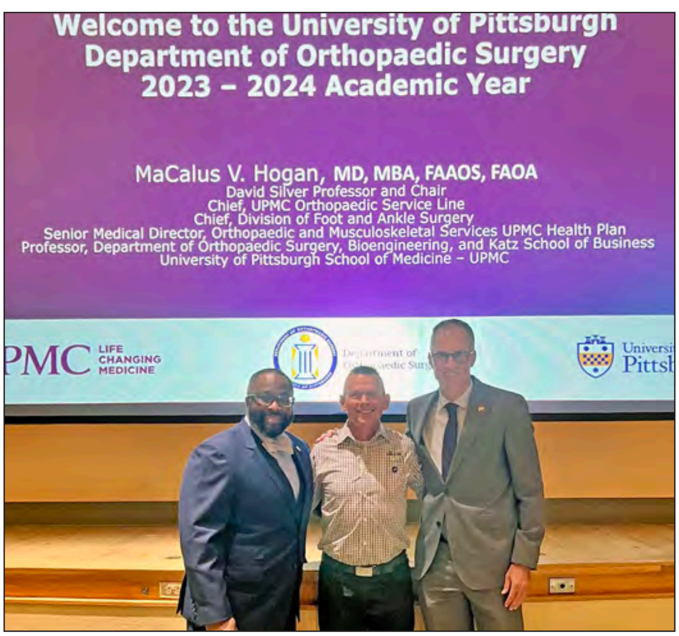
Dean Anantha Shekhar, MD, PhD; Orland Bethel; and Joon Lee, MD, at the announcement of the Bethel Family Musculoskeletal Research Center

Dr. Lee and Dr. Hogan with the Orthopaedic Research Society announcement poster

FREDDIE FU LEADERSHIP AWARD FOR HIGH SCHOOL COMMUNITY SERVICE

Jim Grant, chief executive officer of Elizur, University of Pittsburgh Class of 1984, has graciously decided to fund the Freddie Fu Leadership Award for High School Community Service. This award, presented annually, will recognize residents who distinguish themselves in terms of dedication to their high school sports groups by going above and beyond in patient care and work ethic. Nominations for the award will come from high school athletic trainers or peers and other academic staff. Recipients of the Freddie Fu Leadership Award for High School Community Service will receive $15,000, and as many as five residents can be recognized per academic year.

This award is perfectly in line with carrying on the legacy of Freddie Fu, MD. Dr. Fu was one of the pioneers in establishing the close relationship between UPMC Sports Medicine and high school football in western Pennsylvania. This relationship spans all the way back to 1982, when Dr. Fu's tireless support for Mount Lebanon High School bridged a substantial gap in available on-field medical resources for football at that time. Dr. Fu, along with support and guidance from his UPMC orthopaedic chairman at that time, Albert B. Ferguson Jr., helped to establish the presence of key emergency medical personnel and an ambulance on site at every game. These efforts expanded into organizing the first high school athletic training program in western Pennsylvania. This establishment was responsible for ensuring that healthcare providers would be present to provide coverage at all high school football games. Additionally, UPMC subsequently partnered both with former Pittsburgh Steelers player Andy Russell's charity and with Pittsburgh Public Schools Director of Athletics George Cupples in order to provide financial resources and coordination to ensure that medical coverage would be equally afforded to both economically privileged suburban districts and economically disadvantaged districts. Thus, the Freddie Fu Leadership Award is a fitting testament to Dr. Fu's enduring legacy of going above and beyond to provide excellent sports medicine care for all.



MaCalus Hogan, MD, MBA, and Volker Musahl, MD, pose with Jim Grant, chief executive officer of Elizur.

AAHS TRAVEL SCHOLARSHIP

Morgan Kohls, MD, was the recipient of the American Association for Hand Surgery (AAHS) Annual Meeting Travel Scholarship. This award supports resident, fellow, and active miliary members' participation at the 2024 AAHS Annual Meeting. Dr. Kohls presented her poster titled "Computed Tomography-Based Humeral Templating for Uncemented Elbow Arthroplasty" at the 2024 AAHS meeting, which was held in Nassau, Bahamas. Congrats to Dr. Kohls!

Residents Colin Beckwitt, MD, Morgan Kohls, MD, and Maria Munsch, MD, have dinner with their significant others at the American Association for Hand Surgery annual meeting.

PITT ALUM BORIS A. ZELLE RECEIVES AAOS 2024 DIVERSITY AWARD

Dr. Boris Zelle, MD, FAAOS, FAOA, (UPMC orthopaedic surgery resident '10; trauma fellowship '11) received the American Academy of Orthopaedic Surgeons (AAOS) Diversity Award during the annual meeting in San Francisco, California. This award honors AAOS active fellows and emeritus members who have shown substantial commitment to promoting inclusion and accessibility of orthopaedic surgery for diverse populations.

Dr. Zelle is currently the vice chair of research and the chief of orthopaedic trauma at UT Health San Antonio. Within his clinical duties, a substantial portion of his patient population are from traditionally medically underserved groups. These individuals face challenges such as language barriers, difficulty accessing health care, food insecurity and malnutrition, and often fear and mistrust toward the medical establishment. Dr. Zelle approaches the care of these patients with compassion and dedication.

In addition to direct clinical service, Dr. Zelle has been involved in numerous diversity efforts at the local, state, and national levels. These include previously serving on the AAOS Diversity Advisory Board, working with the Texas Joint Admission Medical Program, and establishing a program focused on detecting and addressing food insecurity amongst trauma patients at his home institution at UT Health San Antonio.

Dr. Zelle has been a prolific researcher and has a particular interest in a data-driven approach to examining the effects of healthcare disparities and culturally competent care. Finally, Dr. Zelle has been a tireless mentor for numerous students, residents, and fellows who come from an array of backgrounds. In particular, Dr. Zelle created a one-year research fellowship at his home institution that has routinely included groups traditionally underrepresented in orthopaedic surgery. Congrats to Dr. Zelle on this award and on all of his incredible work!

UPMC WELL REPRESENTED AT CSRS 2023

The Cervical Spine Research Society (CSRS) hosted its 51st annual meeting and 28th Instructional Course in Las Vegas, Nevada, from November 29 to December 2, 2023. At the meeting, several attendees from UPMC were recognized for recent accomplishments. Both Jonathan Dalton, MD, and Josh Adjei, MD, received Annual Meeting Travel Scholarships. The awards, which are partially funded by Medtronic, cover all expenses associated with attending the conference and include invitation to a Fellow Scholarship Dinner.

Additionally, Jeremy Shaw, MD, accepted a seed/starter grant as the primary investigator on a project titled "*In Vivo* Changes in Disc Stress and Stiffness after One- and Two-Level Cervical Arthrodesis." The goal of this $25,000 grant is to provide seed-starter funding for promising research for young investigators. Congratulations to Dr. Shaw!

Left to right: Residents Josh Adjei, MD, and Jay Dalton, MD, pose with their travel fellowship awards at the Cervical Spine Research Society annual meeting.

Jeremy Shaw, MD, poses with the award for his seed/starter grant at the Cervical Spine Research Society annual meeting.

MACALUS HOGAN RECEIVES CHUCK COOPER FOUNDATION LEADERSHIP AWARD

MaCalus Hogan, MD, MBA, was recently awarded the 2024 Chuck Cooper Foundation Leadership Award. The Chuck Cooper Foundation is a 501(c)(3) non-profit organization, which aims to honor the life and achievements and continuing legacy of Naismith Basketball Hall of Fame member Charles "Chuck" Cooper.

Cooper was born in Pittsburgh and played basketball for the Duquesne University Dukes from 1946–1950. He was the first African American to play in a college basketball game south of the Mason-Dixon line and was the first African American player to be drafted into the National Basketball Association (NBA), when he was chosen by the Boston Celtics as the first pick in the second round of the 1950 NBA Draft. Cooper was inducted into the Naismith Memorial Basketball Hall of Fame on September 9, 2019.

The Chuck Cooper Foundation awards graduate-level scholarships and provides leadership-development programs, mentorship, and networking opportunities to underserved students. For these reasons, Dr. Hogan's leadership, excellence in his field, and advocacy make him the ideal recipient of the 2024 Leadership Award. Thank you, Dr. Hogan, for all that you do for us at Pitt, and congratulations on this latest achievement!

MaCalus Hogan, MD, MBA, receives the 2024 Chuck Cooper Foundation Leadership Award.

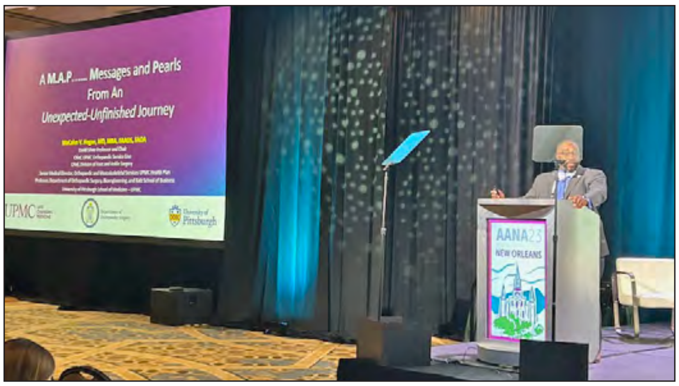
STELLA LEE TREATS TWO COMPLEX PEDIATRIC ONCOLOGY CASES FROM PUERTO RICO

Stella Lee, MD, collaborated with the UPMC Children's Hospital of Pittsburgh (CHP) International Department during the past academic year in order to treat two patients from Puerto Rico who presented with primary bone sarcomas.

Safely resecting these complex tumors, especially in pediatric patients, is a multifaceted endeavor, requiring special care to achieve negative oncologic margins, while minimizing bony and soft-tissue damage in order to ultimately perform limb salvage. These surgeries require a specialized team of sarcoma specialists, including an orthopaedic oncologist. Because of these unique challenges, complex sarcoma cases are not always able to be performed overseas, which makes international cooperation critical. With the success of these two surgeries, Dr. Lee and the staff at CHP look forward to further work with the International Department to expand UPMC's outreach to patients abroad who need sarcoma care. Thank you to Dr. Lee for this incredible work!

AANA MEETING RECOGNIZES SEVERAL PITTSBURGH ORTHOPAEDIC SURGEONS

UPMC Ortho was well represented at the Arthroscopy Association of North America (AANA) annual meeting, which was held May 4–6, 2023, in New Orleans, Louisiana. Established in 1981, AANA is an international professional organization consisting of more than 5,000 orthopaedic surgeons and other medical professionals with a particular emphasis on advancing the field of minimally invasive orthopaedic surgery in order to improve patient outcomes. AANA is considered to be the preeminent source of information regarding continuing medical education, new technology, and emerging surgical techniques within the subspecialty of orthopaedic arthroscopy.



MaCalus Hogan, MD, MBA, delivers his Diversity Lecture at the Arthroscopy Association of North America meeting.

Our chairman, MaCalus Hogan, MD, MBA, served as the Diversity Lecturer at the 2023 AANA meeting and presented an excellent talk titled "A M.A.P. … Messages and Pearls from an Unexpected-Unfinished Journey."

Two UPMC Ortho residents were recognized with the Diversity Research Award. Stephanie Boden, MD, and Shaquille Charles, MSc, MD, received this accomplishment for their paper titled "Capsuloligamentous Laxity Predicts Failure Following Arthroscopic Anterior Bankart Repair."

Our program director, Albert Lin, MD, received the Richard J. O'Connor Research Award for Best Overall Paper for his project titled "Remplissage Reduces Recurrent Instability in High-Risk Patients with On-Track Hill-Sachs Lesion." Congrats to all the award recipients!

MaCalus Hogan, MD, MBA, and James Stone (immediate former president of AANA) pose with the Diversity Lecturer Award.

Albert Lin, MD, Shaquille Charles, MD, and Stephanie Boden, MD, took home awards at the Arthroscopy Association of North America (AANA) meeting.

PITT ORTHO MEMBERS HONORED AT AOSSM MEETING

The American Orthopaedic Society for Sports Medicine (AOSSM) annual meeting was July 13–16, 2023, in Washington, D.C., and Pitt Ortho was well represented with several prominent awards.

Ting Cong, MD, who completed his sports medicine fellowship at UPMC in 2023, was honored with AOSSM's Fellow Best Clinical Science Award. Stephanie Boden, MD, who graduated from UPMC's orthopaedic surgery residency in 2023, received the AOSSM Excellent in Research Award. The team of Chief of Sports Medicine Volker Musahl, MD, received the inaugural *Video Journal of Sports Medicine* (*VJSM*) Best Picture Award. This award is presented to the *VJSM* publication that is determined by a nominating committee as the best overall publication for the year. The title of his team's video was "Revision Anterior Cruciate Ligament Reconstruction and Increased Tibial Slope: When to Perform a Slope-Altering High Tibial Osteotomy."

Jim P. Bradley, MD, who is a graduate of UPMC Ortho and currently serves as the head orthopaedic surgeon for the Pittsburgh Steelers, received the George D. Rovere Education Award. This award, which was begun in 1989, recognizes an individual AOSSM member who has contributed substantially to both sports medicine education over the years and to the educational function of AOSSM. Dr. Bradley has an illustrious, 30-plus-year career of teaching UPMC fellows and contributing to sports medicine education at meetings, courses, and committees at AOSSM.

Finally, Mark Miller, MD, who completed his sports medicine fellowship at UPMC, was celebrated for his successful AOSSM presidency term.

Former sports fellow Brian Godshaw, MD, and Volker Musahl, MD, pose with their *Video Journal of Sports Medicine* Best Picture Award at the American Orthopaedic Society for Sports Medicine meeting.

Volker Musahl, MD, and Alan Getood, MD, orthopaedic surgeon/clinician scientist from the Fowler Kennedy Sport Medicine Clinic of Western Ontario, pose during an intensive teaching session at the American Orthopaedic Society for Sports Medicine meeting in Washington, D.C.

Mark Miller, MD, completed his term as president of the American Orthopaedic Society for Sports Medicine.

PITT ORTHO ALUM RECEIVES AOSSM GRANT

An exciting new grant opportunity was awarded to a UPMC sports medicine fellowship alumnus, Andrew Sheean, MD, for his study titled "Defining the Impact of General Mental Health, Resilience, and Pain Catastrophizing on Return to Duty and Clinical Outcomes after ACL Reconstruction."

This grant, worth $200,000, is funded by the American Orthopaedic Society for Sports Medicine (AOSSM) Military Advanced Surgical Training (MAST) Program. It is the product of a collaboration between the Arthroscopy Association of North America, AOSSM, and the Society for Military Orthopaedic Surgeons. Dr. Sheean's project was described by AOSSM as an excellent selection for this grant because it seeks to elucidate novel, modifiable risk factors predictive of poor outcomes after anterior cruciate ligament (ACL) reconstruction and decreased likelihood of returning to pre-injury levels of activity/occupation.

Dr. Sheean currently specializes in sports medicine at San Antonio Military Medical Center. Thus, this grant has the potential to improve military medical readiness after ACL reconstruction by identifying heretofore unexamined, but potentially modifiable, psychological traits that can impact postoperative return to function. Congrats to Dr. Sheean!

SPORTS MEDICINE ATTENDING RECEIVES YOUNG INVESTIGATOR GRANT

Jonathan Hughes, MD, UPMC Ortho sports medicine fellowship alumnus and current attending in UPMC sports medicine, received the 2023 American Orthopaedic Society of Sports Medicine Steven P. Arnoczky Young Investigator Grant–Clinical Science. This award supports Dr. Hughes' proposal titled "Changes in *In Vivo* Knee Kinematics after Revision ACL-R and Slope Osteotomy," which is a collaborative study with Volker Musahl, MD, William Anderst, PhD, Jay Irrgang, PT, PhD, and M. Enes Kayaalp, MD, in the Biodynamics Laboratory. Congrats to Dr. Hughes!

C. BENJAMIN MA NAMED CHAIR AT UCSF

C. Benjamin Ma, MD, professor in residence in sports medicine and shoulder surgery at the University of California, San Francisco (UCSF), was recently appointed as chair of the UCSF orthopaedic surgery department.

Dr. Ma graduated from the UPMC Ortho residency in 2002 (he was also a former *POJ* editor-in-chief!), and thus he carries on the legacy of great leadership established by former UPMC Ortho Chairs Albert Ferguson, MD, and Freddie Fu, MD. Dr. Ma has been heavily involved in research on cartilage imaging and dynamic magnetic resonance imaging scans of the knee with injuries to the anterior cruciate ligament (ACL). His work has focused on early detection of cartilage damage after ACL injury and improving outcomes after ACL reconstruction.

In addition to his clinical and research accomplishments, Dr. Ma has been recognized by UCSF with the Henry Kaiser Award for Excellence in Teaching in 2008–2009 and 2011–2012, and he was named Diversity, Equity, and Inclusion Champion in 2019. It is an honor to congratulate Dr. Ma on this newest accomplishment, and we look forward to witnessing his continued success as the orthopaedic surgery department chair at UCSF!

VOLKER MUSAHL APPOINTED TO ISAKOS EXECUTIVE COMMITTEE

Dr. Musahl, MD, was recently appointed to the Executive Committee for the 2023–2025 term of the International Society of Arthroscopy, Knee Surgery, and Orthopaedic Sports Medicine (ISAKOS). ISAKOS is the largest society for arthroscopy, knee surgery, and orthopaedic sports medicine and has more than 3,300 members from 109 countries. This appointment is especially meaningful because it carries on the legacy started by Freddie Fu, MD (ISAKOS president 2009–2011).

Renowned for his groundbreaking contributions to sports medicine, particularly in knee and shoulder surgery, Dr. Musahl brings a wealth of expertise and leadership to this prestigious role. His dedication to advancing the understanding and treatment of sports-related injuries has earned him international recognition, making him a natural fit for this position of influence within ISAKOS.

As a member of the Executive Committee, Dr. Musahl will play a pivotal role in shaping the direction of ISAKOS, guiding its mission to promote education, research, and collaboration in the field of orthopaedic sports medicine worldwide. With his innovative approach to surgical techniques and his commitment to evidence-based practice, he is poised to drive forward initiatives that will benefit both patients and practitioners alike. Dr. Musahl's appointment underscores the organization's commitment to excellence and underscores his continued dedication to advancing the field of sports medicine on a global scale. Congratulations to Dr. Musahl!

ERIE SITE NAMED AMONG BEST IN PEDIATRIC ORTHOPAEDICS

UPMC Children's Hospital of Pittsburgh (CHP)–Shriners Hospitals for Children Erie was recognized by *U.S. News & World Report* as being ranked within the top 15 pediatric orthopaedic surgery hospitals in the country for the most recent rankings cycle.

The overwhelming percentage of this score is derived from success with complex fractures; the presence of specialized programs for scoliosis, spina bifida, and the brachial plexus; low rates of surgical complications; excellence in pain management; and infection prevention. The remaining percentage is based on expert opinion of pediatric specialists and subspecialists who recommended the hospital for complicated pediatric orthopaedic cases. A sincere thank you to the CHP attendings for providing an excellent environment to learn and practice pediatric orthopaedic surgery!

PITT ORTHO WELCOMES NEW CHIEF OF ORTHOPAEDIC TRAUMA

George Russell, MD, MBA, was recently appointed as the new chief of orthopaedic trauma and will also serve as an associate chief of surgical quality and executive vice chair of Pitt's Department of Orthopaedic Surgery. Prior to joining the UPMC Ortho faculty, Dr. Russell was previously the chair of the Department of Orthopaedic Surgery at the University of Mississippi Medical Center and chief executive officer of University Physicians.

Dr. Russell earned his medical degree and completed his orthopaedic surgery residency at the University of Cincinnati. He completed an orthopaedic trauma fellowship at the prestigious University of Washington/Harborview Medical Center and subsequently joined the Department of Orthopaedic Surgery at University Mississippi Medical Center in 2000. Dr. Russell also completed an executive MBA from the Northwestern Kellogg School of Management.

Dr. Russell is nationally renowned as one of the country's preeminent orthopaedic trauma surgeons and in particular is recognized as an expert on treating complex fractures in individuals with obesity. Dr. Russell takes an empathetic, compassionate, and technically nuanced approach to these patients who exist at the intersection of socioeconomic, orthopaedic, and medical complexity. He pioneered the clamshell osteotomy, which he described in the *Journal of Bone and Joint Surgery* in 2009 as a groundbreaking approach to the treatment of diaphyseal malunions. He has authored and coauthored numerous publications and has lectured broadly both nationally and internationally on orthopaedic trauma care and leadership within orthopaedic surgery. Welcome to Pitt Ortho, Dr. Russell!

UPMC ORTHO OPENS ITS DOORS TO TRAVELING FELLOWS

During the summer of 2023, UPMC Ortho continued its tradition of leading the effort to foster personal and professional relationships amongst the international orthopaedic surgery community by hosting several groups of traveling fellows.

ISAKOS Global Traveling Fellows: The International Society of Arthroscopy, Knee Surgery, and Orthopaedic Sports Medicine (ISAKOS) global traveling fellows visited the UPMC Department of Orthopaedic Surgery. The purpose of the ISAKOS Global Traveling Fellowship is to cultivate the international exchange of information and skills in sports orthopaedic surgery. During their visit, the fellows delivered an outstanding array of presentations to an audience of UPMC orthopaedic faculty. In addition, those in attendance shared a delicious meal together, and the fellows enjoyed the opportunity to explore the department's operating rooms and labs.

ESSKA/AOSSM Traveling Fellows: The European Society for Sports Traumatology, Knee Surgery, and Arthroscopy (ESSKA)/ American Orthopaedic Society for Sports Medicine (AOSSM) Traveling Fellowship is an international exchange program for bright, young orthopaedic surgeons. The ESSKA/AOSSM Traveling Fellows visited the UPMC Department of Orthopaedic Surgery during the summer of 2023. Highlights of their visit included the Freddie Fu Sport Medicine Clinic's state-of-the-art training center and the opportunity to take part in the clinical assessment of complex cases. The time together was also marked by stimulating discussions, great food, tours of the operating rooms and labs, and an enjoyable bike tour across the city.

JOA Traveling Fellows: In conjunction with the American Orthopaedic Association (AOA), the Japanese Orthopaedic Association (JOA) Traveling Fellowship's purpose is to provide a broad range of experiences for emerging leaders and innovators in the field of orthopaedic surgery. The UPMC Department of Orthopaedic Surgery had the pleasure of hosting the JOA Traveling Fellows in the summer of 2023. During the fellows' stay, everyone engaged in a wide range of enriching discussions, scholarly exchanges, and delicious dinners. Additionally, the fellows enjoyed the opportunity to visit the department's operating rooms and labs.

ISAKOS traveling fellows enjoying dinner at Altius in Pittsburgh

ISAKOS traveling fellows after a day of operating with Dr. Musahl and Dr. Hogan

The sports medicine department with the ESSKA/AOSSM traveling fellows

Dr. Lesniak, Dr. Musahl, and the ESSKA/AOSSM traveling fellows getting ready for some cycling in the 'Burgh

Dr. Musahl looking dapper with the ESSKA/AOSSM traveling fellows

Dr. Musahl and the JOA traveling fellows after a day in the operating room

ALBERT LIN INDUCTED INTO HERODICUS SOCIETY

Albert Lin, MD, was recently inducted into the prestigious Herodicus Society at the 2023 annual meeting held in Port Clear, Alabama, May 18–21, 2023. The Herodicus Society, which affords membership by invitation only, is a preeminent leadership society of appointed specialists in orthopaedic sports medicine. Annual meetings of the Herodicus Society present an opportunity for the exchange of ideas between experts and leaders within the field of sports medicine and are open to members and invited guests only.

Dr. Lin's appointment to the Herodicus Society is in recognition of his dedication and accomplishments within both sports medicine and shoulder surgery. Dr. Lin is an active participant in and regularly invited faculty member for many prestigious organizations, including American Academy of Orthopaedic Surgeons; American Shoulder and Elbow Surgeons (ASES); American Orthopaedic Society for Sports Medicine; Arthroscopy Association of North America; International Society of Arthroscopy, Knee Surgery, and Orthopaedic Sports Medicine; and Mid-Atlantic Shoulder and Elbow Society. Dr. Lin was the co-chair of the ASES Fellows' Day in 2021 and 2022, as well as the vice chair of the shoulder and elbow program of the OSET Summit Meeting in 2022 and 2023.

He serves on the editorial review boards of numerous journals relevant to both sports medicine and shoulder surgery, and he has published more than 300 manuscripts, abstracts, and book chapters. As a principal investigator, he currently holds two National Institutes of Health (NIH) R03 and R21 grants related to shoulder biomechanics, as well as two federally funded NIH R01 and Department of Defense grants as a co-investigator related to shoulder instability research. Finally, Dr. Lin is actively involved in residency and fellowship education and currently serves as the program director of the UPMC Ortho residency. Thank you to Dr. Lin for everything he does for the department, and congratulations on this latest accomplishment!

Albert Lin, MD, and Volker Musahl, MD, at the Herodicus Society meeting

DEPARTMENT WELCOMES NEW TRAUMA FACULTY

We are excited to welcome Tyler Petersen, DO, to the UPMC orthopaedic trauma department as a new faculty member this year. Dr. Petersen grew up in Washington State near Portland, Oregon. He received his medical degree from the West University of Health Sciences in Lebanon, Oregon, and subsequently completed an orthopaedic surgery residency at the Good Samaritan Regional Medical Center in Corvallis, Oregon. He followed this up with a fellowship in orthopaedic trauma surgery at UPMC under the tutelage of our own Ivan Tarkin, MD, Peter Siska, MD, Gele Moloney, MD, and Aaron Taylor, MD. He has particular clinical and research interest in periarticular, lower-extremity traumatic injuries. Welcome to the faculty Dr. Petersen!

PINCH AWARD TO HELP FUND CUFFLINK REHABILITATION INNOVATION

Kevin Bell, PhD, and Michael McClincy, MD, recently received a $15,000 Makers Bonus Award from the Pitt Innovation Challenge (PInCh) in recognition of their research on developing the CuffLink device.

This device is part of a groundbreaking telehealth rehabilitation platform after rotator cuff surgery that combines motion-tracking technology with the safety of mechanical motion exercise equipment in order to accelerate and improve patient recovery. Drs. Bell and McClincy presented their findings on November 11, 2023, at the PInCh meeting and emphasized the scope of rotator cuff pathology in the United States, which generates upwards of four and a half million clinical visits every year, with substantial associated decreased quality of life and healthcare costs.

CuffLink has potential to improve one of the most critical and difficult aspects of rotator cuff surgery—postoperative rehabilitation. Dr. McClincy noted in his presentation that although traditional rehabilitation methods focus on protecting the rotator cuff repair via a static sling, this is associated with pain, stiffness, and slowed healing. The addition of physical therapy to this traditional model improves early range of motion but is costly and further stretches limited healthcare personnel and resources.

In contrast, the CuffLink platform is a home-based solution intended to revolutionize shorter rehabilitation by combining a patented home exercise device with real-time biofeedback and a clinician portal for remote monitoring. CuffLink was borne out of a collaboration involving clinical engineering and health informatics experts from the University of Pittsburgh alongside the Elizur corporation, which is a regional durable medical equipment company. At the time of the PInCh meeting, more than 5,000 patients had already used the CuffLink program for postoperative rehabilitation.

PInCh provides funding and project management with the aim of developing high-quality health science research that can serve people and communities outside of the University of Pittsburgh. Congratulations to Drs. McClincy and Bell for this award!

Michael McClincy, MD, (left) and Kevin Bell, PhD, (right) present their work on the CuffLink device at the Pitt Innovation Challenge (PInCh).

FORMER STEELERS GENERAL MANAGER DELIVERS GRAND ROUNDS

A new academic year was launched on September 6, 2023, with an excellent grand rounds by Kevin Colbert, who served as the general manager of the Pittsburgh Steelers from 2000 to 2021. Mr. Colbert's tenure with the Steelers featured three Super Bowl appearances and two championship wins in 2006 and 2009. Throughout his grand rounds, Mr. Colbert focused on his deep Pittsburgh roots, his career in Pittsburgh that spans longer than four decades, and the keys to his "Sustained Success—From Bottom to Top." Thank you, Mr. Colbert, for an inspiring talk!

The department with Steelers General Manager Kevin Colbert after his grand-rounds presentation

ACL STUDY GROUP MEMBERSHIP AND LEADERSHIP

Chief of Sports Medicine Volker Musahl, MD, entered the Presidential Line of the ACL Study Group, and Jonathan Hughes, MD, was inducted as a new member of this invitation-only group during the group's most recent Biennial Meeting, which took place January 28 to February 1, 2024, in Niseko, Japan.

The ACL Study Group, which is considered to be the premier international anterior cruciate ligament (ACL) meeting, was first organized in 1988 by a small group of orthopaedic surgeons with a common interest in advancing the study and treatment of ACL pathology. Not surprisingly, the ACL Study Group has always had strong ties with Pitt Ortho, UPMC Sports Medicine, and their alumni. The ACL Study Group represents a unique opportunity to collaborate, discuss, and learn about cutting-edge advancements in research, surgical techniques, rehabilitation, and injury prevention. Congratulations to Drs. Musahl and Hughes and the rest of the UPMC Sports Medicine Team for continuing to push our understanding and treatment of the ACL forward!

Volker Musahl, MD, and Jonathan Hughes, MD, at the ACL Study Group meeting in Niseko, Japan

Volker Musahl, MD, and Jonathan Hughes, MD, pose with the ACL Study Group.

PITT MED STUDENT JOINS NFL DIVERSITY PIPELINE PROGRAM

University of Pittsburgh medical student Warren Austin will be joining the Pittsburgh Steelers during training camp as part of the National Football League (NFL) Diversity in Sports Medicine Pipeline Initiative. The NFL started the initiative in 2022 as a means to improve representation in sports medicine and to encourage underrepresented groups to pursue careers in sports medicine. The program allows medical students to work closely with orthopaedic team physicians, primary care physicians, and athletic trainers at an NFL level, while fulfilling the requirements of a clinical rotation. Additionally, the program allows for early exposure and learning about important return-to-play guidelines for various orthopaedic injuries.

Austin has deep Pittsburgh roots, as he graduated from Central Catholic High School and the University of Pittsburgh. Additionally, Austin has been very productive in research within the Department of Orthopaedic Surgery during his medical school years. Congratulations to Austin, and we look forward to watching his future success!

MaCalus Hogan, MD, MBA, and Warren Austin discuss Austin's appointment with the Steelers Diversity in Sports Medicine Pipeline Initiative on "Talk Pittsburgh."

KENNETH URISH NAMED PITT HEALTH SCIENCES ASCENDING STAR

Kenneth Urish, MD, PhD, was recently selected by Anantha Shekhar, MD, PhD, senior vice chancellor for the health sciences and John and Gertrude Petersen Dean of the University of Pittsburgh School of Medicine, as one of the five Health Sciences Ascending Star awardees for 2024. This honor was established in 2022 to recognize highly productive, creative, mid-career faculty members in the six schools of the health sciences. The award is also accompanied by a $25,000 grant for research support and an invitation to give a widely publicized lecture during the remainder of the current calendar year.

Dr. Urish is an orthopaedic surgeon who is fellowship trained in adult reconstructive and arthroplasty and serves as the associate medical director at the Magee Bone and Joint Center. In addition to his clinical practice and leadership role at Magee, he is the director of the Arthritis and Arthroplasty Design Laboratory, which is a National Institute of Health–funded research group with a focus on preventing osteoarthritis and optimizing outcomes after total joint replacement surgery. Congratulations to Dr. Urish and the staff of the Arthritis and Arthroplasty Design Laboratory!

ORL MEMBER RECEIVES ORS NEW INVESTIGATOR AWARD

Congratulations to Luke Mattar, PhD, for receiving the 2024 Orthopaedic Research Society (ORS) New Investigator Recognition Award (NIRA). This award was presented at the ORS Annual Meeting in Long Beach, California, and is intended for early-career researchers who have not had more than five years of active research experience. Dr. Mattar was recognized for his paper titled "Predictors of Patient-Reported Outcomes and Tear Propagation Immediately Following Exercise Therapy for Individuals with Rotator Cuff Tears." Dr. Mattar is a postdoctoral associate in the Orthopaedic Robotics Lab (ORL) within the Department of Orthopaedic Surgery. The ORL is led by codirectors Volker Musahl, MD, and Richard Debski, PhD. Dr. Mattar's work within the ORL focuses on utilizing *in vivo* kinematic analyses and various other parameters to predict the outcomes and efficacy of exercise therapy for management of rotator cuff tears. Congratulations to Dr. Mattar and the entire staff of the ORL for this latest achievement!

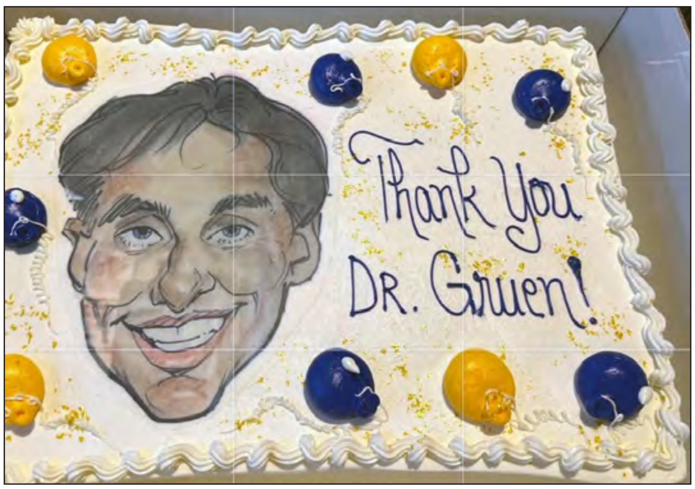
Luke Mattar, PhD, accepts the Orthopaedic Research Society New Investigator Recognition Award.

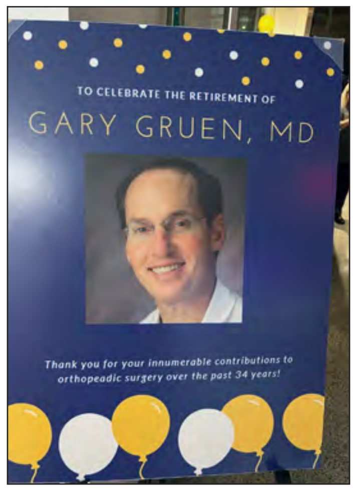
PITT ORTHO HONORS GARY GRUEN UPON RETIREMENT

A retirement reception was held on December 14, 2023, honoring the career and legacy of Gary Gruen, MD. The event marked the capstone of more than three decades of service in the orthopaedic trauma department at UPMC and tireless commitment to resident education.

Dr. Gruen earned his medical degree from the Temple University School of Medicine in Philadelphia, Pennsylvania, and completed residency at both the University of Pittsburgh School of Medicine and Hahnemann/Drexel University College, followed by an orthopaedic trauma fellowship at the prestigious University of Washington in Seattle.

Dr. Gruen was regularly selected as one of the "Top Doctors" by *Pittsburgh Magazine* and served as head of the orthopaedic trauma department prior to Ivan Tarkin, MD. He has published and lectured extensively, and he served as a mentor to a generation of residents and fellows pursuing orthopaedic trauma. Dr. Gruen still runs intern education every Wednesday, with a focus on hands-on teaching with sawbones and, more recently, virtual education. Dr. Gruen's dedication to education was commemorated in 2018 when he was the recipient of the Golden Apple Award, which is selected by the residents in recognition of the best faculty educator. Thank you, Dr. Gruen, and we wish you a well-earned, happy retirement!





Photos from Gary Gruen's retirement party. Thank you for everything, Dr. Gruen!

FOOT AND ANKLE DIVISION WELCOMES NEW FACULTY MEMBER

The UPMC Division of Foot and Ankle Surgery welcomes Lauren Lewis, MD, as a new faculty member this year. Dr. Lewis received her medical degree from the University of Miami Miller School of Medicine and subsequently completed an orthopaedic surgery residency at the University of Texas Medical Branch. She followed with a foot and ankle fellowship at Massachusetts General Hospital. We look forward to working further with Dr. Lewis!

CHEERS GRANT RECOGNIZES MULTIDISCIPLINARY PROJECT

Patrick Smolinski, PhD, and MaCalus Hogan, MD, MBA, were recently awarded a Collaboration in Health Sciences and Engineering Startup (CHEERS) grant for their project titled "Development of a Testbed for Foot and Ankle Orthopaedic Research."

The award, worth $40,000, will last for 12 months and will fund a robotic testing system for foot and ankle research. The CHEERS grant is awarded from the Clinical and Translational Science Institute (CTSI) and the Swanson School of Engineering (SSoE) at the University of Pittsburgh. The goal of this program is to enhance collaboration between faculty members in SSoE and those in the six schools of the health sciences. Thus, the grant represents an excellent opportunity for interdepartmental and interdisciplinary collaboration that is critical to the mission of UPMC Ortho. CHEERS proposals are intended to create a true convergence of engineering and health science aimed at solving substantial challenges and clinical problems. Additionally, the overarching goal of these projects is to create sustained success in order to maximize impact. Congratulations to Dr. Smolinski and Dr. Hogan on this latest achievement!

BUS STOPS HERE AWARDS GRANT TO MUSCULOSKELETAL ONCOLOGY LAB

Congratulations to Kurt Weiss, MD, who was honored with a $10,000 donation to his Musculoskeletal Oncology Lab from the Jerome Bettis Bus Stops Here Foundation at its 16th annual Caring for Kids Gala. The gala event features a dinner and auctions, which help to raise funds for children in the City of Pittsburgh and across western Pennsylvania. Dr. Weiss and Jerome Bettis are both proud alumni of the University of Notre Dame and have maintained a relationship of mutual admiration and collaboration since that time.

The Jerome Bettis Bus Stops Here Foundation was created in 1997 by Hall of Fame Steelers running back Jerome Bettis. Bettis spent 13 seasons in the National Football League, including a Super Bowl win with Pittsburgh over the Seattle Seahawks in his hometown of Detroit. He created the Bus Stops Here Foundation to provide inner-city youth with opportunities and resources to pursue their goals and aspirations.

The burden of primary bone tumors disproportionately affects pediatric patients. Dr. Weiss himself is a survivor of a pediatric osteosarcoma and has dedicated his career as a physician-scientist to both treating and furthering understanding of these complex and challenging tumors. Bettis's donation to Dr. Weiss's lab is perfectly in line with his foundation's mission of "caring for kids." Congratulations to Dr. Weiss!

Kurt Weiss, MD, and Jerome Bettis pose with the check representing the donation to the Musculoskeletal Oncology Lab at the 16th Annual Caring for Kids Gala.

Hall of Fame running back Jerome Bettis speaks at the 16th Annual Caring for Kids Gala.

Kurt Weiss, MD, Michael O'Malley, MD, and Richard McGough, MD, with legendary Notre Dame coach Lou Holtz

PITT ORTHO AND WORLD TOUR OPEN SQUASH TOURNAMENT

Craig Mauro, MD, assistant program director of the orthopaedic sports medicine fellowship, served as the medical director during the Professional Squash Association World Tour Open Squash Tournament at the Rivers Club in Pittsburgh. Dr. Mauro presided over the medical needs of the event, with a team of UPMC physicians and athletic trainers. This event represents the world's best in squash and is a testament to the deep relationship between Pitt Ortho and elite athletics. Congratulations to Dr. Mauro and the rest of UPMC Sports Medicine!

From left to right: Tournament director Diuilo Costa, world rank #6 and tournament champion Karim Abdel Gawad, world rank #10 and tournament runner-up Marwan ElShorbagy, and tournament medical director Craig Mauro, MD

CRAIG MAURO TO LEAD AOSSM FELLOWSHIP COMMITTEE

Craig Mauro, MD, assistant program director of the orthopaedic sports medicine fellowship, was recently appointed as the incoming chair of the Fellowship Committee for the American Orthopaedic Society for Sports Medicine (AOSSM).

This appointment was selected by the leadership at the AOSSM, including current Chair Matthew Provencher, MD. This two-year term will be effective July 1, 2024, through July 31, 2026. In this role, Dr. Mauro will oversee the activities and education for orthopaedic sports medicine fellowship programs and fellows, including via the annual Match program. He will also be a liaison with the Accreditation Council for Graduate Medical Education to assist fellowship programs in delivering high-quality training to fellows and will contribute to the development of the Residents and Fellows Forum at the annual AOSSM meeting. Congratulations to Dr. Mauro on this substantial honor!

UNIVERSITY OF PITTSBURGH DEPARTMENT OF ORTHOPAEDIC SURGERY RESIDENCY PROGRAM

2024 DIRECTOR'S REPORT

Albert Lin, MD, FAAOS
Vice Chair
of Education and Program Director

John Fowler, MD, FAAOS
Associate Program Director

The 2023–2024 academic year marked an exciting year of growth. Albert Lin, MD, FAAOS, and John Fowler, MD, FAAOS, have settled into their roles, having completed their first full year as program directors of this storied residency. As one of Chair MaCalus Hogan's five "Rs," our residency is the lifeblood and legacy of our department. We remain fully committed to helping to lead one of the premier residency programs in the world.

The residency program has eight outstanding graduates this year. We are exceedingly proud of all of them and their accomplishments. Dr. Hogan, Dr. Fowler, Dr. Lin, and the entire faculty thank them for their tireless work and teamwork, all their amazing contributions over the course of their training, and the tremendous level of care that they provide for our patients. They have each done a superb job and will proudly carry forward the Pitt Ortho banner of excellence.

The 2024 graduates bring great diversity in their career interests and will continue their training in a variety of specialties. Our graduates once again matched into prestigious fellowships. Two of this year's graduates will enter the fellowship year in adult reconstruction: Dukens LaBaze, MD, will head to Johns Hopkins in Baltimore, Maryland, and Brandon Couch, MD, will lead the charge at the Texas Orthopaedic Hospital in Houston, Texas. Two residents will enter their fellowships in orthopaedic sports medicine: Benjamin Rothrauff, MD/PhD, will head to the slopes of Vail, Colorado, at the Steadman Clinic and Institute, while Michael Fox, MD, is headed south to Duke University in Durham, North Carolina. There will be a duo threat going into spine surgery fellowships, with Joshua Adjei, MD, headed back to his hometown at New York University in New York, New York, and Jonathan Dalton, MD, headed to the Rothman Institute in Philadelphia, Pennsylvania. Rebekah Belayneh, MD, will be joining Dr. Adjei in New York as she starts her foot and ankle surgery fellowship at the Hospital for Special Surgery in New York, New York. Christopher Gibbs, MD, is heading south for his hand surgery fellowship at Wake Forest University in Winston-Salem, North Carolina.

We are so proud of this class's accomplishments, and we wish them and their families continued success as they continue their career paths in orthopaedic surgery.

This year, we have fully emerged from the COVID-19 pandemic with a complete return to in-person grand rounds, morbidity and mortality conferences, and Wednesday educational conferences. Although vestiges and unprecedented challenges left by the COVID-19 pandemic still remain, the pandemic also brought out the best of who we are. This graduating class entered their residency as interns and junior residents during the COVID shutdown and had to adapt to the shifting training environment like no other time in history. They have shown poise, grit, patience, and professionalism throughout this period of uncertainty. Their resilience during the most challenging of times should be applauded, and their experiences during the most formative periods of training will undoubtedly shape their growth into emerging leaders in their respective fields. Thank you for all your efforts!

Our residents, under the leadership and coordination of Administrative Chief Residents Dr. Belayneh and Dr. Rothrauff, worked together. As conferences and visiting professors were moved back to fully in-person events, significant coordination was necessary to ensure smooth transition from the virtual platform of the past several years. The daily operations of the program would not have been possible without the leadership of our chief residents. We thank all our chief residents for the team approach demonstrated within the program.

For the first time since 2019, we were excited to conduct in-person interviews for the residency program. In total, 86 orthopaedic surgery resident candidates were interviewed over two days. Once again, this effort would not have been possible without the amazing and tireless efforts of Noreen Corcoran, our residency program coordinator, and Amanda Sites, assistant residency program/medical student coordinator, who has been a perfect fit for our residency. We would all be lost without their phenomenal work and genuine care for our residents and program. They continue to keep us on the straight and narrow and navigate us through both calm and choppy waters! Applicants met with the chair, program directors, and faculty interviewers, and they had multiple sessions with the residents to learn as much about the program as possible. Exciting initiatives led by Dr. Hogan for the residency include the Pittsburgh Orthopaedic Development scholarship awards, opportunities for future collaboration and exchange with UPMC International, investments in virtual reality to supplement training, and a return to the Veterans Affairs Medical Center for rotations. The future is very bright indeed! As a result, we matched another exceptional class of new residents who will start in June 2024, and we look forward to all their future contributions to Pitt Orthopaedics.

The Department of Orthopaedic Surgery was pleased to announce the establishment of the Freddie Fu Leadership Award for High School Community Service, graciously funded by Jim Grant, chief executive officer of Elizur, a musculoskeletal solutions industry leader. Presented annually, the Freddie Fu Leadership Award will be given to top-performing residents who show a special affinity for their local high school sports group. Nominees will need to show dedication to their high school community, go above and beyond in patient care, and display an admirable work ethic. Nominations will come from schools' athletic trainers or peers and other staff at the schools. Award recipients receive a monetary award, and up to five residents can be recognized in any given year. This year's inaugural award recipients were Drs. Christopher Como, Melissa Tang, Ehab Nazzal, Gabrielle Fatora, and Rothrauff. Congratulations!

As you read through the journal, you will find that the academic productivity and leadership activity across the residency continue to grow at an exceptionally high level. Our residents continue to make significant contributions across all domains of orthopaedics. We continue to push forward with our mission of excellence in academic leadership, clinical orthopaedics, education, and advocacy. We remain very active nationally in the American Orthopaedic Association and Council for Orthopaedic Residency Directors, Accreditation Council for Graduate Medical Education, and the Resident Review Committee, as well as the American Academy of Orthopaedic Surgeons Resident Assembly forums. Our residents remain highly engaged in initiatives for diversity, equity, and inclusion, serving as guest lecturers and members of committees for the Student National Medical Association and Nth Dimensions. In addition, our residents are also active across multiple orthopaedic subspecialty societies and have been recognized nationally and globally with research awards, scholarships, and invited lectureships. Such activity would not be possible without our dedicated residents and the support of our faculty.

The program has maintained a high ranking in this year's Doximity Residency Rankings—ranking #10 among U.S. orthopaedic programs and #7 in research output. This is a testament to our outstanding residents, dedicated and excellent faculty, and the support and enthusiasm of our chair. Drs. Fowler and Lin thank Dr. Hogan and the faculty for their continued support so that Pitt Ortho remains one of the top orthopaedic surgical education programs in the world.

2024 ALBERT B. FERGUSON RESIDENT RESEARCH DAY
May 8, 2024

The Albert B. Ferguson Jr., MD, Resident Research Day was held in person on Wednesday, May 8, 2024.

Leesa M. Galatz, MD, from the Icahn School of Medicine at Mount Sinai in New York, New York, served as the 2024 Albert B. Ferguson Jr., MD, Visiting Professor in Orthopaedic Surgery. Dr. Galatz is the Mount Sinai Professor and Chair of the Leni and Peter May Department of Orthopaedic Surgery and the Icahn School of Medicine at the Mount Sinai Health System. Dr. Galatz specializes in shoulder and elbow surgery, with expertise in sports and reconstructive procedures. Her grand-rounds presentation was titled
"Lessons in Leadership—Have It All, Just Not All at Once."
As the Ferguson Visiting Professor, Dr. Galatz also served as judge to select the best resident presentation in two categories.
We are pleased to announce this year's resident winners:

Best Junior Presentation:
"Intraoperative Evaluation of Bone and Soft-Tissue Sarcoma Surgical Margins with Indocyanine Green Fluorescence Imaging"
Clark Roth, MD
Faculty advisors: Kurt Weiss, MD, and Ines Lohse, PhD

Best Senior Presentations:
"Bariatric Surgery Results in Increased Failure Rates and Inferior Patient-Reported Outcomes after Arthroscopic Rotator Cuff Repair"
Michael Fox, MD
Faculty advisors: Bryson Lesniak, MD, and Albert Lin, MD

"VEGF-Neutralized Platelet-Rich Plasma with Adipose-Derived Stromal Vascular Fraction Enhanced Osteochondral Repair in a Point-of-Care Goat Model"
Benjamin Rothrauff, MD, PhD
Faculty advisors: Rocky Tuan, PhD, and Freddie Fu, MD

Congratulations to this year's awardees! The monetary awards are generously provided by Jack Smith, MD, president of the Pitt Orthopaedic Alumni Association, and we would like to thank Dr. Smith and the Alumni Association for their continued support.

We sincerely thank Dr. Galatz for her very relevant and thought-provoking presentation and all those who attended and participated in this event.

ALBERT B. FERGUSON JR., MD
June 10, 1919–August 20, 2014

Albert Ferguson was born in New York City on June 10, 1919. He graduated from Dartmouth College in 1941 and from Harvard Medical School in 1943. After spending three years with the U.S. Marines in the Pacific area, Dr. Ferguson trained in surgery and orthopaedic surgery at Boston's Children's, Peter Bent Brigham, and Massachusetts General hospitals. In 1953, he was appointed the Silver Professor of Orthopaedic Surgery and Chairman of Orthopaedic Surgery at the University of Pittsburgh, where he remained until his retirement in 1986.

Dr. Ferguson was an excellent surgeon, researcher, and teacher, in addition to being a pioneer in sports medicine. His specialty was children with dislocated hips, and he used a new approach to minimize scarring that did not involve cutting through muscle. His research resulted in the invention of the I-beam nail to repair hip fractures. Soon after arriving in Pittsburgh, he would become the orthopaedic surgeon for the Pittsburgh Pirates and, later, the company physician for the Pittsburgh Ballet.

Dr. Ferguson's greatest legacy would be the students he trained. He would spend 33 years training several generations of orthopaedic surgeons, many of whom would go on to head orthopaedic departments in the United States and around the world.

"Do the right thing, take care of your patients, and they will take care of you."
—Albert B. Ferguson Jr., MD

Graduating chief residents enjoy lunch with visiting professor Leesa Galatz, MD.

Leesa Galatz, MD, and Pitt Ortho have dinner at the Inn on Negley the night before Resident Research Day.

John Fowler, MD, MaCalus Hogan, MD, MBA, visiting professor Leesa M. Galatz, MD, and Albert Lin, MD, after Resident Research Day

Resident Research Day award winners Michael Fox, MD, Clark Roth, MD, and Benjamin Rothrauff, MD, PhD, with visiting professor Leesa M. Galatz, MD

RESIDENT PRESENTATIONS

JUNIOR RESIDENTS

"Surface Area of the Glenohumeral Joint Capsule: A Novel Method to Quantify Injury and Repair Following Anterior Dislocation and Capsular Plication"
Gillian Ahrendt, MD
Faculty advisors: Albert Lin, MD, Volker Musahl, MD, and Richard Debski, PhD

"Best-Fit Circle Missing Area Method Shows Good Accuracy and Inter-Rater Reliability when Assessing Glenoid Bone Loss"
Cortez Brown, MD
Faculty advisors: Jonathan Hughes, MD, Albert Lin, MD, and William Anderst, PhD

"Dynamic *In Vivo* 3D Atlanto-Occipital Kinematics during Multiplanar Physiologic Motions"
Christopher Como, MD
Faculty advisors: Jeremy Shaw, MD, Joon Lee, MD, and William Anderst, PhD

"Intraoperative Evaluation of Bone and Soft-Tissue Sarcoma Surgical Margins with Indocyanine Green Fluorescence Imaging"
Clark Roth, MD
Faculty advisors: Kurt Weiss, MD, and Ines Lohse, PhD

CHIEF RESIDENTS

"Increased Resource Utilization during Initial Episode of Care Following Intramedullary Nailing of Tibia Fractures in Patients with Preinjury Opiate Use"
Rebekah Belayneh, MD
Faculty advisor: Gele Moloney, MD

"Comparison of Revision Rates Between Cones Versus Sleeves in Revision Total Knee Arthroplasty"
Brandon Couch, MD
Faculty advisors: F. Johannes Plate, MD, Brian Klatt, MD, and Michael O'Malley, MD

"Maximizing the Value of CTS-6: When Is Additional Testing Most and Least Likely to Change Diagnostic Probability?"
Christopher Gibbs, MD
Faculty advisor: John Fowler, MD

"Complication Rates in Total Knee Arthroplasty Patients on GLP-1 Agonists versus Prior Bariatric Surgery: A Comparison Study"
Dukens LaBaze, MD
Faculty advisor: A.J. Yates Jr., MD

"An Analysis of Diversity Perceptions in Surgical Training at a Large Academic Center"
Joshua Adjei, MD
Faculty advisors: MaCalus Hogan, MD, MBA, and Rickquel Tripp, MD, MPH

"The L3 Flexion Angle Predicts Failure of Non-Operative Management in Patients with Tandem Spondylolisthesis"
Jonathan Dalton, MD
Faculty advisor: Joon Lee, MD

"Bariatric Surgery Results in Increased Failure Rates and Inferior Patient-Reported Outcomes after Arthroscopic Rotator Cuff Repair"
Michael Fox, MD
Faculty advisors: Bryson Lesniak, MD, and Albert Lin, MD

"VEGF-Neutralized Platelet-Rich Plasma with Adipose-Derived Stromal Vascular Fraction Enhanced Osteochondral Repair in a Point-of-Care Goat Model"
Benjamin Rothrauff, MD, PhD
Faculty advisors: Rocky Tuan, PhD, and Freddie Fu, MD

2023 SPORTS FELLOWSHIP RESEARCH DAY

Alexis Colvin, MD, from Mount Sinai (New York, New York) attends a dinner with the department the night prior to Sports Fellowship Research Day.

Volker Musahl, MD, Albert Lin, MD, and Craig Mauro, MD, with 2023 Sports Fellowship Research Day Visiting Professor and former UPMC sports medicine fellow Alexis Colvin, MD

The department with Visiting Professor Alexis Colvin, MD, after delivering her lecture for 2023 Sports Fellowship Research Day

The department with Visiting Professor Alexis Colvin, MD, after delivering her lecture for 2023 Sports Fellowship Research Day

VISITING PROFESSORS

Visiting Professor Michael Archdeacon, MD, and our department after he presented his excellent grand-rounds lecture

The orthopaedic trauma faculty with Visiting Professor Michael Archdeacon, MD, department chair from the University of Cincinnati, on the evening prior to his grand-rounds presentation

Kevin Colbert, former general manager of the Pittsburgh Steelers, gives a phenomenal grand-rounds presentation titled "Sustained Success from Bottom to Top."

The department with Kevin Colbert after his grand-rounds talk

Visiting Professor Danny Goel, MD, with the department after his grand-rounds talk on virtual reality in orthopaedic surgery

Danny Goel, MD, visiting professor from the University of British Columbia, with MaCalus Hogan, MD, MBA, and Albert Lin, MD, in front of the bust of Dr. Albert Ferguson after Dr. Goel delivered grand-rounds

Orthopaedic trauma faculty with visiting professor Anna Miller, MD, from Washington University School of Medicine in St. Louis

MaCalus Hogan, MD, MBA, and George Russell, MD, with Visiting Professor Anna Miller, MD, after her excellent grand-rounds presentation on fragility fractures

VISITING PROFESSORS

Freddie Fu Visiting Professor Matthieu Ollivier, MD, PhD, with Pitt orthopaedic sports medicine faculty on the evening prior to his grand-rounds presentation

Volker Musahl, MD, with Matthieu Ollivier, MD, PhD, in front of the bust of Dr. Freddie Fu after the Freddie Fu Visiting Professor Lecture

The department with Matthieu Ollivier, MD, PhD, visiting professor from the Institute of Movement and Locomotion in Aix-Marseille University Hospital, Marseille, France

Ozgur Dede, MD, introducing Visiting Professor Muharrem Yazici, MD, during his grand-rounds presentation on pediatric scoliosis

The department with Visiting Professor Muharrem Yazici, MD, after his grand-rounds presentation

DEPARTMENT OF ORTHOPAEDIC SURGERY
GRADUATING RESIDENTS
CLASS OF 2024

Congratulations to the Graduating Residents!
The Department of Orthopaedic Surgery congratulates the graduating residents, who have matched to excellent fellowship programs.

SUPERCHIEFS

Rebekah Belayneh, MD

Foot and Ankle Fellowship
Hospital for Special Surgery
New York, New York

Brandon Couch, MD

Adult Reconstruction Fellowship
Fondren Orthopaedic Group
Houston, Texas

Christopher Gibbs, MD

Hand and Upper-Extremity Fellowship
Wake Forest University
Winston-Salem, North Carolina

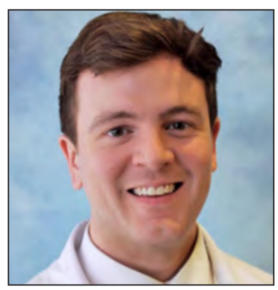
Dukens LaBaze, MD

Adult Reconstruction Fellowship
Johns Hopkins University
Baltimore, Maryland

CHIEFS

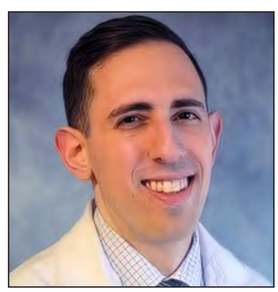
Joshua Adjei, MD

Spine Surgery Fellowship
New York University
New York, New York



Jonathan Dalton, MD

Spine Surgery Fellowship
Rothman Institute
Philadelphia, Pennsylvania



Michael Fox, MD

Sports Medicine Fellowship
Duke University
Durham, North Carolina

Benjamin Rothrauff, MD, PhD

Sports Medicine Fellowship
Steadman Philippon Institute
Vail, Colorado

WELCOME TO THE 2024 INTERN CLASS!

Congratulations and welcome to an exceptional group of interns for the 2024–2025 academic year.
Four interns will participate in the six-year research track, and five interns will participate in the five-year clinical track.

RESEARCH

John Bonamer

University of Cincinnati

Sahil Dadoo

University of North Carolina

Lawrence Garvin

Howard University

Elizabeth Plakseychuk

University of Pittsburgh

CLINICAL

Sandra Catanzaro

State University
of New York Upstate

Elizabeth Clayton

University of Tennessee

Henson Destiné

University of Miami

Janina Kaarre

Sahlgrenska Academy,
University of Gothenburg

Gillian Kane

University of Pittsburgh

We thank everyone for their efforts during the selection and interview process, and we look forward to our new intern class joining us this summer.
Welcome to the 2024 Intern Class!

PITT ORTHO RESIDENTS MATCH WITH EXCELLENT FELLOWSHIPS

Congratulations to the senior residents who have matched into the following fellowship programs for the 2024-2025 academic year.

We are so very proud of their excellent academic achievements, and we know that they will each continue to succeed as they progress in their surgical careers.
Congratulations to all!

RESEARCH

Sumail Bhogal

Hand and Upper-Extremity Fellowship
Rush University
Chicago, Illinois

Stephen Chen

Adult Reconstruction Fellowship
UPMC
Pittsburgh, Pennsylvania

Maria Munsch

Hand and Upper-Extremity Fellowship
Stanford University
Palo Alto, California

Nyaluma Wagala

Sports Medicine and Shoulder Fellowship
University of California San Francisco
San Francisco, California

CLINICAL

Colin Beckwitt

Hand and Upper-Extremity Fellowship,
Brigham and Women's Hospital
Boston, Massachusetts

Susanne Boden

Hand and Upper-Extremity Fellowship
Wake Forest University
Winston-Salem, North Carolina

Gabrielle Fatora

Sports Medicine and Shoulder Fellowship
University of Texas Health Science Center at Houston
Houston, Texas

Morgan Kohls

Hand Surgery Fellowship
Ohio State University
Columbus, Ohio

UNIVERSITY OF PITTSBURGH SCHOOL OF MEDICINE DEPARTMENT OF ORTHOPAEDIC SURGERY

MaCalus V. Hogan, MD, MBA, David Silver Professor and Chair

CLINICAL FACULTY

Adult Reconstruction
Brian Klatt, MD
Malcolm Dombrowski, MD
Michael O'Malley, MD
F. Johannes Plate, MD, PhD
AJ Yates, MD

Concussion Program
Michael Collins, PhD
Jonathan French, PsyD
Nathan Kegel, PhD
Alicia Trbovich, PhD
Vanessa Fazio Sumrok, PhD

Foot and Ankle
MaCalus Hogan, MD, MBA
Lauren Lewis, MD, MPH

General Orthopaedics–Surgical
David Fowler, MD

General Orthopaedic and Trauma
George V. Russell, MD, MBA
Tyler Petersen, DO
Peter Siska, MD
Rebekah Belayneh, MD
Brandon Couch, MD
Christopher Gibbs, MD
Dukens LaBaze, MD

Hand and Upper-Extremity
Robert Goitz, MD
Jennifer Dauria, MD
John Fowler Jr., MD
Robert Kaufmann, MD

Mercy Division
Gele Moloney, MD
Aaron Taylor, MD

Musculoskeletal Oncology
Richard McGough III, MD
Stella Lee, MD
Kurt Weiss, MD

Pediatric Orthopaedics
W. Timothy Ward, MD
Ozgur Dede, MD
Robert Goitz, MD
Jan Grudziak, MD, PhD
Jessica Hughes, MD
Stephen Mendelson, MD
Michael McClincy, MD
Amanda McCoy, MD
Z. Deniz Olgun, MD

Podiatry
Jarrett Cain, DPM
Jeffrey Manway, DPM
Kate Steklachich, DPM
Juanita Thorpe, DPM

Primary Care Sports Medicine
Jeanne Doperak, DO
Kelley Anderson, DO
Sean Carnahan, DO
Timothy Dancy, MD
Elizabeth Herrman, DO
Aaron Mares, MD
Melissa McLane, DO

Spine Surgery
William Donaldson III, MD
S. Joseph de Groot, MD
Joon Lee, MD
Jeremy Shaw, MD
W. Timothy Ward, MD

Sports Medicine
Volker Musahl, MD
Jonathan Hughes, MD
Bryson Lesniak, MD
Albert Lin, MD
Michael McClincy, MD
Stephen Rabuck, MD
Mark Rodosky, MD
Dharmesh Vyas, MD, PhD

Community Division
Aashish Jog, MD

UPMC Somerset
Steven Agabegi, MD
Nilesh Patil, MD
Vivek Sharma, MD

Vice President,
UPMC Orthopaedic Services
Andrea Badway

RESEARCH LABS

Arthroplasty Design
and Outcomes Lab
Kenneth Urish, MD, PhD

Biodynamics Laboratory
William Anderst, PhD

Concussion Program Lab
Michael Collins, PhD
Jonathan French, PsyD
Nathan Kegel, PhD
Anthony Kontos, PhD
Vanessa Fazio Sumrok, PhD

Ferguson Laboratory
for Orthopaedic and Spine Research
Nam Vo, PhD
Peter Alexander, PhD
Joon Lee, MD
Gwendolyn Sowa, MD, PhD

Foot and Ankle Injury Research
Group [F.A.I.R]
MaCalus Hogan, MD, MBA
Jarrett Cain, DPM

MechanoBiology Lab
James H-C Wang, PhD
Jianying Zhang, PhD

Musculoskeletal Oncology Lab
Kurt Weiss, MD
Ines Lohse, PhD

Neuromuscular Research
Laboratory
Bradley C. Nindl, PhD, FACSM

Orthopaedic Engineering and Sports
Medicine Lab
Patrick Smolinski, PhD

Orthopaedic Robotics Lab
Volker Musahl, MD
Richard Debski, PhD

Outcome Research
James Irrgang, PhD, PT, ATC
Christine McDonough, PT, PhD

Tissue Engineering
and Osteoarthritis Research Lab
Hang Lin, PhD

CLINICAL AFFILIATED FACULTY
D. Kelly Agnew, MD
Justin Arner, MD
Marshall Balk, MD
Mark Baratz, MD
James Bradley, MD
Charles Burke III, MD
Glenn Buterbaugh, MD
Franklin Chou, MD
Stephen Conti, MD
James DeLullo, MD
Nathan Formaini, DO
Michael Gaffney, MD
Trenton Gause, MD
Yram Groff, MD
Fred Heidenreich, MD
Thomas Hughes Jr., MD
Joseph Imbriglia, MD
Harvey Insler, MD
James Irvine Jr., MD
Ashish Jog, MD
Alex Kline, MD
Craig Mauro, MD
Edward McClain III, MD
Dana Mears, MD
James Mullen, MD
Thomas Muzzonigro, MD
Periklis Papapetropoulos, MD
Loukia Papatheodorou, MD, MSc, PhD
Nilesh K. Patil, MD
Anton Plakseychuk, MD, PhD
Mounif Rifkah, MD
Lee Sasala, MD
Christopher Schmidt, MD
Vivek Sharma, MD
Vincent Silvaggio, MD
Patrick Smith, MD
Dean Sotereanos, MD
S. Joshua Szabo, MD
Robert Waltrip, MD

JOINT FACULTY/ADJUNCT
Ameet Aiyangar, PhD
Fabrisia Ambrosio, PhD
Eric Anish, MD
K. Chris Beard, PhD
Jacques Chelly, MD
Constance Chu, MD
Richard Debski, PhD
Anthony Delitto, PhD
Aaron Grand, MD
Beth Gusenoff, DMP
Eni Halilaj, PhD
Johnny Huard, PhD
Nicole Jarrett, MD
Scott Lephart, PhD
Hongshuai Li, MD, PhD
C. Owen Lovejoy, PhD
Mark Lovell, PhD
Raymond Pan, MD
H-C. Pape, MD
Anthony Pardo, DVM
John Payne, DVM
Marc Philippon, MD
Adam Popchak, PT, PhD
Nalini Rao, MD
Cara Reddy, MD
Arman Saparov, MD, PhD
Karen Schoedel, MD
Patrick Smolinski, PhD
Gwendolyn Sowa, MD, PhD
Alex Spiess, MD
Yasutaka Tashiro, MD, PhD
Arvydas Usas, MD, PhD
Rebecca Watters, PhD
Stefano Zaffagnini, MD
Brian Zuckerbraun, MD

DEPARTMENT OF ORTHOPAEDIC SURGERY
ACADEMIC ORGANIZATIONAL STRUCTURE

MaCalus V. Hogan, MD, MBA, David Silver Professor and Chair
George V. Russell, MD, executive vice chair, orthopaedic surgery
William Donaldson III, MD, executive vice chairman for clinical services
Mark Baratz, MD, vice chairman for community outreach
John Fowler, MD, associate residency director
Albert Lin, MD, vice chairman for education and residency director
James J. Irrgang, PhD, vice chairman for clinical outcomes research
Anthony Kontos, PhD, vice chairman for clinical research
James H-C Wang, PhD, vice chairman for orthopaedic research
W. Timothy Ward, MD, vice chairman for pediatric surgery
Kurt R. Weiss, MD, vice chairman for translational research
Nam Vo, PhD, deputy vice chairman for orthopaedic research
Adolph Yates, MD, vice chairman for quality management

2023 GRADUATION

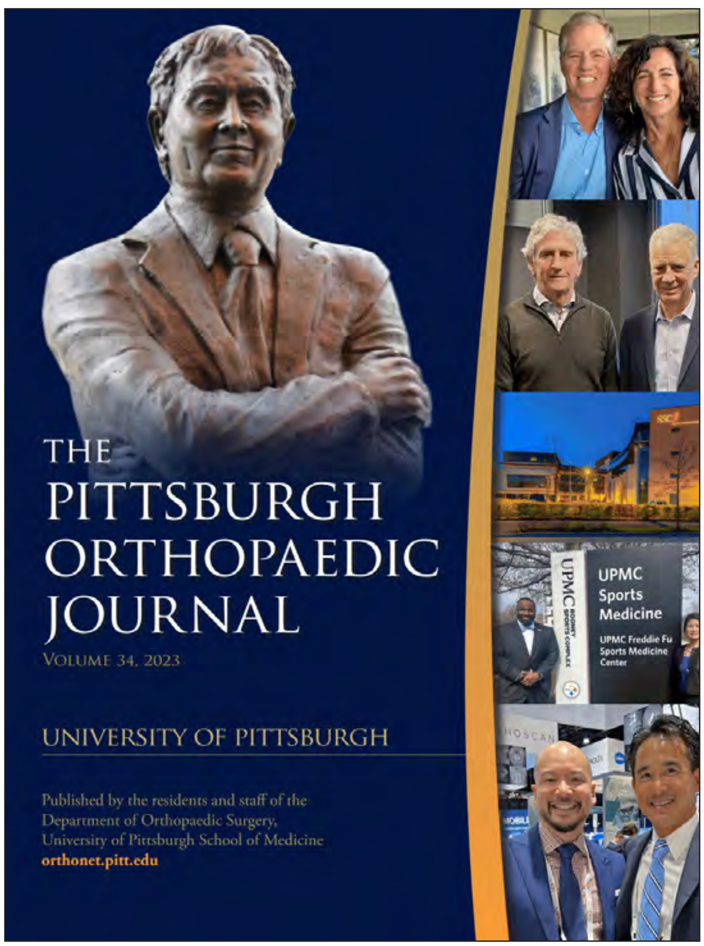
The 2023 Best Senior Resident Award was given to Alan Wilson, MD.

The 2023 orthopaedic surgery residency graduation ceremony was hosted at the Duquesne Club.

The graduating chiefs at the 2023 graduation

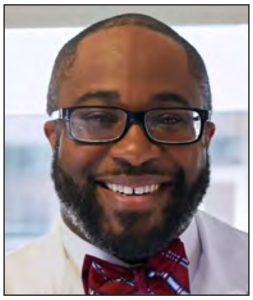
2023 GRADUATION

Graduating chiefs with Golden Apple Award recipient Deniz Olgun, MD



The 2023 edition of the *Pittsburgh Orthopaedic Journal* featured the bust of Dr. Fu on the cover.

DIVISION OF FOOT AND ANKLE SURGERY



MaCalus V. Hogan, MD, MBA
Chief

The 2023–2024 academic year brought forth several changes for the Division of Foot and Ankle Surgery. Transitioning forward as healthcare delivery continues to recover from the impacts of the pandemic, the division continues to grow across the clinical care, education, and research domains.

The Division of Foot and Ankle Surgery is led by MaCalus V. Hogan, MD, MBA, and podiatrists Jarrett Cain, MS, DPM, and Jeffrey Manway DPM. Kate Steklachich, DPM, joined the podiatry team in August 2023. She completed her podiatry residency training at UPMC and was fellowship trained in reconstructive rear foot and ankle surgery at Irvine Multispecialty Center in California. Prior to joining the UPMC practice, she practiced at Kaiser Permanente, where she specialized in sports medicine. Lauren Kelly Lewis, MD, MPH, joined the orthopaedic foot and ankle team in September 2023. She completed her residency training at the University of Texas Medical Branch and was fellowship trained in foot and ankle surgery at Massachusetts General Hospital. The division is also supported by many physician assistants and nurses who are critical to our excellent patient care experience and clinical practice.

The division cares for patients across the spectrum of foot and ankle conditions, including but not limited to fractures, dislocations, overuse syndromes, degenerative conditions, sports-related injuries, dance medicine, and complex forefoot and hindfoot reconstruction. Eight senior orthopaedic residents rotate on the foot and ankle service, during the orthopaedic third year for residents on the research track and the orthopaedic fourth year for those on the clinical track. Each orthopaedic intern completes a four-week rotation on the service.

With the addition of Dr. Lewis to the division, interns rotating on the service have a unique opportunity to get increased operating time and insight into what starting a new practice entails in an academic setting. This allows for the chiefs to have more individualized operating time with the senior foot and ankle surgeon, Dr. Hogan, sharpen their surgical skills, and gain perspective in clinical decision making before embarking on their respective fellowship journeys. Residents receive additional foot and ankle exposure during their orthopaedic two-year rotations at UPMC St. Margaret, through the division's longstanding collaboration with Alex Kline, MD.

The Division of Foot and Ankle Surgery also welcomed Omar Yaldo, MD, to the Three Rivers Orthopaedic Associates–UPMC practice, where he will be seeing patients at the UPMC St. Margaret and Natrona Heights locations. He completed his orthopaedic surgery residency at Michigan State University–Spectrum Health, before completing his orthopaedic foot and ankle surgery fellowship at the University of Pittsburgh School of Medicine in 2021–2022.

Dr. Cain, who serves as the UPMC chief of podiatry, continues to lead efforts in optimizing the alignment of the podiatric and wound-care practices across the enterprise. Additionally, his clinical practice and research efforts continue to grow since he joined the division in 2020. These research efforts have resulted in multiple collaborations with the MechanoBiology Laboratory. Their collaborative work on "The Effects of Reduced HMG1 on Non-Unions in Diabetic Rat Models" was recently presented by Dr. Cain at a podium presentation during the 70th Annual Orthopaedic Research Society Annual Meeting in Long Beach, California.

The division continues to deliver care across the UPMC Allegheny County footprint, with offices at UPMC East, UPMC Mercy, and UPMC Shadyside, as well as Dr. Hogan's practices at UPMC Monroeville and the UPMC Lemieux Sports Complex and his service as the lead consultant for the UPMC Sports Medicine Institute. The remaining clinicians in the division have clinical practices and practice at UPMC East. The division continues to support the UPMC wound healing service line, which now includes centers at UPMC Cranberry, UPMC Hamot, UPMC Horizon, UPMC McKeesport, and UPMC Northwest.

These centers offer a comprehensive wound-healing approach, with UPMC Mercy serving as the designated "Amputation Prevention Center" and as a tertiary referral center for patients in need of complex limb salvage focused on reconstructive surgery. Dr. Cain provides essential services for the UPMC Jameson and Horizon markets.

The University of Pittsburgh Orthopaedic Foot and Ankle Fellowship continues to grow in a collaborative effort across the UPMC foot and ankle centers. Two orthopaedic fellows were trained during this past year: Richard Smith, MD, and Jay Patel, MD, and three fellows are anticipated to be added to the division for the 2024–2025 academic year. The fellowship director is Dr. Kline, who works closely with codirectors William Saar, DO, and Dr. Hogan. The division is dedicated to the education and training of the next generation of orthopaedic foot and ankle surgeons. We congratulate graduating resident and super chief Rebekah Belayneh, MD, who will be starting her foot and ankle fellowship training at the Hospital for Special Surgery in the upcoming academic year.

The UPMC foot and ankle service line continues to serve as a model for the hospital system in a virtual collaboration between the Division of Community Medicine Incorporated. The division employed orthopaedic foot and ankle surgeons within the UPMC network: Steve Conti, MD, Christopher Edwards, MD, and Drs. Kline and Saar. In addition, this group also provides a collaborative forum for employed and private orthopaedic foot and ankle surgeons and podiatrists across the vast UPMC network. This collaboration continues to drive research collaboration and value-based care delivery across the system.

This was another great year of academic achievement and research activity for the division. The Foot and Ankle Injury Research group continues to push to new heights through collaborations with the Department of Orthopaedic Surgery's MechanoBiology Laboratory, led by James Wang, PhD, and the Biodynamics Laboratory, led by William Anderst, PhD. Furthermore, growing relationships with Peter Alexander, PhD, and Hang Lin, PhD, continue to position the division's scholarly productivity to progressively higher planes in innovation and research excellence. A clinical trial with the MechanoBiology Laboratory recently started recruiting patients to investigate the ability of metformin utility as a treatment option in cases of Achilles tendinopathy.

The division's global service and leadership continue to expand. Dr. Hogan completed his first full academic year as chairman of the department. He is the chair-elect of the Leg, Ankle, and Foot Committee of the International Society of Arthroscopy, Knee Surgery, and Orthopaedic Sports Medicine. Dr. Hogan also is the president-elect of the AOFAS (American Orthopaedic Foot and Ankle Society) Foundation Board of Directors.

DIVISION OF HAND AND UPPER EXTREMITY SURGERY

Robert Goitz, MD

The Hand and Upper-Extremity Division in the Department of Orthopaedic Surgery has enjoyed a year with excellent hand fellows, outstanding visiting professors, productive research, increased clinical productivity, and numerous milestones.

Our hand fellowship continues to attract the brightest applicants from across the country. We are particularly proud of our outgoing fellows: Max Hamaker (Chesapeake Orthopaedics, Maryland), Jessica Hawken (Med Star, Maryland), Riikka Koso (Ft. Collins, Colorado), Anthony Logli (Ortho Illinois), Karly Lorbeer (Silver Spring, Maryland), and Alejandro Morales-Restrepo (Paramus, New Jersey). Our current fellows are: Jeff Chen (New York University), Eileen Colliton (Tufts), Brian Foster (Geisinger), Justine Kim (Pitt Plastics), Luke Latario (University of Massachusetts), and Nicole Shaw (University of Maryland).

Our weekly Wednesday hand conference has remained virtual. It typically starts with an attending lecture followed by case presentations. It is well attended by numerous hand surgeons from around the city as well as many hand therapists and other students. Mark Baratz, MD, has maintained great enthusiasm for teaching the weekly bioskills lab, with many faculty contributing. Our fellows have access to a microscope training room to further enhance their education. The fellows rotate attending national meetings, including the American Society for Surgery of the Hand (ASSH), American Association for Hand Surgery, American Academy of Orthopaedic Surgeons, Philly hand course, and Snowmass course.

We have had outstanding visiting professors this past year, including Dawn LaPorte, MD, who presided over the quality-improvement projects. Tom Norris, MD, was the ninth Annual Imbriglia Lecturer. ASSH President Jennifer Wolf, MD, PhD, was our 2023 fellowship graduation attendant. Additional visitors included Ed Athanasian, MD, Matt Ramsey, MD, Angela Wang, MD, and Dan Zlotolow, MD.

John Fowler, MD, has been extremely busy this year, continuing to work as associate dean of medical student research and now also associate residency director and associate fellowship director. Dr. Fowler was also the chair of an ultrasound forum at the ASSH meeting. Rob Kaufmann, MD, has continued to serve as interim medical director of West Mifflin Surgical Center and has continued to try to bring his uncemented elbow prosthesis to market. Our clinical services have expanded to patients in West Mifflin, UPMC East, Bethel, Oakland, Cranberry, and the Children's Hospital of Pittsburgh satellite in Wexford. We have added Jake Kaufman as a new physician assistant to our division.

Our division has experienced some highs and lows this year. We were blessed with the addition of Mariella Rachael D'Auria, born on leap day; she is beautiful. After almost 11 years working with us, physician

Future hand surgeons with Dr. Fowler and Dr. Goitz at the American Society for Surgery of the Hand meeting

Bob Goitz with Allison Woods

Jennifer D'Auria with 2-day-old Mariella Rachael

Rob Kaufmann with Kathleen Masterson

This year's fellows and spouses at a Christmas party

assistant Allison Woods decided to retire to care for her family, with her third child on her way. She has been outstanding and impossible to replace, but we wish her well. We also had to say goodbye to Kathleen Masterson after five years of outstanding service directing our fellowship so adeptly. We wish her well in her next challenge.

Selected Publications

Hawken JB, Goitz RJ. Dorsal approach for management of PIP joint flexion contracture. *JHS Global*. 2023.

Hallihan CL, Goitz RJ, Kaufmann RA, Fowler JR. Effect of capitolunate positioning on outcomes in scaphoid excision and 4-bone fusion patients. *Hand (NY)*. 2023.

Chow I, Kaufmann RA, Goitz RJ, Fowler JR. A logistic regression analysis of factors associated with guarded outcome after carpal tunnel release in symptomatic carpal tunnel syndrome. *Plast Reconstr Surg*. 2023.

Dalton JF, Luchetti TJ, Cluts LM, Bhogal SS, Kaufmann RA, Goitz RJ, Fowler JR. Comparison of patient-reported outcomes with or without prophylactic carpal tunnel release after distal radius fracture stabilization. *Orthopedics*. 2023.

Reddy RP, Gao T, Chen J, Goitz R, Kaufmann RA, Fowler JR. The effect of timing between traumatic flexor tendon injury of the hand and surgical intervention on repair failure rates. *Orthopedics*. 2023.

Mirvish AB, Fowler JR. Surgical management of lateral epicondylitis: a retrospective review of technique success. *Hand (NY)*. 2023.

Suszynski TM, Fowler JR, Munsch M, Bourne DA, Chow I, Balk ML, Hagberg WC, Buterbaugh GA, Sivak WN, Imbriglia JE. Prospective cohort study comparing ligament reconstruction with tendon interposition and suture-only suspension arthroplasty for the treatment of basal joint arthritis. *Plast Reconstr Surg*. 2023.

Aloi NF, Rahman H, Fowler JR. Area Deprivation Index is not associated with the severity of carpal tunnel syndrome. *Hand (NY)*. 2023.

Vernick RC, Fowler JR. A “clear” carpal tunnel syndrome diagnosis on ultrasound examination does not predict improved outcomes when compared with a “borderline” diagnosis. *Hand (NY)*. 2023.

Teunis T, Domico A, Ring D, Fowler J. Correspondence of the Boston Carpal Tunnel Questionnaire with severity of median neuropathy. *J Hand Surg (Eur Vol)*. 2023.

Teunis T, Domico A, Ring D, Fowler J. Diagnosis of mild-to-moderate idiopathic median neuropathy at the carpal tunnel based on signs and symptoms is discordant from diagnosis based on electrodiagnostic studies and ultrasound. *Clin Orthop Relat Res*. 2023.

Vernick RC, Beckwitt CH, Fowler JR. Subjective and objective differences in patients with unilateral and bilateral carpal tunnel syndrome and the role of obesity in syndrome severity. *Plast Reconstr Surg*. 2023.

Carrozzi S, Schulz W, Beckwitt CH, Wera J, Wasil K, Fowler JR. Patients prefer ultrasound to nerve conduction studies for the diagnosis of carpal tunnel syndrome. *Plast Reconstr Surg Glob Open*. 2023.

Ernst J, Baratz ME, Fowler JR. Characterization of unpublished manuscripts by applicants to an orthopedic hand surgery fellowship. *J Hand Surg Glob Online*. 2023.

Koso RE, Njoku-Austin CO, Piston HE, Mirvish AB, Li R, Fowler JR. Corticosteroid injection in the operative hand prior to a trigger finger or carpal tunnel release: if it is not at the surgical site then what is the big deal? *Hand (NY)*. 2024.

Yamakawa S, Wilps TJ, Takaba K, Chan CK, Takeuchi S, Kaufmann RA, Debski RE. A dynamic elbow testing apparatus for simulating elbow joint motion in varying shoulder positions. *J Hand Surg Glob Online*. 2023.

Taday R, Schiffner E, Gehrmann SV, Wilms LM, Kaufmann RA, Windolf J, Latz D. Establishing regions of interest of the lower leg and ankle for perioperative volumetric assessment with a portable 3D scanner in orthopedic and trauma surgery—a pilot study. *J Foot Ankle Res*. 2023.

Kohls MR, Robertson ED, Beckwitt CH, Ghodadra AA, Kaufmann RA. Computed tomography-based humeral templating for uncemented elbow arthroplasty. *Hand (NY)*. 2023.

Robertson ED, Gu J, Beckwitt CH, Munsch MA, Baratz ME, Kaufmann RA. Static stability of novel uncemented elbow hemiarthroplasty stabilized with ligament reconstruction. *J Shoulder Elbow Surg*. 2024.

Wilps TJ, Chan CK, Yamakawa S, Takaba K, Takeuchi S, Kaufmann RA, Debski RE. the effect of elbow flexion on valgus carrying angle. *J Hand Surg (Am Vol)*. 2023.

Gibbs CM, Combs TN, Nelson BK, Kaufmann RA. Testing of a novel method for securing ligaments against bone during simultaneous medial and lateral elbow ligament reconstruction. *J Hand Surg Am*. 2023.

Suszynski TM, Coutinho D, Kaufmann RA. Flexor tendon repair in zone ii augmented with an externalized detensioning suture: protected flexor tendon repair. *J Hand Surg Am*. 2023.

Nazzal EM, Mattar LT, Newell BW, Coutinho DV, Kaufmann RA, Baratz ME, Debski RE. Do intramedullary screws provide adequate fixation for humeral and ulnar components in total elbow arthroplasty? A cadaveric analysis. *J Hand Surg (Am Vol)*. 2023.

Goyal N, Coutinho D, Ghodadra A, Baratz ME, Kaufmann RA. Computed tomography-based templating of proximal ulna intramedullary screw fixation. *Hand (NY)*. 2023.

Gibbs CM, Nelson B, Combs T, Moody D, Kaufmann RA. Posterior flange cyclic loading in a novel total elbow arthroplasty. *J Hand Surg Glob Online*. 2023.

Coutinho DV, Fatehi A, Nazzal EM, Baratz ME, Kaufmann RA. Comparing static stability of native elbow with static stability of novel bidirectional ligament reconstruction at different degrees of elbow flexion. *J Hand Surg Glob Online*. 2023.

Combs TN, Nelson BK, Jackucki M, Knopp B, Schneppendahl J, Moody D, Kaufmann RA. Testing of novel total elbow prostheses using active motion experimental setup. *J Hand Surg (Am Vol)*. 2023.

Hulet DA, D'Auria JL, Earp BE, Zhang D, Benavent K, Blazar PE. Long-term outcomes and return to work after isolated coronal shear fractures of the capitellum. *J Hand Surg Glob Online*. 2023.

Ray S, D'Auria J, Lee H, Baratz M. Allyship for diversity, equity, and inclusion in hand surgery. *Hand Clin*. 2023.

Bhogal S, D'Auria J, Gehrmann S, Baratz M, Kaufmann R. Polymethyl methacrylate for elbow arthroplasty: is there another way? *J Hand Surg Global Online*. 2024.

Tom Norris with last year's fellows at the Imbriglia Lecture

INTERPOSITION ARTHROPLASTY AND BIDIRECTIONAL STABILIZATION OF THE ELBOW: A NOVEL SURGICAL TECHNIQUE

Chen JS, Robertson ED, Bosetti AA, Beckwitt CH, Baratz ME, Kaufmann RA

Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.

INTRODUCTION

Management of elbow arthritis in younger and higher-demand patients is challenging. Interposition arthroplasty of the elbow is a well-described procedure which avoids the lifting restrictions and high complication rates of total elbow arthroplasty. Clinical results have implicated instability as a determinant of poor outcomes.[1] We propose an interposition technique that employs an Achilles allograft as both an interposition material and a source of collateral ligament grafts. This approach utilizes a novel ligament retention device that allows simultaneous tensioning of medial and lateral ligament grafts. An additional benefit of the proposed technique is that postoperative external fixation is unnecessary.

TECHNIQUE

The step-by-step technique is described and illustrated. In brief, the distal humerus is exposed through a triceps-sparing posterior approach. The distal humerus and proximal ulna are prepared for placement of the cylindrical ligament retention device (CLRD). Distal humerus cartilage is denuded, and bone tunnels are placed. An Achilles allograft is prepared, and two collateral ligament grafts are trimmed from its edges. The interpositional graft is secured, and the ligament grafts are loaded in the CLRD. The elbow is reduced, and the grafts are tensioned and secured to the ulna under a two-plate system.

DISCUSSION

Elbow interposition arthroplasty with bidirectional ligament reconstruction offers a novel technique for treatment of elbow arthritis in younger and higher-demand patients while addressing instability and avoiding postoperative external fixation. Future studies on clinical outcomes are necessary.

REFERENCE

1. Lanzerath F et al. *Int Orthop.* 2022;46(11),:2603-10.

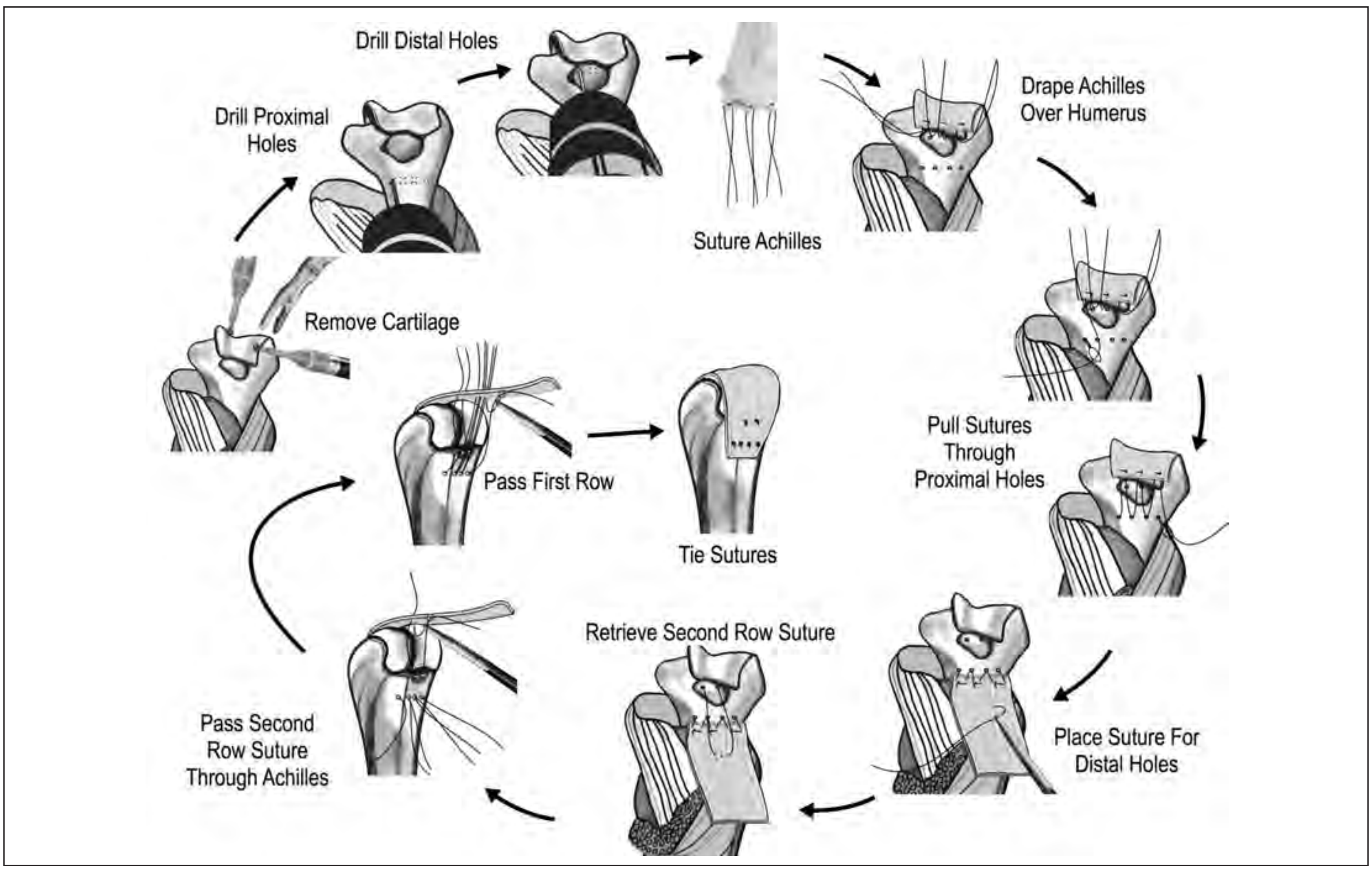


Figure 1. Interposition arthroplasty technique. Denude distal humerus articular cartilage. Drill bone tunnels through the supracondylar humerus and across the olecranon fossa. Load Achilles allograft with sutures. Position allograft over distal humerus and pull sutures through the supracondylar drill holes such that the limbs of each suture are separated by a bone bridge. Pass another suture through allograft at the level of the olecranon fossa holes and pass limbs through holes. Using a free needle, pass all suture tails through other side of graft. Tie all sutures to secure allograft to distal humerus.

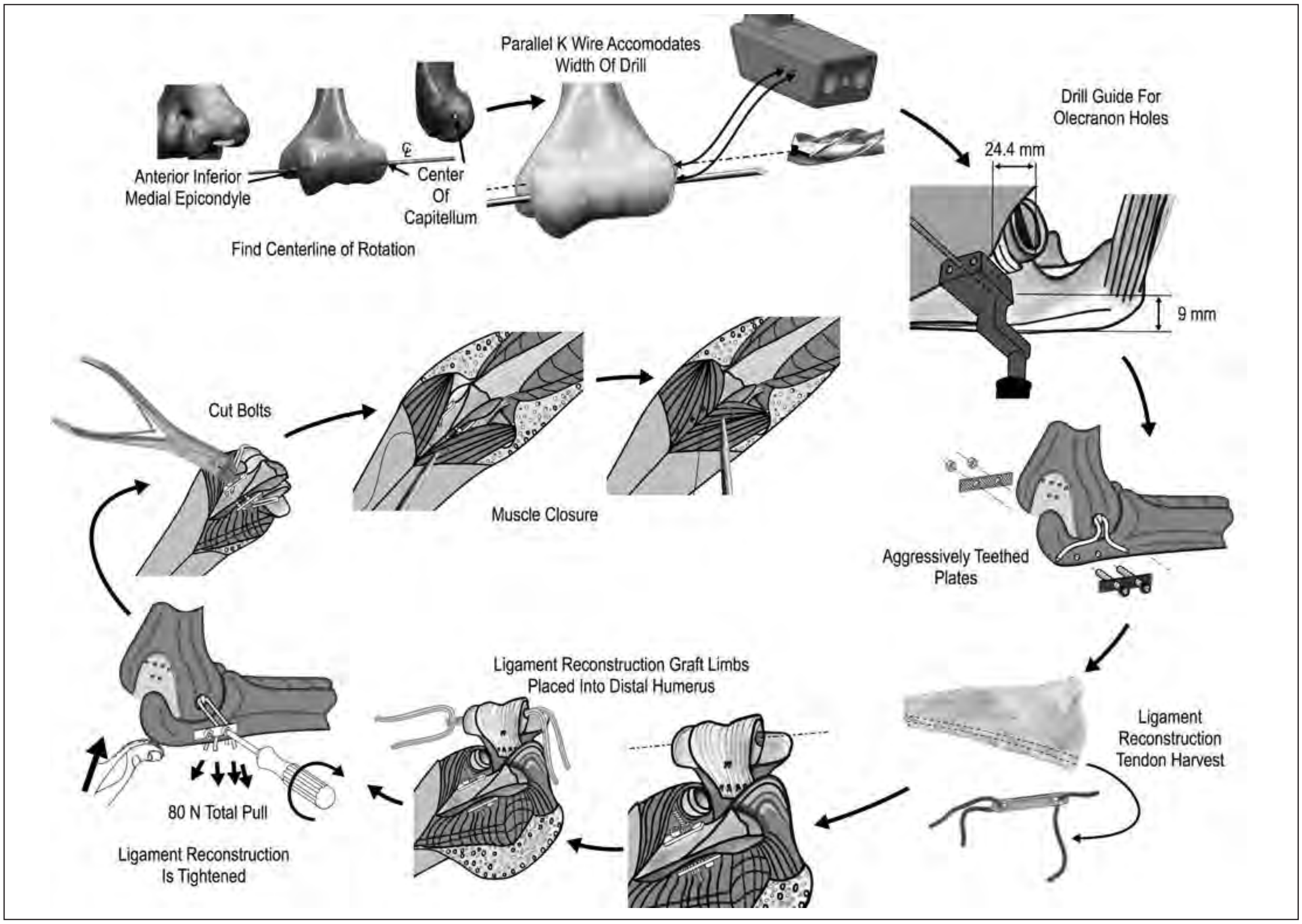


Figure 2. Cylindrical ligament retention device (CLRD) technique. Identify centerline of rotation of distal humerus by placing a K-wire at the center of the capitellum laterally and the anterior inferior aspect of the medial epicondyle medially. Place a second, parallel K-wire on both sides. Remove first set of K-wires and drill over second set of K-wires, connecting tunnel centrally. Make two transverse drill holes across supinator crest. Secure ligament reconstruction plates with trans-ulnar bolts and nuts. Harvest ligament reconstruction grafts and load into CLRD. Pass CLRD across distal humerus. With interpositional graft applied and elbow reduced, apply approximately 80 N across the ligament grafts and tighten bolts and nuts, securing grafts to the ulna. Trim bolts and close soft-tissue sleeves and native ligaments over subcutaneous ulna.

STATIC STABILITY OF INTERPOSITION ARTHROPLASTY STABILIZED WITH NOVEL LIGAMENT RECONSTRUCTION

Beckwitt CH, Chen JS, Robertson E, Bosetti AA, Baratz ME, Kaufmann RA

Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.

INTRODUCTION

The purpose of this study was to compare static stability of the native elbow with elbow stability following a novel interposition arthroplasty and bidirectional ligament reconstruction technique that employs a novel plate system to simultaneously tension medial and lateral collateral ligament grafts.

METHODS

Static varus and valgus elbow stability was tested in seven cadaver elbows with intact ligaments and capsule at five flexion angles (0º, 30º, 60º, 90º, and 120º). The elbows were then destabilized through release of all ligaments and capsular attachments. The distal humerus was denuded of cartilage and resurfaced with an interposition arthroplasty. Ligament reconstruction was subsequently performed, and elbow stability was measured by deflection distance and compared to the native state.

RESULTS

An interposition arthroplasty was implanted in seven cadaver specimens. Following ligament reconstruction, specimens reproduced the flexion angle-dependent stability of native elbows to both varus and valgus stress. The highest change in deflection between the elbows after interposition arthroplasty and native elbows was 2.7% medially and 2.3% laterally, which was not statistically significant. There was no loosening of the interposition graft or slippage of the ligament reconstruction grafts.

CONCLUSIONS

Cadaveric elbow specimens underwent interposition arthroplasty with a novel technique for bidirectional ligament reconstruction. Static stability was maintained at varying degrees of elbow flexion, comparable to that of the native elbow. Interposition and ligament reconstruction grafts maintained secure fixation following static biomechanical testing.

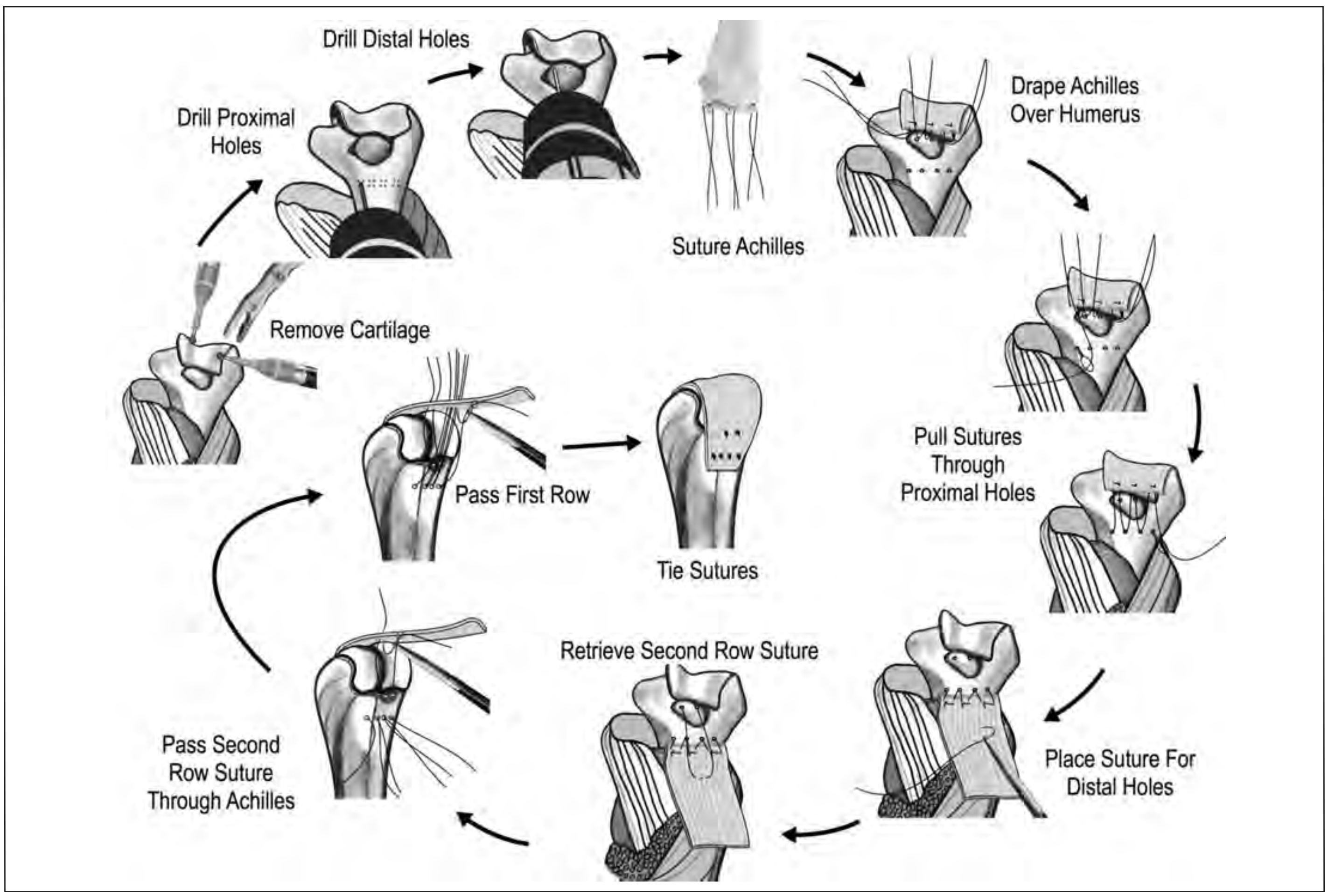


Figure 1. Interposition arthroplasty technique

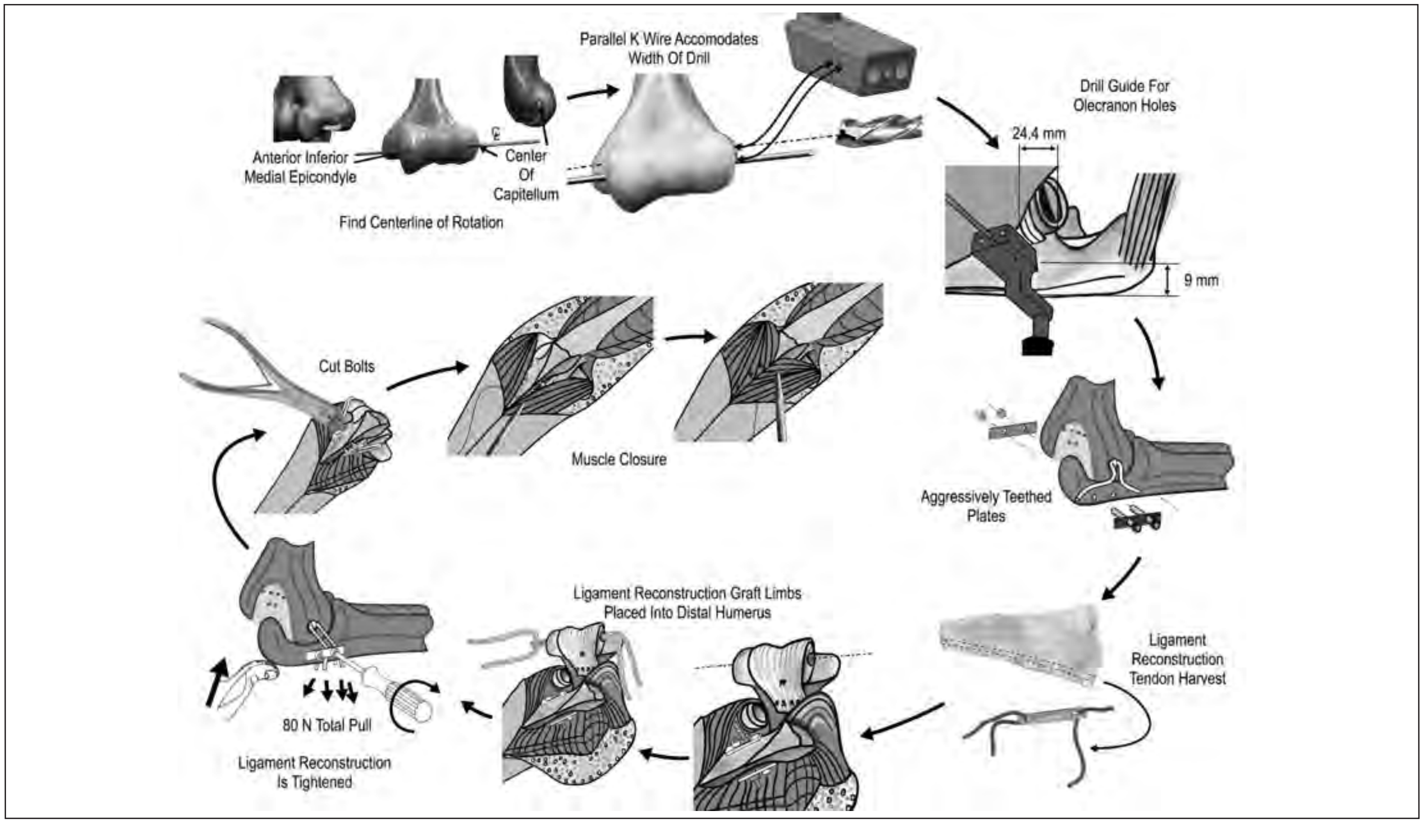


Figure 2. Cylindrical ligament retention device technique

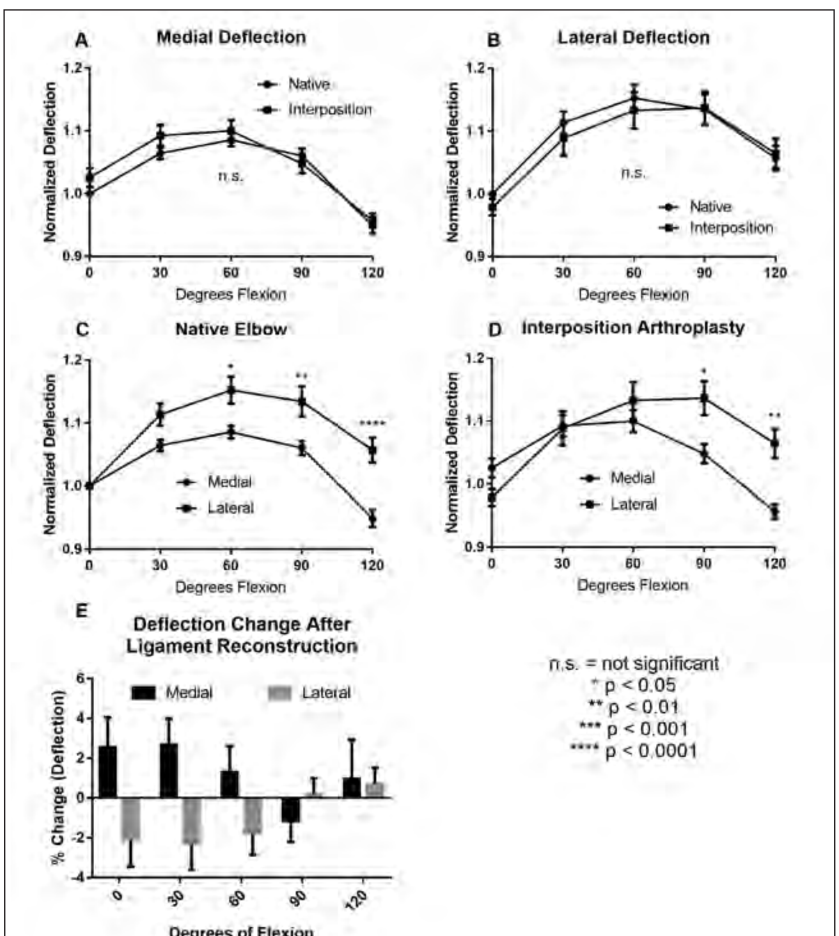


Figure 3. Elbow deflection throughout range of motion is quantified for 0º, 30º, 60º, 90º, and 120º of elbow flexion on the medial (A) and lateral (B) sides under 3 lb of valgus and varus stress, respectively, for native elbows and elbows after interposition arthroplasty with ligament reconstruction. Normalized deflection is compared between the medial and lateral sides for native elbows (C) and elbows after interposition arthroplasty with ligament reconstruction (D). Percentage change in deflection from the native elbow at various flexion angles after interposition arthroplasty with ligament reconstruction (E). Statistics were analyzed with two-way analyses of variance (A-D). Error bars represent standard error of the mean.

THE DIAGNOSTIC UTILITY OF ULTRASOUND AND ELECTRODIAGNOSTIC STUDIES IN THE YOUNG AND OLD

Finger LE[1], Patel S[1], Boyd T[2], Fowler JR[1]

[1]Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.
[2]Department of Plastic Surgery, University of Texas Southwestern, Dallas, Texas

INTRODUCTION

The diagnostic parameters for carpal tunnel syndrome currently used in the general adult population may not be valid in elderly or younger cohorts. The purpose of this study was to determine the diagnostic accuracy of nerve conduction studies (NCS) and ultrasound (US) in different age groups utilizing CTS-6 as the reference standard.

METHODS

Subjects who underwent US and NCS were separated into three groups based on the median age of carpal tunnel syndrome patients (55 years of age) and two standard deviations (standard deviation = 13.5 years) above and below the median. The "young" group was 28 years of age or younger, the "middle" group was 29–71 years of age, and the "old" group was 72 years of age or older. Using CTS-6 as a reference standard, the researchers calculated sensitivity and specificity for NCS and US.

RESULTS

A total of 295 hands were included in the analysis, with 23 hands in the "young" group and 24 hands in the "old" group. NCS showed a 31% sensitivity and 100% specificity in the young group compared to 54% sensitivity and 90% specificity for US. NCS showed a 94% sensitivity and 25% specificity in the old group compared to 81% sensitivity and 38% specificity for US. Overall accuracy for US and NCS was 66% for both tests at all ages. The accuracy in the young group was 70% for US and 61% for NCS, whereas the accuracy in the old group was 67% for US and 71% for NCS.

CONCLUSIONS

US has comparable sensitivity and specificity to NCS in patients two or more standard deviations above or below the mean age for presentation of CTS. US may be more accurate in younger patients, although NCS limits the number of false-positive tests. There remains a substantial amount of inaccuracy for both tests when a validated clinical diagnostic tool (CTS-6) is used as the reference standard.

	All	Young n = 23	Middle n = 248	Old n = 24	P value
Median nerve (mm²)	10.3	8.44 (SD = 3.02)	10.38 (SD = 3.02)	11.83 (SD = 3.7)	< 0.05*
CTS-6	12.8	10.61 (SD = 6.31)	12.87 (SD = 6.31)	13.85 (SD = 7.09)	0.48
Distal motor latency (ms)	4.76	3.63 (SD = 0.95)	4.74 (SD = 1.75)	6.63 (SD = 2.38)	< 0.05**
CMAP (mV)	10.8	16.8 (SD = 19.2)	10.19 (SD = 3.9)	7.41 (SD = 9.44)	< 0.05*
Distal sensory latency (ms)	3.44	2.68 (SD = 1.74)	4.58 (SD = 2.65)	6.73 (SD = 3.2)	< 0.05**
SNAP (uV)	34.2	72.1 (SD = 55.5)	25.6 (SD = 28.1)	10.4 (SD = 13.9)	< 0.05**
BCTQ SSS	2.79	2.49 (SD = 0.84)	2.85 (SD = 0.01)	2.47 (SD = 0.65)	< 0.05***
BCTQ FSS	2.18	1.87 (SD = 0.74)	2.19 (SD = 0.84)	2.39 (SD = 0.95)	0.12

*Significant difference between middle versus young and young versus old
**Significant difference between middle versus young, young versus old, and middle versus old
***Significant difference between middle versus young and middle versus old
CTS-6 = Carpal Tunnel Syndrome 6 score,
CMAP = Compound Muscle Action Potential,
SNAP= Sensory Nerve Action Potential,
BCTQ SSS = Boston Carpal Tunnel Syndrome Questionnaire Symptom Severity Scale,
BCTQ FSS = Boston Carpal Tunnel Syndrome Questionnaire Functional Status Scale

Table 1. Summary of Groups

	All (95% CI)	Young (95% CI)	Middle (95% CI)	Old (95% CI)
Sensitivity	72.2% (65.2–78.5)	53.9% (25.1–80.8)	72.8% (65.1–79.6)	81.3% (54.4–95.9)
Specificity	56.5% (46.6–66)	90% (55.5–99.8)	54.4% (43.6–65)	37.5% (8.5–75.5)
Positive predictive value	74.2% (69.5–78.4)	87.5% (50.5–97.9)	73.7% (68.7–78.2)	72.2 % (59.1–82.4)
Negative predictive value	54% (46.9–60.9	60% (44.6–73.7)	53.3% (45.3–61.0)	50% (20.5–79.5)
Accuracy	66.4% (60.7–71.8)	69.6% (47.1–86.8)	66.1% (59.9–72)	66.7% (44.7–84.3)

CI—confidence interval

Table 2. Sensitivity and Specificity of Ultrasound

	All (95% CI)	Young (95% CI)	Middle (95% CI)	Old (95% CI)
Sensitivity	74.3% (67.5–80.4)	30.8% (9.1–61.4)	76% (68.5–82.4)	93.8% (69.8–99.8)
Specificity	50.9% (41.1–60.7)	100% (69.1–100)	47.8% (37.1–58.6)	25% (3.2–65.1)
Positive predictive value	72.4% (68–76.4)	100% (39.8–100)	71.9% (67.3–76)	71.4% (62.2–79.2)
Negative predictive value	53.4% (45.8–60.9)	52.6% (43.6–61.5)	53.1% (44.33–61.7)	66.7% (17.5–95)
Accuracy	65.8% (60–71.2)	60.9% (38.5–80.3)	65.7% (59.5–71.6)	70.8% (48.9–87.4)

CI—confidence interval

Table 3. Sensitivity and Specificity of Electrodiagnostic Testing

COMPARISON OF FUSION RATES/COMPLICATIONS BETWEEN DIFFERENT TYPES OF THUMB METACARPOPHALANGEAL FUSION TECHNIQUES

Finger LE, Hamaker MC, Singh-Varma A, Goitz RJ, Kaufmann RA, Fowler JR

Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.

BACKGROUND

Thumb metacarpophalangeal (MP) fusion is generally successful; however, complications have been reported to occur in 0–30% of cases. Nonunion rates vary by method but overall are reported to occur in 0–15% of cases. Many fixation techniques have been described, but there is no consensus on the optimal fusion technique. The authors' goal was to compare complication and union rates of different thumb MP arthrodesis techniques.

METHODS

The researchers performed a retrospective review of patients who underwent primary thumb MP fusion from 2000–2022. Patients who underwent revision fusion, fusion for infection, or amputation were excluded. Fusions of MP joints of other fingers were also excluded. Data collection consisted of demographic data, complications, time to fusion, rate of delayed union, and rate of nonunion. Five different fusion constructs were evaluated during the study period: staples, Kirschner wires (K-wires), cerclage, K-wires with cerclage, and intramedullary screw.

RESULTS

Forty-seven patients underwent fusion with staples, 16 with K-wires, 14 with cerclage, nine with K-wires and cerclage, and six with an intramedullary screw. The individual complication and nonunion rates differed significantly among the groups, with the intramedullary screw group having a statistically higher rate of nonunion ($p = 0.004$). Furthermore, smoking, diabetes, and being overweight were associated with nonunion.

CONCLUSION

Union rates were significantly lower in patients treated with an intramedullary screw and those who were smokers, diabetics, and/or overweight. Caution should be exercised when using intramedullary screw fixation for MP fusion, especially in patients with those comorbidities.

	Intramedullary Screw	Staples	K-Wires	Cerclage	K-Wire w/ Cerclage	P-value
Time to union (days)	77.0 ± 28.1	65.0 ± 20.3	78.0 ± 25.8	76.4 ± 27.7	78.1 ± 20.5	0.25
Complication rate	50.0%	10.6%	0%	7.1%	0%	0.008*
Delayed union rate	0%	0%	0%	0%	0%	n/a
Overall nonunion rate	50.0%	6.4%	0%	7.1%	0%	0.004*
Intramedullary screw versus staple nonunion rate	50.0%	6.4%	-	-	-	0.001*
Intramedullary screw versus cerclage nonunion rate	50.0%	-	-	7.1%	-	0.03*
Staple versus cerclage nonunion rate	-	6.4%	-	7.1%	-	0.92

* statistical significance

Table 1. Complication and Union Outcome Measures Based on Fixation Method

	Nonunion	Union	P value
Inflammatory arthritis	7	8	1.00
No inflammatory arthritis	0	77	
Smoking	5	20	0.01*
Nonsmoking	2	65	
Diabetic	4	16	0.02*
Nondiabetic	3	69	
Female	4	53	0.78
Male	3	32	
BMI < 25	0	36	0.03*
BMI > 25	7	49	

BMI—body mass index
* statistical significance

Table 2. Association between Nonunion and Demographic Variables

MAXIMIZING THE VALUE OF CTS-6: WHEN IS ADDITIONAL TESTING MOST AND LEAST LIKELY TO CHANGE DIAGNOSTIC PROBABILITY?

Gibbs CM, Fowler JR

Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.

PURPOSE

Electrodiagnostic studies (EDS) have been shown to have little value when the pretest probability of carpal tunnel syndrome (CTS) is high. Ultrasound (US) is useful for diagnosing CTS, but its effect on the diagnostic probability of CTS has not been well studied. The purpose of this study was to evaluate the change in probability of CTS following EDS and US. The authors hypothesized that EDS and US would be of low value for patients with a high CTS-6 and that US would have a similar effect on the change in probability compared to EDS.

METHODS

A cohort of 295 patients being assessed for compressive neuropathies of the upper extremity was prospectively enrolled to be evaluated with CTS-6, EDS, and US. The researchers calculated pretest probability of CTS using CTS-6. They used Bayesian analysis to calculate post-test probability following EDS and US. Correlation, change in probability, and between-group differences were calculated.

RESULTS

The pretest probability of CTS was 0.74 ± 0.29 (range: 0.11–0.99). For all patients, there was a mean increased change in probability of CTS following EDS testing, but US resulted in a mean decrease in probability. The mean probability of CTS increased for patients with pretest probability < 0.5. All patients with CTS-6 8–12 had a change in probability > 10% following EDS and US, but with CTS-6 > 17, a change > 10% was seen in no patients following EDS and in 15% following US.

CONCLUSIONS

Adjunct testing is of greatest value for patients with CTS-6 of 8–12. Conversely, for patients with CTS-6 > 17, adjunct testing is of little value. With low pretest probability, the diagnostic probability was found to increase on average, raising concern of possible overdiagnosis.

COMPUTED TOMOGRAPHY–BASED HUMERAL TEMPLATING FOR UNCEMENTED ELBOW ARTHROPLASTY

Kohls MD[1], Robertson ED[1], Beckwitt CH[1], Ghodadra AA[2], Kaufmann RA[1]

[1]Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.
[2]Department of Radiology, Interventional Radiology Division, University of Pittsburgh, PIttsburgh, Pa.

BACKGROUND

Intramedullary (IM) screw insertion into the distal humerus provides fixation for a novel, uncemented elbow arthroplasty.[1] A multitude of screw sizes is required to accommodate variable humeral morphology. Previous studies have demonstrated that both humeral and ulnar intramedullary screws can achieve good pullout strength and effect a stable arthroplasty design.[2] It has been demonstrated that ulnar intramedullary screws can be successfully templated using computed tomography (CT).[3] The goal of this study was to utilize computed CT for humeral IM screw sizing and to validate this templating by inserting screws into 3D-printed models.

METHODS

CT humerus scans for 30 patients were reformatted in the plane of the distal IM canal using VitreaCore Software (ViTAL, Minnetonka, Minnesota). Implant body size was determined with trochlear diameter. The researchers templated screw size by measuring the canal diameter at three locations corresponding to the three screw lengths (see Figure 1). Measurements for all scans were then repeated, 15 by the same author and 15 by another for inter- and intra-rater reliability assessment. 3D models of five humeri were printed, and IM screws were placed to achieve a secure endosteal fit.

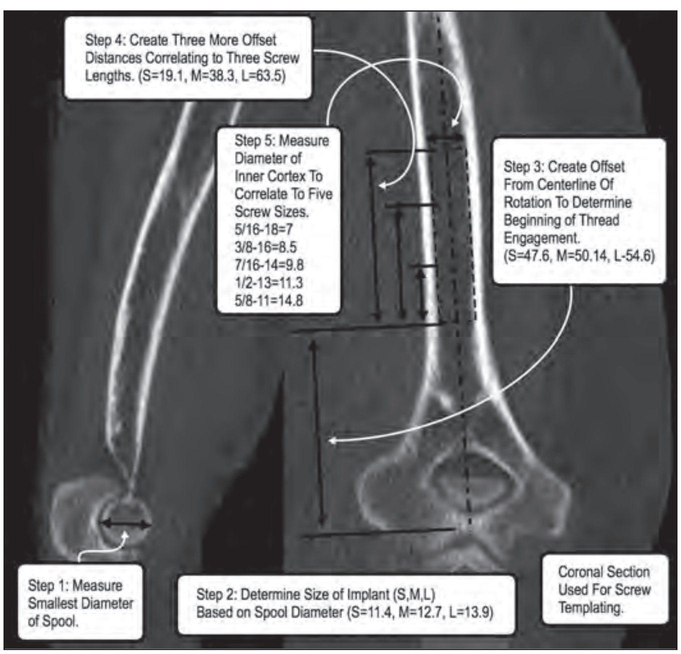


Figure 1. Algorithm for computed tomography scan–based templating of humeral screws

RESULTS

Using reformatted CT, the authors identified combinations of body components and IM screw length and diameter for all patients to seat this uncemented elbow arthroplasty. All raw measurements and screw width determinations were reliable, but screw length selection was less reliable. Canal diameter was found to correlate with age but was unrelated to sex. Screws were inserted into five 3D-printed models, which matched at least one of two templates. These screws demonstrated mechanical and radiographic evidence of secure fit (see Figure 2).

CONCLUSIONS

This study characterizes distal humerus anatomy in the context of IM screw fixation. Thirty patient humerus CT scans were able to be templated, and validation via implantation of intramedullary screws into 3D models was successful. CT templating will allow surgeons to predict optimal screw size prior to implantation. A broad range of screw lengths and diameters is critical for implantation of this novel elbow arthroplasty.

REFERENCES

1. Beckwitt CH, Robertson ED, Gu JH et al. Elbow Uncemented hemiarthroplasty: surgical technique. *J Hand Surg Global Open*. 2023;6(1):91-7.
2. Nazzal EM, Mattar LT, Newell BW, Coutinho DV, Kaufmann RA, Baratz ME, Debski RE. Do intramedullary screws provide adequate fixation for humeral and ulnar components in total elbow arthroplasty? A cadaveric analysis. *J Hand Surg (Am Vol)*. 2023:S0363-5023(23)00356-8.
3. Goyal N, Coutinho D, Ghodadra A, Baratz ME, Kaufmann RA. Computed tomography-based templating of proximal ulna intramedullary screw fixation. *Hand (NY)*. 2023:15589447231184894.

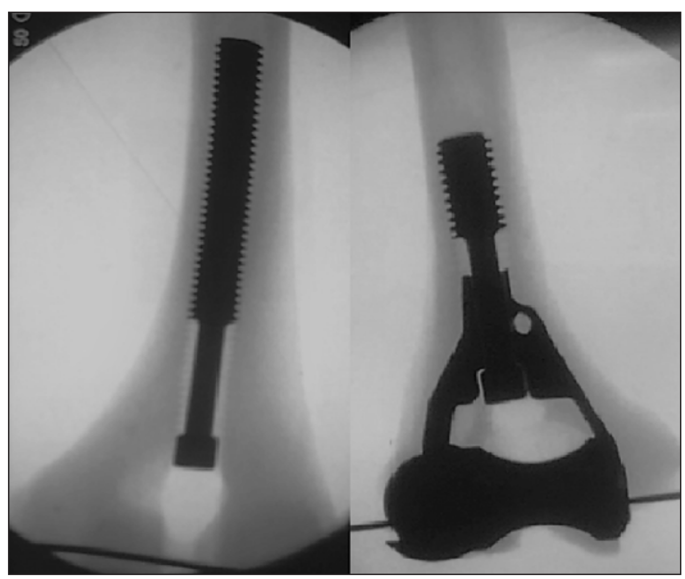


Figure 2. Screw insertion into 3D-printed models. Radiograph of test construct pictured left. Implant body is included (overlapped) for reference, pictured right.

BILATERAL ELBOW LIGAMENT RECONSTRUCTION: SURGICAL TECHNIQUE

Munsch MA[1], Moody DW[2], Kaufmann RA[1]

[1]University of Pittsburgh Department of Orthopaedic Surgery, Pittsburgh, Pa.
[2]Bolttech Mannings Inc., North Versailles, Pa.

INTRODUCTION

Bidirectional ligamentous elbow instability is an uncommon problem. It may be caused traumatically or intraoperatively during interposition arthroplasty. After the distal humerus is resurfaced, the elbow is invariably destabilized and may require external fixation or an epicondyle osteotomy followed by fixation to ensure postoperative stability. A need exists to treat grossly unstable elbows via reconstruction with simultaneous medial and lateral tensioning, employing hardware that does not require removal. Bidirectional ligament reconstruction with a cylindrical ligament retention device (CLRD) is proposed for this purpose.

MATERIALS AND METHODS

The distal humerus and proximal ulna are exposed, and the centerline of ulnohumeral rotation is identified. A trans-humeral tunnel is drilled, connecting the medial and lateral epicondyles about the ulnohumeral axis (see Figure 1). This tunnel allows for passage of the appropriately sized CLRD.

Tendon grafts pass freely through the CLRD eyelets. The CLRD is centrally located in the trans-humeral tunnel and secures the graft limbs (see Figure 2).

Aggressively teethed plates are secured to the proximal olecranon with two trans-ulnar bolts and splined nuts (see Figure 3).
Medial and lateral sides are simultaneously and equally tensioned. This force is maintained by compression of the ulnar plates. The ulnohumeral joint is seated with pressure exerted between the ulna and the distal humerus while the tendons are tensioned and the bolts are tightened. The grafts then sit in an isometric location and heal to bone.

RESULTS

This procedure is indicated for treatment of acute or chronic bidirectional elbow instability. Isometric graft placement allows for elbow motion without stretching of either graft limb and, thus, minimizes potential graft impingement, stiffness, stretching, and subsequent failure. Simultaneous graft tensioning aims to impart symmetrical stability and restore native elbow kinematics. Graft tension is maintained with aggressively teethed plates that exert compression between the graft and the proximal ulna.

CONCLUSIONS

Bidirectional ligamentous reconstruction offers a novel technique for treatment of acute or chronic grossly unstable elbows.

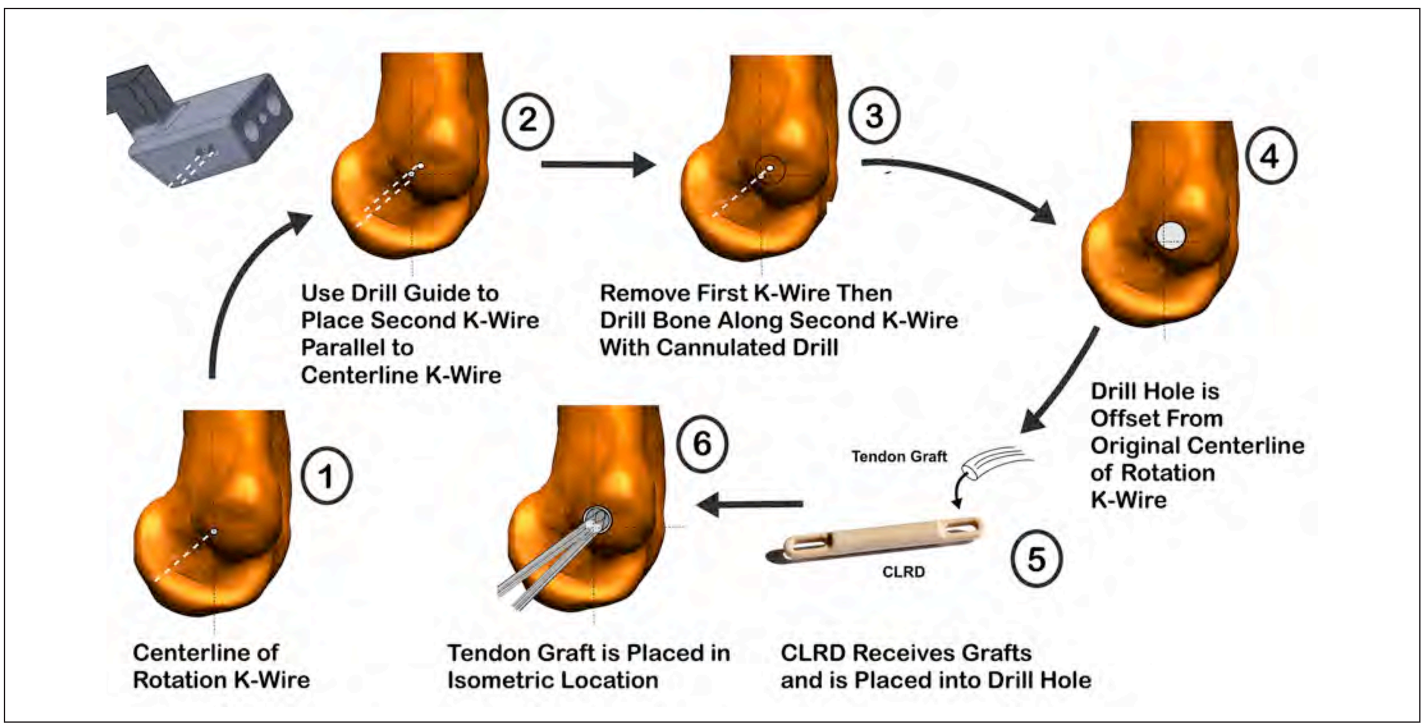


Figure 1. Proper placement of the trans-humeral tunnel facilitates CLRD passage and isometric graft placement

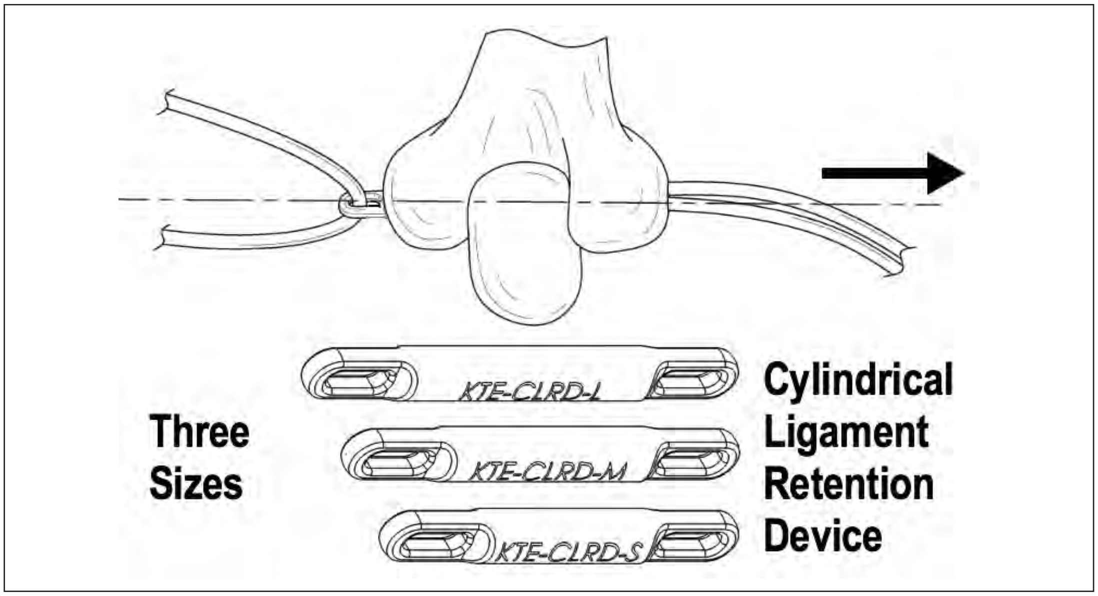


Figure 2. Three sizes of CLRD are available. Its diameter and eyelets have uniform dimensions and allow for free ligament passage.

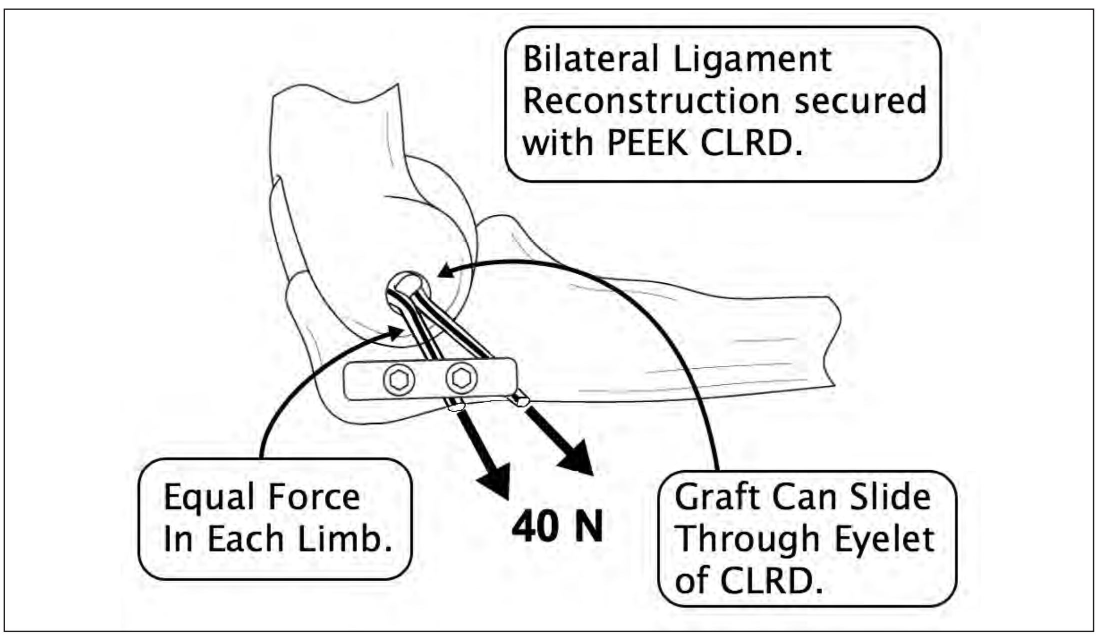


Figure 3. Medial and lateral sides are tensioned with a combined pull of 80 N.

DIVISION OF ADULT RECONSTRUCTION

Brian A. Klatt, MD

It has been another year of growth as both academic and clinical productivity continued in the Division of Adult Reconstruction. The faculty based in the Shadyside office includes Brian Klatt, MD, AJ Yates, MD, Michael O'Malley, MD, F. Johannes Plate, MD, PhD, and Malcolm Dombrowski, MD. Drs. O'Malley and Plate operate at both UPMC Shadyside and UPMC East. Patients are seen in offices at Shadyside, Monroeville, and Bethel and at the UPMC Lemieux Sports Complex. Also in the Monroeville office and at UPMC East is David Fowler, MD. The division continues to be complemented in the Shadyside office by the Division of Musculoskeletal Oncology with Richard McGough III, MD, Kurt Weiss, MD, and Stella Lee, MD.

The Shadyside team now routinely has six residents on service—three on the reconstruction side and three on the oncology side. The residents continue to benefit from an increasing number and variety of surgical cases. Thursday morning teaching conferences continue to stimulate lively discussions as we work through a topic-based curriculum as well as pre- and postoperative case presentations. As always, it is great to be joined by Brian Hamlin, MD, Edward McClain III, MD, and Kenneth Urish, MD, PhD. This provides fresh ideas and perspectives.

The Adult Reconstruction Fellowship was reestablished in 2021. Dr. Klatt serves as fellowship director. In 2023–24, the fellowship received grant funding from an Omega grant, a Smith and Nephew educational grant, and an American Association of Hip and Knee Surgeons (AAHKS) grant. Faculty for the fellowship include Drs. Klatt, O'Malley, Hamlin, McClain, Plate, Urish, Dombrowski, and Yates. Fellows rotate through UPMC Shadyside, UPMC East, UPMC Magee-Womens Hospital, and UPMC St. Margaret. A well-rounded approach with various surgical approaches, implants, and technology makes this a solid clinical experience. In addition, fellows are involved with ongoing arthroplasty research. Three of the four graduates of the program have taken academic jobs upon graduation. Our current fellow, Dallas Vanorny, MD, has taken a faculty position at the University of Iowa. The fellowship has successfully matched for the next two years. In 2024, the fellowship will expand to two fellows per year.

Members of the division continue to work on joint pathways, shared savings (bundle payment), the Joint Center of Excellence Committee, the Orthopaedic Steering Committee, Pro Football Hall of Fame Health, and efforts toward a UPMC total joint registry. All of these are systemwide initiatives that significantly impact our surgical practices. These processes will be a template for other specialties at UPMC moving forward.

Adult reconstruction research at UPMC Shadyside has been productive this past year. Research was presented at multiple international and national meetings as podium and poster presentations, including the annual meetings of the American Academy of Orthopaedic Surgeons (AAOS), Musculoskeletal Infection Society (MSIS), Eastern Orthopaedic Association (EOA), and Pennsylvania Orthopaedic Society (POS). Faculty members were invited to give instructional course lectures at the AAOS annual meeting on treatment options for periprosthetic joint infections (PJIs) and preoperative patient optimization. Multiple prospective and retrospective studies are currently underway assessing same-day discharge after joint replacement, diagnosis and treatment of PJI, postoperative pain control, and total joint outcomes.

Dr. Klatt continues to serve as chief of the Division of Adult Reconstruction and director of the Adult Reconstruction Fellowship. In August 2022, he was promoted to the academic rank of associate professor. Dr. Klatt serves as second past president of MSIS, and he is in the fifth year of a five-year term on the executive board of MSIS. He also has served as the Education Committee chair and as a member of the Program Committee for MSIS. Dr. Klatt recently completed his second three-year term on the AAOS Knee Arthroplasty Program Committee. He is completing a second three-year term with the AAHKS Advocacy Committee. He also will be working closely on advocacy efforts with POS in the coming years. Dr. Klatt continues his work on the Editorial Board of the *Journal of Arthroplasty*, and he is a reviewer for *Clinical Orthopaedics and Related Research* and the *Journal of the AAOS*. Dr. Klatt maintains active membership in MSIS, AAOS, AAHKS, and POS. He continues to work with multiple clinical studies in the division. Collaborations with anesthesia, physical therapy, the Biodynamics Laboratory, and the Spine Division are ongoing. He worked with the American College of Rheumatology (ACR) and AAHKS on the update to the perioperative management guideline. At the medical school, he is the faculty sponsor for the Orthopaedic Special Interest Group. Dr. Klatt serves as treasurer of the Medical Alumni Association.

Dr. Yates continues to serve as professor and vice chair for quality for the department as well as chief of orthopaedics at UPMC Shadyside. He is chair-elect for the AAOS Board of Specialty Societies, which includes ongoing service on the AAOS Board of Directors and the Executive Committee of the political action committee. He helped AAHKS and ACR bring to conclusion their shared "Clinical Practice Guideline for the Optimal Timing of Elective Hip or Knee Arthroplasty," which is now published. He helped to coordinate and publish "The International Initiative to Measure Perceived Risk in Arthroplasty: The Results from a Multinational Survey," which included results from eight countries and led to co-authorship on a *Journal of Arthroplasty* editorial on the same topic. He continues to serve as an elite reviewer for both the *Journal of Bone and Joint Surgery* and the *Journal of Arthroplasty*; he was named "2023 Best Reviewer" by the latter. He has been active in advocacy efforts for orthopaedic surgeons on Capitol Hill and led a symposium and spoke on physician payment reform at the AAOS National Orthopaedic Leadership Conference.

Dr. O'Malley leads UPMC in same-day discharge following total hip and knee arthroplasty at UPMC East and UPMC Shadyside. He performs a high volume of surgery with excellent outcomes. Dr. O'Malley remains an advocate for robotic-assisted surgery in total joint replacement and has established two robots at UPMC East and UPMC Shadyside. He teaches robotic-assisted total joint surgery and direct anterior approach for hip replacement nationally. He is an active member of MSIS and is on the Annual Meeting Program Committee. Dr. O'Malley also serves AAOS on the Hip Arthroplasty Program Committee. He teaches several instructional course lectures and moderates sessions at the annual AAOS meeting. Dr. O'Malley volunteers his time for annual Operation Walk orthopaedic medical missions and recently completed his fourth trip to Antigua, Guatemala. He is a reviewer for the *Journal of the American Academy of Orthopaedic Surgeons* and *Journal of Knee Surgery*. He continues to initiate and promote clinical research at the University of Pittsburgh. Dr. O'Malley is involved with ongoing anesthesia/orthopaedic research collaboration to enhance pain control postoperatively and facilitate outpatient joint replacement.

Dr. Plate continues as associate professor; director of adult reconstruction research; co-chair of the MSK Registry Committee for the Department of Orthopaedic Surgery; and clinical associate director of the Pitt Health + Explainable AI (Pitt HexAI) Research Laboratory in the Department of Health Informatics in the School of Health and Rehabilitation Sciences at the University of Pittsburgh, led by Ahmad Tafti, PhD. Dr. Plate is in the second year of his two-year health policy fellowship in advocacy with AAHKS and anticipates visiting Capitol Hill in 2024 to advocate for total joint–related issues with the Centers for Medicare & Medicaid Services.

In collaboration with MSIS and the European Bone and Joint Infection Society (EBJIS), Dr. Plate started the "Joint Approach" podcast as a co-host. The podcast discusses management, research, and novel therapeutic strategies for patients with musculoskeletal infections, with infectious disease specialists and orthopaedic surgeons as guests.

Dr. Plate remains an active fellow of AAOS, and he moderated and participated in two successful instructional course lectures at the annual meeting in San Francisco. He maintains active membership in AAHKS, MSIS, EOA, POS, and the Piedmont Society. He has been nominated for membership in the American Orthopaedic Association. Dr. Plate remains on the editorial board for the *Journal of Arthroplasty* as an elite reviewer and volunteers as a reviewer for the *Journal of the AAOS*, *Journal of Knee Surgery*, and *Knee*, among others.

Dr. Dombrowski is the newest addition to the division. He is a 2022 graduate of the residency, and he now joins us as an assistant professor in the department of orthoapedics. Dr. Dombrowski completed his fellowship in adult reconstruction at the world-renowned OrthoCarolina hip and knee institute. At OrthoCarolina, he trained under giants in the field, including Bryan Springer, MD, and Dr. Tom Fehring, MD. Dr. Dombrowski brings new ideas and techniques with him from that training, which we are excited to learn. He is a welcome addition to the team. He is the first faculty in the division to do on-table direct anterior approach total hip replacement. Dr. Dombrowski will also focus on complex revision hip and knee replacement. His research foci are infection control and biodynamics related to hip and knee replacement.

REAL COMPONENT SPACERS FOR TWO-STAGE EXCHANGE DEMONSTRATE LOW BACTERIAL COLONIZATION

Wilson AE, Couch BK, Finger L, Plate FJ, Klatt BA, O'Malley MJ

Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.

BACKGROUND
Patients undergoing two-stage exchange arthroplasty for chronic periprosthetic joint infection (PJI) with real component spacers benefit from improved function. Although real component spacers have shown similar reinfection rates following reimplantation compared to other spacer types, concerns exist regarding the potential for bacterial biofilm formation on the metal components, which may compromise treatment outcomes.

QUESTIONS/PURPOSES
The study sought to explore the following research questions:
Do real component spacers have a higher risk for bacterial colonization compared to articulating cement spacers and static spacers?
Do real component spacers have higher rates of early (90-day) failure compared to other spacer types?

METHODS
The researchers conducted a retrospective, single-center study that included all patients who completed two-stage exchange arthroplasty for treatment of Musculoskeletal Infection Society–defined hip or knee PJI from January 2016 to February 2022. All explanted spacer components were sent for sonication fluid culture (SFC). The researchers reviewed medical records to collect demographic variables, laboratory values, culture results, and clinical outcome data. The primary end point was positive SFC. Repeat debridement within 90 days was a secondary end point. Statistical analysis was performed with Fisher's exact test, with statistical significance defined as $p < 0.05$.

RESULTS
A total of 121 patients (57 hips, 64 knees) underwent a two-stage revision for PJI. Sixty (49.6%) patients received an articulating cement spacer, 35 (28.9%) received a real component spacer, and 26 (21.5%) received a static spacer. No positive SFCs were identified with real component spacers compared to 18.3% with articulating cement spacers and 11.5% with static spacers ($p = 0.01$). No patients who received a real component spacer required repeat debridement within 90 days, whereas 11.8% with articulating cement spacers and 4.5% with static spacer required repeat debridement ($p = 0.14$). No other statistically significant differences were identified in rates of positive sonication/tissue cultures or need for repeat debridement within 90 days.

CONCLUSION
Multiple types of spacers may be used in the treatment of PJI with two-stage exchange arthroplasty. Real component spacers provide functional benefits to the patient and facilitate second-stage surgery without compromising the treatment of PJI. Real component spacers showed decreased bacterial colonization compared to other spacer types, supporting the routine use of these spacers following resection total knee arthroplasty and total hip arthroplasty for the treatment of PJI. The results of this study also suggest that real component spacers may be used in both hip and knee PJI without an increased risk of repeat debridement when compared to static and articulating cement spacers.

EXPLAINABLE AI IN ORTHOPAEDICS: CHALLENGES, OPPORTUNITIES, AND PROSPECTS

Amirian S[1], Carlson LA[2,3], Gong MF[3], Lohse I[3], Weiss KR[3], Plate JF[3], Tafti AP[2]

[1]School of Computing, University of Georgia, Athens, Ga.
[2]School of Health and Rehabilitation Sciences, University of Pittsburgh, Pittsburgh, Pa.
[3]Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.

INTRODUCTION
Although artificial intelligence (AI) has had many successful applications in various domains, its adoption in health care lags a bit behind other high-stakes settings. Several factors contribute to this slower uptake, including regulatory frameworks, patient privacy concerns, and data heterogeneity. However, one significant challenge that impedes the implementation of AI in health care, particularly in orthopaedics, is the lack of explainability and interpretability regarding AI models. Addressing the challenge of explainable AI (XAI) in orthopaedics requires developing AI models and algorithms that prioritize transparency and interpretability, allowing clinicians, surgeons, and patients to understand the contributing factors behind any AI-powered predictive or descriptive models. The current contribution outlines several key challenges and opportunities that manifest in XAI in orthopaedic practice. This work emphasizes the need for interdisciplinary collaborations among AI practitioners, orthopaedic specialists, and regulatory entities to establish standards and guidelines for the adoption of XAI in orthopaedics.

DISCUSSION/CONCLUSION
In orthopaedics, AI is expanding quickly and has a lot of potential to help with diagnosis, prognosis, therapy, and rehabilitation. XAI, which offers justifications and interpretations for AI models, is now one of the most promising areas of AI research in orthopaedics. This is crucial for orthopaedics because it enables surgeons, medical professionals, stakeholders, and most importantly patients to comprehend how AI-powered mechanisms make decisions—and to trust the AI's predictive and descriptive results.

XAI is rapidly transforming the healthcare industry, and orthopaedics is no exception. XAI-powered tool sets have the potential to improve patient and clinical outcomes in a number of ways. Although implementing XAI in orthopaedics presents various opportunities and challenges, adopting a collaborative approach, emphasizing user-centric methodology, offering comprehensive training, addressing ethical considerations, highlighting value, conducting small-scale pilot projects, and enabling continuous evaluation and monitoring are key components for success.

Our future work focuses on developing advanced techniques for AI explainability in orthopaedics, including exploring novel AI explainability methods for interpreting complex AI models, enhancing the transparency of deep learning–powered algorithms, designing visualization strategies to provide more actionable explanations in different orthopaedic settings, and benchmarking AI explanation methods using evaluation metrics.

CURRENT PRACTICE PREFERENCES FROM ATTENDEES OF THE 2022 MUSCULOSKELETAL INFECTION SOCIETY ANNUAL MEETING

Finger L[1], Vanorny D[1], Gong MF[1], Seyler TM[2], O'Malley M[1], Plate JF[1], Klatt B[1]

[1]Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.
[2]Department of Orthopaedic Surgery, Duke University, Durham, N.C.

INTRODUCTION
Musculoskeletal (MSK) infections, particularly prosthetic joint infections (PJIs), remain a significant source of morbidity for total joint arthroplasty (TJA) patients. However, no universal standard of care exists for the diagnosis or management of these conditions, leading providers to develop distinct practice paradigms. The authors sought to report on practice preferences recounted by orthopaedic and infectious disease specialists dedicated to the diagnosis and treatment of MSK infections who attended the 2022 Musculoskeletal Infection Society (MSIS) annual meeting.

METHODS
Attendees at the 2022 MSIS annual meeting were surveyed for their preferences on a broad scope of topics concerning MSK infection, including provider demographics, patient population, preoperative optimization, infection-prevention practices, diagnosis of PJI, and surgical management of MSK infections (specifically PJI).

RESULTS
Of the 40 respondents, 43.2% were orthopaedic surgeons and 56.8% were infectious disease specialists, primarily from academic institutions (75.5%) and MSK infection referral centers (91.9%). Most respondents utilize optimization protocols for TJA (96.4%), including delaying elective cases for anemia (91.3%), nutritional deficiency (81.0%), hemoglobin A1c > 7.5 (57.2%), and body mass index > 40 (73.7%). Most respondents utilize only cefazolin (96.6%) for antibiotic prophylaxis though frequently add vancomycin when patients test positive for methicillin-resistant *Staphylococcus aureus* (MRSA) colonization (72.4%). A majority of respondents (78.6%) utilize the most recent MSIS guidelines for the diagnosis of PJI in total hip arthroplasty and total knee arthroplasty, but only 56% believe that current guidelines are sufficient. Respondents unanimously perform debridement and implant retention for acute PJI and two-stage revisions for chronic PJI, though most had also performed one-stage revisions (57.1%) at least once previously.

DISCUSSION
Practice preferences for the prevention, diagnosis, and treatment of MSK infections remain highly variable despite previous efforts to create universal guidelines. Continued investigations to determine best practices and further collaboration among orthopaedic surgeons and infection disease specialists are critical to the establishment of more uniform standards.

PERFORMANCE OF CEMENTLESS HIP ARTHROPLASTY STEM COMPONENTS BY TYPE BASED ON CONSOLIDATED LARGE REGISTRY DATA

Finger LE[1], Gong MF[1], Mirvish A[2], Gabrielli A[1], Tafti AP[3], O'Malley MJ[1], Brian A. Klatt BA[1], Plate JF[1]

[1]Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.
[2]School of Medicine, University of Pittsburgh, Pittsburgh, Pa.
[3]School of Health and Rehabilitation Sciences, University of Pittsburgh, Pittsburgh, Pa.

INTRODUCTION

Improvements in cementless total hip arthroplasty (THA) have been directed at optimizing osseointegration of the femoral implant while reducing failure rates. Stem design plays a critical role in the performance of these implants. Given the increase in new stem designs and the creation of an updated classification system, improved understanding of the outcomes of each stem type is warranted. The purpose of this study was to determine overall revision rates based on stem design and proprietary model.

METHODS

The researchers collected joint registry data on reported overall cases and revisions for each cementless stem brand from the annual reports of the American Joint Replacement Registry (2021), United Kingdom National Joint Registry (2021), New Zealand Joint Registry (2020), and Australian Orthopaedic Association National Joint Replacement Registry (2021). Each individual stem brand was classified into a stem type derived from the classification system described by Radaelli and colleagues https://pubmed.ncbi.nlm.nih.gov/36122690/.

RESULTS

The most utilized stem types were 1) type B2 stems, 2) type A stems, and 3) type C1 stems. The most utilized stem models were the 1) Corail stem (B2), 2) Accolade II (type A), and 3) Taperloc 133 (type A). The highest and lowest overall revision rates observed were in the type B1 stems (8.09%) and type C3 stems (1.12%), respectively. The three stem models with the highest overall revision rates were the Synergy HA stem (9.04%), CBC stem (8.59%), and CLS stem (7.96%). The three stems with the lowest respective overall revision rates were the C2 stem (0.00%, 0 of 933 cases), Actis Duofix (0.59%), and VerSys stem (0.89%).

CONCLUSION

Based on consolidated data from large registries, some cementless femoral stem types and models appear to perform better than others when compared on the basis of stem design.

REFERENCE

1. Radaelli et al. J Arthroplasty. 2022.

Type	Stem Brand	Total Cases	Usage Rate (%)	Total Revisions	Revision Rate (%)	p value
Type B2	Corail	318729	32.16	18,520	5.81	<0.01*
Type A	Accolade II	71179	7.18	1,356	1.91	
Type A	Taperloc 133	51133	5.16	1,049	2.05	
Type C1	Furlong HAC	41649	4.20	1,648	4.96	
Type B2	PolarStem	40467	4.08	804	1.99	
Type A	M/L Taper	34119	3.44	886	2.60	
Type C1	Summit	31275	3.16	748	2.39	
Type A	Accolade	29471	2.97	1,657	5.62	
Type C1	Synergy	26132	2.64	846	3.24	
Type A	Anthology	24401	2.46	708	2.90	

* Denotes statistical significance

Table 1. Absolute Number of Revisions and Revision Rates for the Top-10 Most Used Uncemented Stems as well as Statistical Significances of Differences in Revision Rates

AI FAIRNESS IN HIP BONY ANATOMY SEGMENTATION: ANALYZING AND MITIGATING GENDER AND RACIAL BIAS IN PLAIN RADIOGRAPHY ANALYSIS

Littlefield N[1], Plate JF[1], Weiss KR[1], Lohse I[1], Chhabra A[1], Siddiqui IA[1], Menezes Z[1], Mastorakos G[2], Amirian S[3], Moradi H[4], Tafti AP[1]

[1]University of Pittsburgh, Pittsburgh, Pa.
[2]Cortechs.ai, San Diego, Calif.
[3]University of Georgia, Athens, Ga.
[4]University of Mississippi Medical Center, Jackson, Miss.

INTRODUCTION

Automatic segmentation of hip bony anatomy is a critical component of orthopaedics, enabling healthcare providers and clinicians to efficiently and objectively accomplish several tasks related to medical image analysis, including diagnosis of hip fractures, arthritis, deformity, and dislocation. This autonomous process assists surgeons in preoperative planning by determining the location and size of surgical incisions, the placement of hip implants, and/or the placement of other surgical instruments. Although deep learning computer vision algorithms for hip segmentation have demonstrated almost human-like performance in past literature, analyzing the fairness and any potential bias within such models has been very limited so far. Thus, the present work aims to provide a better understanding of any visible gender, ethnicity, and racial bias in hip bony anatomy segmentation using plain radiographs.

METHODS

This study leveraged the Osteoarthritis Initiative data repository.[1] The researchers used the dataset to randomly select 68 radiographs for manual annotation of hip bony anatomy. Among those 68 hip radiographs, the researchers provided three image annotators with 20 of the same images in two batches (10 in each batch) to measure the level of inter-rater agreement. The researchers trained a U-Net model[2] with a ResNet18[3] backbone for hip bone segmentation using Python 3.8.10 and PyTorch 1.13.1. The model was trained and optimized with the training and validation datasets and subsequently evaluated with the test set. Finally, the intersection over union (IoU) scores of the models for each segment were utilized as a measure of accuracy and to evaluate model fairness. To assess the effectiveness of different approaches for bias mitigation, the researchers utilized a baseline model and investigated several bias mitigation techniques.

RESULTS

Overall, the findings suggest that the balanced and stratified modeling techniques are the most effective at mitigating both race and gender biases while maintaining high performance levels. In contrast, the group-specific modeling strategy is particularly useful for mitigating gender bias.

CONCLUSION

The current work provides evidence that implementing fairness strategies such as balanced, stratified, and group-specific models can improve model fairness in this problem setting. It demonstrates that the balanced and stratified models for racial groups exhibit a significant decrease in standard deviation (SD) and standard error of regression (SER) when compared to the baseline model, indicating a reduction in prediction variability and increased fairness. These findings suggest that the balanced and stratified models are more equitable in their predictions across racial groups than the baseline model.

REFERENCES

1. The Osteoarthritis Initiative (OAI). Available at: https://nda.nih.gov/oai.
2. O. Ronneberger O, Fischer P, Brox T. U-net: convolutional networks for biomedical image segmentation. *Medical Image Computing and Computer-Assisted Intervention* (pp. 234-241). 2015.
3. He K, Zhang X, Ren S, Sun J. Deep residual learning for image recognition. *CVPR* (pp. 770-778). 2016.

HEXAI-TJATXT: A TEXTUAL DATASET TO ADVANCE OPEN SCIENTIFIC RESEARCH IN TOTAL JOINT ARTHROPLASTY

Amirian A[1], Ghazaleh H[2], Carlson L[3], Gong M[3], Finger L[3], Plate JF[3], Tafti AP[4,5]

[1]School of Computing, University of Georgia, Athens, Ga.
[2]Department of Computer Science, Quincy University, Quincy, Ill.
[3]Department of Orthopaedic Surgery, School of Medicine, University of Pittsburgh, Pittsburgh, Pa.
[4]Department of Health Information Management, School of Health and Rehabilitation Sciences, University of Pittsburgh, Pittsburgh, Pa.
[5]Intelligent Systems Program, School of Computing and Information, University of Pittsburgh, Pittsburgh, Pa.

INTRODUCTION

Total joint arthroplasty (TJA) is the most common and fastest inpatient surgical procedure in the elderly, nationwide. Due to the increasing number of TJA patients and advancements in health care, there is a growing number of scientific articles being published on a daily basis. These articles offer important insights into TJA, covering aspects such as diagnosis, prevention, treatment strategies, and epidemiological factors. However, there has been limited effort to compile a large-scale text dataset from these articles and make it publicly available for open scientific research in TJA. Utilizing computational text analysis on these large columns of scientific literature holds great potential for uncovering new knowledge to enhance our understanding of joint diseases and improve the quality of TJA care and clinical outcomes.

This work aims to build a dataset entitled HexAI-TJAtxt, which includes more than 61,936 scientific abstracts collected from PubMed using MeSH (Medical Subject Headings) terms within “MeSH Subheading” and “MeSH Major Topic,” with publication date from January 1, 2000, to December 31, 2022. The current dataset is freely and publicly available at https://github.com/pitthexai/HexAI-TJAtxt, and it will be updated bimonthly manner from new abstracts published on PubMed.

DISCUSSION/CONCLUSION

By assembling a large-scale collection of scientific abstracts from PubMed using MeSH terms, the HexAI-TJAtxt dataset not only provides broad coverage of TJA-related agendas but also enables computational text analytics to unlock new knowledge and insights in joint diseases. Furthermore, the dataset offers the potential for trend analysis and evaluation of changes in TJA clinical practices over time. By achieving these objectives, the HexAI-TJAtxt dataset can contribute significantly to the broader goals of better understanding TJA, improving patient care, and enhancing clinical and patient outcomes in this critical area of health care.

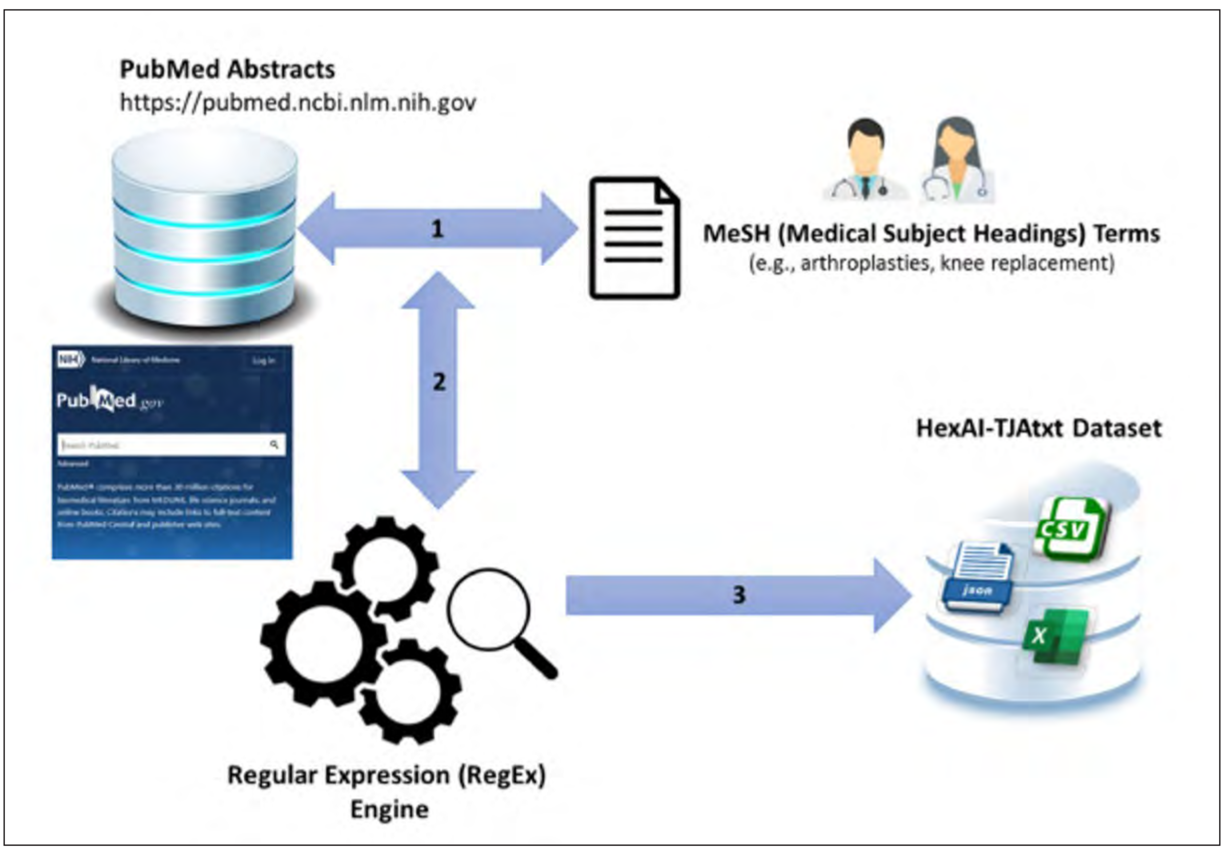


Figure 1. The proposed pipeline to build the HexAI-TJAtxt textual dataset. Utilizing this proposed pipeline, the HexAI-TJAtxt dataset will be frequently updated in a bi-monthly manner employing new abstracts published at PubMed.

NEW MEDICARE-MANDATED PATIENT-REPORTED OUTCOMES AFTER JOINT ARTHROPLASTY PERFORMANCE MEASURE

Plate JF[1,2], Deen JT[2,3], Deans CF[2,4], Pour AE[5], Yates AJ[1], Sterling R[6]

[1]Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.
[2]American Association of Hip and Knee Surgeons Health Policy Fellowship Program
[3]Department of Orthopaedic Surgery and Sports Medicine, University of Florida, Gainesville, Fla.
[4]Department of Orthopaedic Surgery and Rehabilitation, University of Nebraska Medical Center, Omaha, Neb.
[5]Department of Orthopaedics and Rehabilitation, Yale University, New Haven, Conn.
[6]Department of Orthopaedic Surgery, George Washington University, Washington, D.C.

INTRODUCTION

The Centers for Medicare and Medicaid Services (CMS) has implemented a new hospital-level, risk-standardized performance measure for elective total hip arthroplasty (THA) and total knee arthroplasty (TKA) based on patient-reported outcomes (THA/TKA PRO-PM). Hospital participation will be mandatory following two voluntary reporting periods. Failure to meet the program requirements can result in payment reduction. This article aims to inform arthroplasty surgeons of this new requirement, which will impact hospitals where total joint surgeries are performed.

All Medicare fee-for-service beneficiaries who are 65 years or older and planning to undergo THA or TKA at an inpatient facility are included in this measure. The THA/TKA PRO-PM is the proportion of risk-standardized THA or TKA patients who met or exceeded the substantial clinic benefit (SCB) threshold of pre- and postoperative outcome measures (22 points for Hip Disability and Osteoarthritis Outcome Score for Joint Replacement and 20 points for Knee Injury and Osteoarthritis Outcome Score for Joint Replacement). This binary outcome of meeting the threshold (yes/no) is then divided by all eligible patients, creating a percentage of reported patients reaching SCB. That then is the basis for percentile scoring amongst the hospitals, which will be used in the public reporting of the Hospital Inpatient Quality Reporting system (which generates the CMS “star” ratings). The mean success rate of reaching SCB was 60% in the dry-run reporting by the Yale Center for Outcomes Research and Evaluation.

THA/TKA PRO-PM is undergoing phased implementation, including two voluntary reporting periods, with collections having started in 2022, to be applied in 2025 and 2026. Mandatory reporting will capture preoperative scores from April 2024 through June 2025 and reporting by September of 2025; postoperative scores (at 12–14 months) are to be collected from April 2025 through August 2026 to be reported by September 2026. CMS is requiring 50% reporting rates; failure in the first mandatory year can lead to reductions in the Annual Payment Update in fiscal year 2028. Average successful reporting in the Comprehensive Care for Joint Replacement (CJR) collection period used to develop this measure was 31% for all hospitals and 43% for hospitals reporting 25 or more full datasets.

CONCLUSIONS

CMS intends the THA/TKA PRO-PM to be a patient-centered, meaningful, and relatable measure that informs the public of hospital total joint performance. Following two voluntary reporting periods, THA/TKA PRO-PM will become mandatory for all Medicare inpatient THA and TKA starting in July 2024. Surgeons may use this as an opportunity to collaborate with hospitals for developing and implementing a data-collection system for THA and TKA patients. Further implementation of this measure for THA and TKA performed in outpatient settings and ambulatory surgery centers has been proposed by CMS. The voluntary period is currently ongoing, with mandatory reporting to begin in less than a year. Significant resources will be needed to succeed in the expected capture rates.

FAVORABLE MIDTERM OUTCOMES FOLLOWING UNICOMPARTMENTAL KNEE ARTHROPLASTY WITH WIDER PATIENT SELECTION: A SINGLE-CENTER EXPERIENCE

Gowd AK[1], Plate JF[2], Lichtig A[1], Gencer A[1], Yanmis O[1], D'Agostino R[1], Poehling GG[1]

[1]Department of Orthopaedic Surgery, Wake Forest Medical Center, Winston-Salem, N.C.
[2]Department of Orthopaedic Surgery, University of Pittsburgh Medical Center, Pittsburgh, Pa.

OBJECTIVE

The purpose of this study was to determine surgical outcomes of robotic-assisted unicompartmental knee arthroplasty (UKA) utilizing a wider set of indications than traditionally utilized. Additionally, the researchers sought to determine alternate predictive factors as potential surgical indications and contraindications.

METHODS

The researchers queried a prospectively maintained institutional joint registry at a single academic center for all patients who underwent robotic-assisted UKA between January 2010 and December 2016. Surgical indication included isolated medial or lateral compartment degenerative disease with a stable knee based on physical exam. In 2013, a hemoglobin A1C level higher than 7.5% was considered a contraindication, which was lowered to 7.0% in 2015. Preoperative alignment, age, activity level, and degree of pain were not contraindications for surgery. Preoperative demographics, Oxford scores, radiography (joint space), comorbidities, and operative data were collected and reviewed to determine factors related to conversion to total knee arthroplasty (TKA) and survivorship of the primary implant.

RESULTS

In total, 1,878 cases were performed; however, excluding multi-joint knees, there were a total of 1,186 knees in 1,014 patients with a minimum four-year follow-up. The mean age was 63.4 ± 10.7 years, and mean follow-up was 76.4 ± 17.4 months. Mean body mass index (BMI) was 32.3 ± 6.5 kg/m2; the sample was 52.9% female and 47.1% male. There were 901 patients undergoing medial UKA, 122 patients undergoing lateral UKA, and 69 patients undergoing patellofemoral UKA. In total, 85 (7.2%) knees underwent conversion to TKA. Preoperative factors such as degree of preoperative valgus deformity ($p = 0.01$), greater operative joint space ($p = 0.04$), previous surgery ($p = 0.01$), inlay implant ($p = 0.04$), and pain syndrome ($p = 0.01$) were associated with increased risk of revision surgery. Factors associated with decreased implant survivorship included history of previous surgery ($p < 0.01$), history of pain syndrome ($p < 0.01$), and greater preoperative joint space (> 2 mm) ($p < 0.01$). The study found no association between BMI and conversion to TKA.

CONCLUSION

Robotic-assisted UKA with wider patient selection demonstrated favorable outcomes at four years, with survivorship greater than 92%. The present series agrees with emerging indications that do not exclude patients based on age, BMI, or degree of deformity. However, increased operative joint space, inlay design, history of surgery, and coexistence of pain syndrome are factors that may increase risk of conversion to TKA.

ENFORCING EXPLAINABLE DEEP FEW-SHOT LEARNING TO ANALYZE PLAIN KNEE RADIOGRAPHS: DATA FROM THE OSTEOARTHRITIS INITIATIVE

Littlefield N[1], Moradi H[2], Amirian S[3], Kremers HM[4], Plate JF[5], Tafti AP[6]

[1]School of Computing and Information, University of Pittsburgh, Pittsburgh, Pa.
[2]School of Population Health, University of Mississippi Medical Center, Jackson, Miss.
[3]School of Computing, University of Georgia, Athens, Ga.
[4]Division of Epidemiology, Mayo Clinic, Rochester, Minn.
[5]Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.
[6]School of Health and Rehabilitation Sciences, University of Pittsburgh, Pa.

INTRODUCTION

Knee radiography analysis has been a very active area of research in the orthopaedic setting, with applications expanding from patient-specific diagnosis and treatment to preoperative and intraoperative planning, and even knee implant design. The widespread adoption of x-ray radiography and its availability at low cost make it the primary component in assessing knee pain and pathology, such as congenital deformities, arthritis, trauma, and sports injuries.

However, the interpretation of knee x-ray images is still highly subjective and can be challenging for healthcare providers due to overlapping structures within the radiographs and the large volume of images that must be be analyzed on a daily basis. This may lead to wrong interpretations or even missed diagnoses. To address this issue, advanced computational methods such as artificial intelligence and deep learning medical image analysis are needed to *objectively* and *automatically* interpret knee radiographs and assist with the timely triage of abnormal images.

METHODS

The researchers utilized the Osteoarthritis Initiative's dataset to first manually annotate knee radiographs, then use those gold-standard annotated images to build, train, validate, and test deep few-shot learning models in two directions: (1) knee joint area localization and (2) knee joint space segmentation. Generally speaking, by few-shot learning, we mean N-way-K-shot-learning, where N demonstrates the number of classes, and K is the number of samples considered from each class for training. Given two image sets—a training set, D^{train}, and a test set, D^{test}—the goal is to learn a good representation using a subset of D^{train} ($n = N * K$) such that at the test time, the model is well generalized on a new task. The objects in the training set are different from the objects in the test set. Each set is composed of a support set, S, and a query set, Q. During training, the model is optimized to make good predictions on the query set given the support set.

RESULTS

With $K = 5$, the average intersection over union (IoU) as to compare bounding boxes provided manually with the ones predicted by the model(s) was 0.527 and 0.50 (across two knees [left and right]) for the first and second example, respectively. The mean average precisions @0.5 (mAP@0.5) were 0.91 and 0.91. The average level of confidence for the first bounding boxes, however, was 0.485, and for the second one was 0.42. Using $K = 7$, the researchers found that the average IoU was 0.859 for the first radiography example and 0.844 for the next one. The mAP@0.5 were 0.95 and 0.93 for the first and second examples. And the average level of confidence for the first bounding boxes resulted in 0.75, and for the second example was 0.74. Finally, with $K = 10$, the researchers got the average IoUs of 0.939 and 0.942, mAP@0.5 at 0.99 and 0.99, and the average levels of confidence of 0.895 and 0.845, respectively. Starting from $K = 5$ to 10, there has been a significant improvement in the precise localization of the knee joint area and the level of confidence for the bounding boxes.

CONCLUSION

These findings indicate that deep few-shot learning has significant potential in the localization of the knee joint area and knee joint space segmentation with a few manually annotated radiographs. This is a viable approach in settings where gold-standard annotated training data are lacking. Our future works will further focus on other anatomical structures (e.g., hip) plus implementation and uptake.

LEARNING UNBIASED IMAGE SEGMENTATION: A CASE STUDY WITH PLAIN KNEE RADIOGRAPHS

Littlefield N[1], Plate JF[1], Weiss KR[1], Lohse I[1], Chhabra A[1], Siddiqui IA[1], Menezes Z[1], Mastorakos G[2], Thakar SM[1], Abedian M[1], Gong MF[1], Carlson LA[1], Moradi H[3], Amirian S[4], Tafti AP[1]

[1]University of Pittsburgh, Pittsburgh, Pa.
[2]Cortechs.ai, San Diego, Calif.
[3]University of Mississippi Medical Center, Jackson, Miss.
[4]University of Georgia, Athens, Ga.

INTRODUCTION

Despite the impressive capabilities of deep learning models, there is a growing concern regarding fairness and potential biases.[1-4] It is now essential to assess fairness and potential biases in deep learning models used for knee bone segmentation. This evaluation is crucial for promoting equitable healthcare delivery and preventing disparities in patient outcomes, thereby enhancing the provision of equitable and inclusive health care in the field of orthopaedics. However, assessment of fairness and biases in these models is currently limited. It is thus crucial to thoroughly investigate these issues and develop computational methods that can analyze and subsequently mitigate biases. These measures are necessary to ensure consistent and accurate performance of the algorithms across diverse patient populations.

METHODS

This study utilizes the Osteoarthritis Initiative[5] data repository. The researchers randomly selected 403 radiographs/patients for the purpose of manually annotating different knee segments. To assess inter-rater agreement for manual segmentation, three image annotators were provided with 20 identical images in two separate batches (10 images in each batch). The annotated data were then divided into train, validation, and test sets, comprising 70%, 15%, and 15% of the data, respectively. By utilizing the annotated data, the deep learning models developed in this study aim to achieve robust and accurate analysis of knee joint segmentation in radiographs. The models learn and identify critical patterns necessary for precise segmentation, resulting in enhanced performance.

RESULTS

The baseline model achieves high intersection over union (IoU) scores for both white/Caucasian and black/African American individuals, with values of 0.833 and 0.834, respectively. However, when applying the balanced model, intended to address biases, the researchers saw a slight decrease in performance for both racial groups, with IoU scores of 0.836 for white/Caucasian individuals and 0.832 for black/African American individuals. When considering gender groups, the baseline model exhibited high IoU scores of 0.836 for males and 0.813 for females. However, employing the balanced model resulted in lower IoU scores, increased prediction error variability, and a decrease in fairness. Stratified modeling demonstrated better fairness outcomes for gender groups compared to the baseline model, although the accuracy is slightly compromised, the standard error of the regression (SER) values indicate improved fairness. On the other hand, group-specific modeling seemed to introduce larger disparities, indicating that this approach is less effective in mitigating gender biases.

CONCLUSION

This study revisited the implementation of deep learning in knee bony anatomy segmentation of plain radiographs to uncover gender and racial biases and implement strategies for bias mitigation. Within the multiple models, the researchers found that different bias-mitigation strategies present a compromise between fairness and accuracy of predicted knee anatomy segmentation. Optimizing a deep learning model that can fairly account for racial and gender bias in the interpretation of knee plain radiographs has significant implications in several areas.

REFERENCES

1. Toutiaee M, Amirian S, Miller J, and Li S. Stereotype-free classification of fictitious faces. 2020.
2. Lokhande V, Akash A, Ravi S, Singh V. Fairalm: augmented Lagrangian method for training fair models with little regret. In: *ECCV* (pp. 365-81). Springer; 2020.
3. Du M, Yang F, Zou N, and Hu X. Fairness in deep learning: a computational perspective. IEEE Intelligent Systems. 2020;36(4):25-34.
4. Tripathi S, Musiolik TH. Fairness and ethics in artificial intelligence-based medical imaging. In: *Research Anthology on Improving Medical Imaging Techniques for Analysis and Intervention* (pp. 79-90). IGI Global; 2023.
5. The Osteoarthritis Initiative. Available at: https://nda.nih.gov/oai.

SHARED AND UNIQUE RISK FACTORS FOR READMISSION EXIST FOLLOWING UPPER AND LOWER EXTREMITY ARTHROPLASTY IN THE 30-DAY POSTOPERATIVE PERIOD

Scholten DJ II[1], Gwam CU[1], Recker AJ[2], Plate JF[3], Waterman BR[1]

[1]Department of Orthopaedics, Wake Forest Baptist Health, Winston-Salem, N.C.
[2]School of Medicine, Wake Forest University, Winston-Salem, N.C.
[3]Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.

PURPOSE
Joint arthroplasty has become increasingly more common in the United States, and it is important to examine the patient-based risk factors and surgical variables associated with hospital readmissions. The purpose of this study was to identify stratified rates and risk factors for readmission after upper-extremity (shoulder, elbow, and wrist) and lower-extremity (hip, knee, and ankle) arthroplasty.

METHODS
All patients undergoing upper- and lower-extremity arthroplasty from 2008–2018 were identified in the National Surgical Quality Improvement Program dataset. Patient demographics, medical comorbidities, and surgical characteristics were examined with uni- and multivariate analysis for significant predictors of 30-day hospital readmission.

RESULTS
A total of 523,523 lower- and 25,215 upper-extremity arthroplasty patients were included in this study. A number of lower-extremity (22,183; 4.2%) and upper-extremity (1,072; 4.4%) arthroplasty patients were readmitted within 30 days of discharge. Significant risk factors for 30-day readmission after lower-extremity arthroplasty included age; body mass index (BMI); longer operative time; dependent functional status; American Society of Anesthesiologists score $\geq$ 3; increased length of stay; and various medical comorbidities, such as diabetes, tobacco dependency, and chronic obstructive pulmonary disease (COPD). An overweight BMI was associated with lower odds of 30-day readmission when compared to a normal BMI for lower-extremity arthroplasty. Analysis for upper-extremity arthroplasty revealed similar findings of significant risk factors for 30-day hospital readmission, although diabetes mellitus was not found to be a significant risk factor.

CONCLUSION
Nearly one in 25 patients undergoing upper- and lower-extremity arthroplasty experiences hospital readmission within 30 days of index surgery. There are several modifiable risk factors for 30-day hospital readmission shared by both lower- and upper-extremity arthroplasty, including tobacco smoking, COPD, and hypertension. Optimization of these medical comorbidities may mitigate the risk of short-term readmission following joint arthroplasty procedures and improve overall cost effectiveness of perioperative surgical care.

SAFETY AND EFFICACY OF ZYNRELEF® IN COMBINATION WITH A SINGLE UNILATERAL OR BILATERAL NERVE BLOCK PERFORMED PRIOR TO SURGERY

Goel S[1], Luke C[1], Holtzman M[2], Davies B[3], O'Malley M[4], Lavage D[1], Siedlecki C[1], Chelly JE[1,2]

[1]Department of Anesthesiology and Perioperative Medicine, University of Pittsburgh Medical Center, Pittsburgh, Pa.
[2]Department of Surgery, UPMC Shadyside Hospital, Pittsburgh, Pa.
[3]Department of Urology, UPMC Shadyside Hospital, Pittsburgh, Pa.
[4]Department of Orthopaedic Surgery, UPMC Shadyside Hospital, Pittsburgh, Pa.

PURPOSE
The U.S. Food and Drug Administration (FDA) recently approved Zynrelef® (a viscous solution of extended-release bupivacaine and meloxicam) to be applied at closure to provide postoperative analgesia for 72 hours. Although the FDA didn't restrict the use of nerve blocks in combination with this formulation, the safety and efficacy of such a combination have yet to be documented. This quality-improvement study investigated this combination within the FDA-approved indications.

METHODS
Selected surgeons at two hospitals were chosen to use Zynrelef. According to the standard of care, surgeons were also allowed to request single nerve blocks before surgery. The type of nerve blocks (unilateral or bilateral) performed included quadratus lumborum and paravertebral blocks for abdominal surgery and adductor canal block for total knee replacement. Each block was performed with 20 mL of 0.375% bupivacaine (n = 129) or 0.5% of ropivacaine (n = 30). Pain scores, opioid consumption, and prescription refill requests at discharge were recorded. Patients discharged on the same day of surgery were separated into two groups: those who received single nerve blocks plus Zynrelef (group 1) versus those receiving Zynrelef only (group 2). The researchers analyzed using an unpaired t-test.

RESULTS
A total of 184 patients received Zynrelef, including 25 patients who didn't receive blocks, 44 who received unilateral blocks, and 114 who received bilateral blocks. No symptoms suggestive of local anesthetic toxicity were observed. The use of the combination was associated with a 50% reduction in the number of patients filling their opioid prescriptions.

CONCLUSION
This study provides evidence that the combination of a single unilateral or bilateral nerve block with Zynrelef is safe. The work was published in the *Journal of Pain and Relief* in October 2023; doi: 10.4172/2167-0846.1000002.

THE ROLE OF INHALATION AROMATHERAPY IN THE MANAGEMENT OF PERIOPERATIVE PAIN AND OPIOID CONSUMPTION FOLLOWING PRIMARY UNILATERAL TOTAL HIP ARTHROPLASTY: A PROSPECTIVE, RANDOMIZED, PLACEBO-CONTROLLED STUDY

Chelly JE[1,2], Klatt[2 B], O'Malley M[2], Groff Y[2], Kearns J[1], Khetarpal S[1], Sadhasivam S[1]

[1]Department of Anesthesiology and Perioperative Medicine, University of Pittsburgh Medical Center, Pittsburgh, Pa.
[2]Department of Orthopaedic Surgery, University of Pittsburgh Medical Center, Pittsburgh, Pa.

INTRODUCTION

Aromatherapy is claimed to be effective for the treatment of psychosocial disorders, but objective evidence of its effectiveness is still lacking. Psychosocial disorders have been demonstrated to increase postoperative pain and opioid consumption by up to 50%. This study was designed to assess the effectiveness of aromatherapy in controlling postoperative pain and opioid consumption in anxious patients.

METHODS

This prospective, randomized, placebo-controlled study was conducted on anxious patients who underwent primary unilateral total hip arthroplasty. After obtaining signed informed consent, the researchers asked each patient to complete a PROMIS (Patient- Reported Outcomes Measurement Information System) anxiety survey. Patients whose T-scores were > 57.2 were randomized to either active treatment (Lavender Peppermint Elequil® aromatabs) or a placebo Elequil aromatab treatment. The researchers collected demographics, pain, opioid consumption, postoperative nausea and vomiting (PONV), and psychosocial surveys on postoperative day (POD) 1, POD2, POD7, and POD30. At the time of discharge and on POD30, each patient was asked to complete a satisfaction questionnaire, and they were asked to complete an SF-12 survey on POD30. Differences between means were assessed with absolute standardized mean differences.

RESULTS

Sixty patients were included in the intend-to-treat analysis. Use of lavender and peppermint was associated with a decrease of 26% in pain (POD7; 0.46), 33% in opioid consumption (POD2; 0.42), 48% in acetaminophen consumption (POD7; 0.54), and 78% in PONV (POD2; 0.44). Psychosocial scores decreased following surgery ($p = 0.001$). Overall satisfaction ratings at discharge were similar, as were functional recovery scores.

DISCUSSION

The data provide evidence that in patients with preoperative anxiety, lavender and peppermint aromas decrease postoperative pain and opioid requirements compared to placebo. Additional research is required to confirm the results.

CONCLUSION

This randomized, placebo-controlled study provides evidence of the usefulness of inhalation of lavender and peppermint aromas in patients undergoing primary unilateral total hip arthroplasty.

The work was published in the *Journal of Pain and Relief* in September 2023; doi: 10.4172/2375-4494.1000003.

SuRxgWell: STUDY PROTOCOL FOR A RANDOMIZED, CONTROLLED TRIAL OF TELEMEDICINE-BASED DIGITAL COGNITIVE BEHAVIORAL INTERVENTION FOR HIGH ANXIETY AND DEPRESSION AMONG PATIENTS UNDERGOING ELECTIVE HIP AND KNEE ARTHROPLASTY

Kaynar AM[1,2,3,4], Lin C[1,2], Sanchez AG[1,2], Lavage DR[1,2], Monroe A[1,2], Zharichenko N[1,2], Strassburger M[5], Saucier K[5], Groff YJ[6], Klatt BA[6], O'Malley MJ[6], Szigethy E[5], Wasan AD[1,2], Chelly JE[1,2,6]

[1]Department of Anesthesiology and Perioperative Medicine, University of Pittsburgh Medical Center, Pittsburgh, Pa.
[2]Department of Anesthesiology and Perioperative Medicine, Center for Innovation in Pain Care, Pittsburgh, Pa.
[3]Department of Critical Care Medicine, University of Pittsburgh, Pittsburgh, Pa.
[4]Department of Critical Care Medicine, Clinical Research Investigation and Systems Modeling of Acute Illness Center, University of Pittsburgh, Pittsburgh, Pa.
[5]Department of Psychiatry, University of Pittsburgh, Pittsburgh, Pa.
[6]Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.

INTRODUCTION

Background mood disorders (anxiety, depression), sleep disorders, and catastrophizing lead to increased postoperative pain perception, increased postoperative opioid consumption, decreased engagement with physical activity, and increased resource utilization in surgical patients. Psychosocial disorders significantly affect postoperative outcomes. Unfortunately, studies focused on perioperative psychological assessment and treatment are scarce.

The authors are testing whether a digital cognitive behavioral intervention (dCBI) could help surgical patients. dCBI such as RxWell™ is a proven treatment for mood disorders in medical patients, such as reducing depression in patients with inflammatory bowel disease. The authors hypothesize that RxWell will also be effective in surgical patients. This study aims to test whether RxWell can improve preoperative mood disorders and subsequently reduce postoperative pain and opioid requirement in patients scheduled for primary total hip arthroplasty (THA) and total knee arthroplasty (TKA). The trial is named the SuRxgWell trial.

METHODS

This is a randomized, controlled trial that will enroll primary and unilateral THA and TKA patients with anxiety and/or depression symptoms before surgery to receive the SuRxgWell dCBI program and investigate its impact on postoperative outcomes, including postoperative pain, anxiety, depression, sleep disorder, and catastrophizing.

After signing an informed consent, subjects will be screened with the PROMIS (Patient-Reported Outcomes Measurement Information System) questionnaires, and subjectswith a T-score of ≥ 60 on the short PROMIS 4a Anxiety and/or short PROMIS 4aDepression questionnaires will be randomized to either usual care (control group) or the cognitive behavioral intervention, RxWell, plus usual care (intervention group).

The control group will receive information on how to locate tools to address anxiety and depression, whereas the intervention group will have access to SuRxgWell one month prior to surgery and up to three months after surgery. The allocation will be 3:1 (intervention to control).

Investigators will be blinded, but research coordinators approaching patients and research subjects will not. The primary outcome will be anxiety or depression symptoms on the day of surgery, as measured with the PROMIS Short Form v1.0 Anxiety 4a/Depression and Generalized Anxiety Disorder Measure (GAD-7) and Patient Health Questionnaire (PHQ-8). Secondary end points will include other health-related quality-of-life outcomes, including sleep disturbance, fatigue, ability to participate in social roles, pain interference, cognitive function, pain catastrophizing, and physical function. Other secondary outcomes will involve collecting data about preoperative and postoperative pain scores, pain medication usage, and orthopaedic functional recovery at baseline; day of surgery; and one, two, and three months after surgery, as measured by the Pain Catastrophizing Scale, the Knee injury and Osteoarthritis Outcome Score, and Hip injury and Osteoarthritis Outcome Score. In addition, subjects will be asked to complete GAD-7 and PHQ-8 questionnaires biweekly (via the RxWell app for the interventional group or REDCAP for the control group).

Data about postsurgical complications and resource utilization will also be recorded. The researchers will also receive monthly reports measuring the usage and engagement of RxWell use for each participant randomized to that arm. The primary hypotheses will be assessed with intention-to-treat estimates, and differences in primary outcome will be tested with independent two sample t-tests. This trial is registered to the ClinicalTrials.gov database (NCT05658796) and supported by the Department of Anesthesiology and Perioperative Medicine (DAPM), UPMC Health Plan, and the National Institutes of Health.

DISCUSSION

Our trial will evaluate the feasibility of a dCBI as a perioperative tool to improve anxiety and depression before and after major orthopaedic surgery in comparison to education. If the dCBI proves to be effective, this might have important clinical implications, reducing the incidence of chronic postsurgical pain and improving outcomes.

For more information, visit https://doi.org/10.1186/s13063-023-07634-0.

DIVISION OF MUSCULOSKELETAL ONCOLOGY

Richard L. McGough III, MD

This academic year has been a most interesting time for us. As medicine has changed over the past few years, our division has seen multiple changes in how we deliver care.

Our first change has been in where our care is delivered. For the first time, musculoskeletal oncology care is being given *outside* of the core academic hospitals in our system. Stella Lee, MD, has taken the initiative to begin seeing select oncology patients at UPMC Passavant, a hospital previously fairly closed to the university department but now opening up for multiple divisions. Quite a lot of patients are no longer willing to drive into the "big city," braving the streets and the parking to obtain their care. Other divisions within the Department of Orthopaedic Surgery have been expanding their footprints for some time, and other cancer care within the UPMC Hillman Cancer Center system has been working "offsite" or at satellite locations for decades. With our patient population and the rarity of the diseases we treat, this is our first foray into this process, but I am confident that Dr. Lee's attention to detail will serve her well as she ventures outside what has been our only home for 20 years.

In working to optimize that offsite situation, we are in the process of hiring a nurse coordinator. The individual will optimize patient visits and will hopefully eliminate wasteful studies and the uncertainty that exists for our patients obtaining care at multiple institutions. Likewise, we anticipate that ongoing care will be substantially smoothed by these coordination efforts. This role is sorely needed and will be greatly appreciated.

Our surgeons continue to work hard, and we continue to have one of the largest musculoskeletal oncology practices in the country. This provides unparalleled education for our residents and surgical oncology fellows. In meeting that goal, our physician assistants, Julie Shepard and Nicole Cuddy, provide postoperative clinical support as well as telemedicine and problem-solving services (in addition to their exceptional assistance in the operating room). Their dedication allows the surgeons to see more patients in a more timely manner, optimizing orthopaedic cancer treatment for our patients.

Lastly, the nature of change is that it is constant, and I frequently need to add goodbyes to these updates. This year's goodbye is to Georgette "Georgi" McCary, who has begun full-time nursing school. Our loss will be the world's gain, as I have no doubt that Georgi will be an outstanding nurse, and I am proud of her for furthering her career in this way. Fortunately, our department was able to find a small full-time-equivalent role for Georgi in helping Kurt Weiss, MD, with both his clinical and research work. This keeps her "at home" with us while she pursues her advanced studies.

COMPARISON OF USE OF PHOTODYNAMIC BONE STABILIZATION IN MALIGNANT VERSUS NONMALIGNANT PROXIMAL HUMERUS FRACTURES

Canton SP, Steuer F, Rogers M, LaBaze D, Hughes J, McGough R

Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.

INTRODUCTION

Management of proximal humerus fractures has remained a challenging problem. Nonoperative management is the mainstay of treatment; however, the evolution of innovative reconstructive options has expanded the indications for surgical management of complex proximal humerus fractures.

Particularly, the advent of photodynamic bone stabilization (PBS) allows for intramedullary fixation using light-curable liquid monomer, contained within an expandable balloon, to create a patient-conforming, rigid implant within the bone canal. It is a minimally invasive technique that can mitigate surgical time, limit surgical exposure, decrease blood loss, and potentially reduce recovery time in patients with impaired biology and limited life expectancy.

PBS has been shown to be effective in the treatment of malignant pathologic humerus fractures (MPHFs), but there has been increasing use in the setting of nonmalignant, typically osteoporotic humerus fractures (PHFs). The purpose of this study was to provide an initial analysis to compare operative times, length of stay, and estimated blood loss (EBL) of PHFs fixed with PBS (PBS-PHF) compared with MPHFs fixed with PBS (MPHF-PBS), intramedullary nail (MPHF-IMN), or cemented plate fixation (MPHF-CPF).

METHODS

The researchers collected retrospective data on patients who underwent PHF or MPHF surgery by four different fellowship-trained orthopaedic surgeons: five PBS-PHF, 19 MPHF-PBS, 65 MPHF-IMN, and 21 MPHF-CPF. Demographics, intraoperative parameters, and postoperative information were collected and analyzed.

RESULTS

Demographics were similar across groups. The PBS-PHF cohort was younger on average and had a greater percentage of diabetic patients. The PBS-PHF cohort averaged the least number of nights in the hospital postoperatively (0.2 days [range = 0-1]) and the greatest percentage of discharge in less than 24 hours across all groups (100%). However, average operative time was greatest for PBS-PHF, 172.4 minutes [126-138], with 0% of the PBS-PHF procedures being completed in less than 1 hour. EBL was 170.0 [100-200] for PBS-PHF, exceeded only by the MPHF-CPF group, 233.2 [20-757].

DISCUSSION

Intraoperative variables, including operative times and EBL, were generally greater for PHF-PBF compared with the other MPHF groups. Postoperatively, however, the length of stay was less for PHF-PBS. There is evidence that PBS for nonmalignant proximal humerus fracture has promise, but larger studies that include patient-reported outcomes and short-term and long-term complications (e.g., reoperation rates, broken implants) will better elucidate the viability of this surgical intervention.

REFERENCES

1. Hoellwarth JS et al. *Injury*. 2020;51*(*4),:947-54.
2. Weiss KR et al. *JBJS*. 2011;93(8):1093-97.

MULTIDISCIPLINARY APPROACH TO PATIENT-CENTERED CARE FOLLOWING TRAUMATIC BILATERAL TRANSFEMORAL AMPUTATION AND TWO-STAGE OSSEOINTEGRATION: A CASE REPORT

Hua K[1], Brown CL[1], Shepard J[1], Hurwitz M[2], McGough R[1]

[1]Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.
[2]Department of Physical Medicine & Rehabilitation, University of Pittsburgh, Pittsburgh, Pa.

INTRODUCTION

Patients sustaining polytraumatic injuries often require a multidisciplinary team to return to their prior level of function. Tertiary care hospitals work diligently to ensure that these teams are prepared for any scenario.

This case report discusses how a multidisciplinary team aided a level 1 trauma patient who sustained bilateral lower-extremity degloving injuries, along with several others, after a coal truck pinned his lower body. The reports focuses primarily on his two-staged bilateral transfemoral osseointegration procedures. To the authors' knowledge, no other case reports have been published for this procedure.

CASE PRESENTATION

A 49-year-old male presented to a tertiary care hospital with bilateral lower-extremity degloving injuries after a coal truck reversed onto his lower body. He also sustained a pelvic ring injury; multiple stable cervical, thoracic, and lumbar spine fractures; and pelvic and gluteal hematomas. The general surgery trauma team performed emergent bilateral trans-knee guillotine amputations. Later that week, he returned for pelvic-ring injury management with a sacroiliac screw. The following week, he returned to the orthopaedic trauma team for bilateral transfemoral amputations. The plastic surgery team assisted with closure of the left lower-extremity wounds. He was seen by the orthopaedic spine team to process his cervical, thoracic, and lumbar fractures. They were all managed nonoperatively.

Since the accident, he has been admitted multiple times to the general surgery trauma team for irrigation and debridement of abscesses. To address his lower-extremity pain, the anesthesia team performed a femoral nerve block. He was seen by the orthopaedic oncology team and determined to be a good candidate for bilateral transfemoral osseointegration. One year after his initial injury, he underwent two-staged bilateral transfemoral osseointegration. He has since presented to the physical medicine and rehabilitation team for amputation rehabilitation and continues to require pain management.

OSSEOINTEGRATION

Osseointegration surgery of the appendicular skeleton for reconstruction in amputees is defined as a procedure in which a metal implant is directly anchored to the residual bone to provide a stable fixation for attachment of a prosthetic limb using a transcutaneous connector.[1-2] It provides physiological weight-bearing, improved range of motion in the proximal joint, and osseoperception,[3-4] leading to a cumulative success rate of 92% at twoyear follow-up and dramatic improvements in quality of life reported by transfemoral amputees.[3,5]

Despite improvements in osseointegration technique, prostheses can be complicated by postoperative issues that can negatively impact mobility and quality of life, including soft-tissue problems, infections, fractures, and failure of the implant.[6] Studies have shown that the rate of soft-tissue infection may be as high as 42% within the first six months after implantation. In patients with soft-tissue problems at the stoma, 77% required unplanned interventions such as reoperations or soft tissue revision.[7]

CURRENT STATUS

To date, the patient can complete all activities of daily living independently. Additionally, he can stand with a wheeled walker for four minutes (see Figure 1). He is currently following the Osseointegration Rehabilitation Guidelines by the Walter Reed National Military Medical Center.

REFERENCES

1. Brånemark P et al. *Quintessence*. 1997.
2. Hoellwarth J et al. *JBJS*. 2020.
3. Lundberg M et al. *Prosthet Orthot Int*. 2011.
4. Rusaw D et al. *J Rehabil Res Dev*. 2012.
5. Brånemark R et al. *Bone Joint J*. 2014.
6. Al Muderis M. *Bone Joint J*. 2016.
7. Juhnke D et al. *J Rehabil Res Dev*. 2015.

Figure 1. The patient stands for the first time following bilateral transfemoral osseointegration.

DIVISION OF SPINAL SURGERY

William F. Donaldson III, MD

This was another exciting and productive year in the Division of Spinal Surgery at UPMC. Given the high volume of spine cases, our institution currently houses offices in Oakland, Shadyside, Monroeville, Bethel Park, UPMC Lemieux Sports Complex, and UPMC Freddie Fu Sports Medicine Center. Steven Agabegi, MD, and Vivek Sharma, MD, also see patients and operate at UPMC Somerset and UPMC East.

Thanks to the generous donation of Orland Bethel, the Orland Bethel Family Musculoskeletal Research Center (BMRC) was announced and will be a major advancement for future orthopaedic research at our institution. Joon Lee, MD, was appointed the executive director of the BMRC and hopes to spark collaboration with a new center for our orthopaedic labs, in addition to funded fellowships for students, residents, and fellows to further advance orthopaedic research. Dr. Lee is also the Orland Bethel Endowed Professor and clinical director of the Ferguson Laboratory.

William F. Donaldson III, MD, continues to direct the spine fellowship and serve as chief of the spine division.

Jeremy D. Shaw, MD, continues to serve as the director of spine education as an associate professor. Dr. Shaw has worked extensively with residents and fellows to enhance their education in the operating room and in the classroom. Additionally, Dr. Shaw works closely with the Biodynamics Laboratory, investigating postoperative patient-reported outcomes and biomechanics of patients following cervical and lumbar spine surgeries.

Joseph de Groot, MD, has been developing his practice and is involved with multiple clinical spine projects, as well as resident education on the spine service.

This year's fellows are Michael J. Spitnale, MD, who trained at the University of South Carolina/Prisma Health Midlands for orthopaedic residency, and John Weddle, MD, who trained at Penn State Milton S. Hershey Medical Center.

The Division of Spinal Surgery collaborates with the Biodynamics Laboratory, led by William Anderst, PhD, as well as the Ferguson Laboratory, led by Nam Vo, PhD, and Gwendolyn Sowa, MD, PhD. Additionally, Dr. Lee and Dr. Shaw lead the Pittsburgh Orthopaedic Spine Research (POSR) group, focusing on clinical spine research projects. This year, work from those labs and POSR has resulted in numerous publications and presentations at national meetings, including the Orthopaedic Research Society (ORS), Cervical Spine Research Society (CSRS), AO Spine, American Academy of Orthopaedic Surgeons (AAOS), International Society for the Study of the Lumbar Spine, and the Lumbar Spine Research Society.

Publications

Artz N, Dalton JF, Ramanathan R, Lin RT, Sadhwani S, Li V, Nwankwo J, Como CJ, Oyekan AA, Tang YM, Lee JY, Shaw JD. Characterizing negative online reviews of spine surgeons. *Spine*. 2024.

Lin RT, Dalton JF, Como CJ, Chang AY, Tang MY, Oyekan AA, Sadhwani S, Wawrose RA, Lee JY, Shaw JD. Formal radiologist interpretations of intraoperative spine radiographs have low clinical value. *Spine*. 2024.

Ridolfi D, Oyekan AA, Tang MY, Chen SR, Como CJ, Dalton JF, Gannon EJ, Jackson KL II, Bible JE, Kowalski C, de Groot SJ, Donaldson WF, Lee JY, Shaw JD. Modified Clavien-Dindo-Sink Classification System for operative complications in adult spine surgery. *Journal of Neurosurgery*. 2024.

Chen SR, LeVasseur, CM, Como CJ, Couch BK, Talentino SE, Klatt BA, O'Malley MJ, Donaldson WF, Lee JY, Shaw JD, Anderst WJ. Dynamic changes in lumbar spine kinematics during gait may explain improvement in back pain and disability in patients with hip-spine syndrome. *Spine*. 2023;48(12):867-73.

Chen SR, LeVasseur CM, Como CJ, Couch BK, Talentino SE, Klatt BA, O'Malley MJ, Donaldson WF, Lee JY, Shaw JD, Anderst WJ. Response to Letter to the editor by Fukuda et al. regarding dynamic changes in lumbar spine kinematics during gait may explain improvement in back pain and disability in patients with hip-spine syndrome. *Spine*. 2023;48(23):1698.

Dalton JF, Fourman MS, Rynearson B, Wawrose RA, Cluts L, Shaw JD, Lee JY. The L3 flexion angle predicts failure of non-operative management in patients with tandem spondylolithesis. *Global Spine Journal*. 2023.

Setliff J, Dalton J, Sadhwani S, Tang MY, Mirvish A, Adida S, Wawrose R, Lee JY, Fourman M, Shaw J. Examining the safety profile of a standard dose TXA regimen in spine surgery. *Neurosurg Focus*. 2023;55(4):E16.

Tang MY, Sowa GA, Vo N, Kang J. Gene therapy for intervertebral disc degeneration: an overview of current strategies and applications. *Medical Research Archives*. 2023.

Oyekan AA, LeVasseur CM, Shaw JD, Donaldson WF, Lee JY, Anderst WJ. Changes in intervertebral sagittal alignment of the cervical spine from supine to upright. *Journal of Orthopaedic Research*. 2023;41(7):1538-45.

Oyekan AA, LeVasseur CM, Chen SR, Padmanabhan A, Makowicz N, Donaldson WF, Lee JY, Shaw JD, Anderst WJ. The effects of cervical orthoses on head and intervertebral range of motion. *Spine*. 2023;48(22):1561-7.

Oyekan A, Dalton J, Fourman MS, Ridolfi D, Cluts L, Couch B, Shaw JD, Donaldson W, Lee JY. Multilevel tandem spondylolisthesis associated with a reduced "safe zone" for a transpsoas lateral lumbar interbody fusion at L4-5. *Neurosurg Focus*. 2023;54(1):E5.

Oyekan AA, Eagle S, Trbovich AM, Shaw JD, Schneider M, Collins M, Lee JY, Kontos AP. neck symptoms and associated clinical outcomes in patients following concussion. *J Head Trauma Rehabil*. 2023.

Wawrose RA, Oyekan AA, Tang YM, Chen SR, Chen J, Couch BK, Wang D, Alexander PG, Sowa GA, Vo NV, Lee JY. MicroRNA-29a: a novel target for non-operative management of symptomatic lumbar spinal stenosis. *Eur Spine J*. 2023.

Presentations

Hua K, LeVasseur CM, Pitcairn S, Sebastiani R, Como CJ, Oliveira Barbosa S, Shaw JD, Lee JY, Anderst WJ. Pre-operative patient-specific factors predict the change in adjacent segment range of motion 3 years after anterior cervical discectomy and fusion. ORS Annual Meeting. 2024. Podium presentation.

LeVasseur CM, Gale T, Megherhi S, Pellegrini C, Shoemaker J, Johnson M, McKernan G, Anderst WJ. Variability in intervertebral kinematics during physiologic loading in individuals with chronic low back pain. ORS Annual Meeting. 2023. Podium presentation.

Oyekan AA, LeVasseur CM, Chen SR, Padmanabhan A, Makowicz N, Donaldson WF, Lee JY, Shaw JD, Anderst WJ. The effects of cervical orthoses on multiplanar intervertebral range of motion. CSRS Annual Meeting. 2023. Podium presentation.

Shoemaker J, LeVasseur CM, Gale T, Megherhi S, Pellegrini C, Johnson M, McKernan G, Anderst WJ. Comparison between supine and upright imaging for measuring intervertebral lordosis and disc height in individuals with chronic low back pain. ORS Annual Meeting. 2023. Podium presentation.

Como CJ, Wawrose R, Oyekan A, Chen S, Couch B, Chen J, Shaw JD, Donaldson WF, Sowa G, Vo N, Lee JY. MicroRNA-29a: a novel therapeutic target to treat lumbar spinal stenosis. ORS Annual Meeting. 2024. Poster presentation. Philadelphia Spine Research Society. 2023. Poster presentation.

Como CJ, LeVasseur CM, Hua K, Oliveira Barbosa S, Sebastiani R, Pitcairn S, Shaw JD, Donaldson WF, Lee JY, Anderst WJ. *In vivo* changes in dynamic adjacent segment motion three years after one- and two-level cervical arthrodesis. ORS Annual Meeting. 2024. Poster presentation.

Oliveira Barbosa S, LeVasseur CM, Hua K, Como CJ, Sebastiani R, Pitcairn S, Shaw JD, Donaldson WF, Lee JY, Anderst WJ. Changes in adjacent segment disc strain 3 years after cervical arthrodesis. ORS Annual Meeting. 2024. Poster presentation.

Sebastiani R, LeVasseur CM, Pitcairn S, Hua K, Como CJ, Oliveira Barbosa S, Shaw JD, Donaldson WF, Lee JY, Anderst WJ. graft type affects residual motion but not clinical outcomes three years after anterior cervical discectomy and fusion. ORS Annual Meeting. 2024. Poster presentation.

Megherhi S, LeVasseur CM, Shoemaker J, Tang MY, Shaw JD, Lee JY, Donaldson WF, McKernan G, Anderst WJ. Osteophyte location and severity in individuals with chronic low back pain. ORS Annual Meeting. 2023. Poster presentation.

Oyekan AA, LeVasseur CM, Chen SR, Donaldson WF, Lee JY, Shaw JD, Anderst WJ. The effects of cervical orthoses on head and intervertebral range of motion. ORS Annual Meeting. 2023. Poster presentation.

Pellegrini C, LeVasseur CM, Gale T, Megherhi S, Shoemaker J, Johnson M, McKernan G, Anderst WJ. Errors in measuring overall lumbar spine kinematics using traditional motion capture are dependent upon plane of movement as well as patient pain and age. ORS Annual Meeting. 2023. Poster presentation.

Tang MY, LeVasseur CM, Pitcairn S, Okonkwo D, Kanter A, Shaw JD, Donaldson WF, Lee JY, Anderst WJ. Adjacent segment motion does not increase three years after cervical arthrodesis. ORS Annual Meeting. 2023. Poster presentation.

Oyekan AA, Dalton JF, Ridolfi DT, Couch B, Clutz LM, Zheng A, Mirvish AB, Chang AY, Shaw JD, Donaldson WF, Lee JY. Multi-level tandem spondylolisthesis associated with reduced "safe zone" for lateral lumbar interbody fusion at L4-5. AAOS Annual Meeting. 2023. Poster presentation.

Tang MY, Oyekan AA, Dalton JF, Artz N, Ramanathan R, Li V, Nwankow J, Humphrey E, Lee JY, Shaw JD. Characterizing negative online reviews of spine surgeons. ORS Annual Meeting. 2023. Poster presentation.

Oyekan AA, Tang YM, Ridolfi D, Chen S, Abtahi AA, Fourman M, Donaldson WF, Lee JY, Shaw JD. Influence of baseline patient reported outcome measures on hospital experience scores after elective cervical spine surgery. ORS Annual Meeting. 2023. Poster presentation.

Oyekan AA, Tang YM, Zhen A, Adjei J, Ridolfi D, Onyekweli Ti, Austin W, Couch B, Patel S, Talentino S, Buldo-Licciardi M, Evanshwick-Rogler T, Gannon E, Shaw JD, Donaldson W, Lee JY. Longer constructs do not increase revisions rates in posterior cervical decompression and fusion. ORS Annual Meeting. 2023. Poster presentation.

Tang MY, Krischil R, Wang D, Zhou C, Dong Q, Guo D, Lee J, Sowa G, Vo N. Rapamycin ameliorates age-associated intervertebral disc degeneration in marmosets with sex specific effects. ORS Annual Meeting. 2023. Poster presentation.

Tang YM, Oyekan AA, Ridolfi D, Chen S, Gannon EJ, Jackson KL, Bible JE, Kowalaski, C, De Groot J, Donaldson WF, Lee JY, Shaw, JD. Validation of the Clavien-Dindo-Sink Complication Classification System for adult spine surgery. ORS Annual Meeting. Poster presentation.

Oyekan AA, Tang YM, Shannon MF, Canton S, Lee JY, Shaw JD. Outcomes of non-operative management of Jefferson fractures: a case series. ORS Annual Meeting. 2023. Poster presentation.

Tang YM, Oyekan AA, Dalton J, Sharma V. Early experience with single paraspinal incision, single-level minimally invasive transforaminal lumbar interbody fusion (MITLIF) with 3D printed titanium cage and unilateral pedicle screw construct. Global Spine Congress Annual Meeting. 2023. Poster presentation.

Tang YM, Oyekan AA, Dalton J, Sharma V. The implementation of minimally invasive spine surgery at a UPMC peripheral community hospital. Global Spine Congress Annual Meeting. 2023. Poster presentation.

Bailes AH, McKernan GP, Greco C, Redfern M, Sowa GA, Bell KM, Piva S, Brach JS, Cham R, LB^{3}P Investigators. Disentangling the roles of pain and pain-related psychological factors in gait for chronic low back pain: a preliminary study. HEAL Annual Meeting. 2024. Poster presentation.

Tonelli Enrico V, Piva S, Patterson C, McKernan G, Greco C, Vo N, Sowa GA, LB^{3}P Investigators. Plasma proteomics analysis in chronic low back pain subjects: a preliminary analysis. HEAL Annual Meeting. 2024. Poster presentation.

Tonelli Enrico V, Methe B, Li K, Fitch A, Patel A, Vo N, Morris A, Sowa GA. Unique gut microbiome signature associated with pain and disability in a cLBP population: an exploratory analysis. HEAL Annual Meeting. 2024. Poster presentation.

Tonelli Enrico V, McKernan G, Vo N, Sowa GA. Association between leptin plasma concentration, pain, and function in chronic low back pain subjects. HEAL Annual Meeting. 2024. Poster presentation.

Aguilar B, McKernan G, Piva S, Sowa GA, Bean A. Association and feasibility of quadriceps strength and function with pain and disability in patients with chronic low back pain. AAP Annual Meeting. 2024.

Alexander P, Sowa GA, Vo N. Assessing the effect of PROTEC 753b senolytic on intervertebral disc aging. ORS Annual Meeting. 2024. Poster presentation. Philadelphia Spine Research Society. 2023. Podium presentation.

Tonelli Enrico V, McKernan G, Vo N, Sowa GA. Association between leptin plasma concentration, pain and function in chronic low back pain subjects. Philadelphia Spine Research Society. 2023. Podium presentation.

Clark K, Tang MY, Silwal P, Vo N, Lee JY, Alexander P. A 3D culture system to model the ligamentum flavum in health and disease. ORS Annual Meeting. 2024. Poster presentation. Philadelphia Spine Research Society. 2023. Poster presentation.

Zou T, Wang D, Lee JY, Sowa GA, Vo N. Role of MOF in epigenetic regulation via histone lactylation of annulus fibrosus cells. ORS Annual Meeting. 2024. Poster presentation. Philadelphia Spine Research Society. 2023. Poster presentation.

Silwal P, Lee JY, Sowa GA, Vo N. Role of G0/G1 switch gene 2 in TGF- β1 induced hypertrophy of ligamentum flavum. ORS Annual Meeting. 2024. Poster presentation. Philadelphia Spine Research Society. 2023. Poster presentation.

Zou T, Wang D, Lee JY, Sowa GA, Vo N. epigenetic regulation of collagen i expression by histone lactylation in annulus fibrosus cells. International Society for the Study of the Lumbar Spine Annual Meeting. 2024. Poster presentation.

Kritschil R, Li V, Wang D, Lee JY, Sowa GA, Vo N. Impact of autophagy depletion on intervertebral disc cell function, cell viability and matrix degeneration. International Society for the Study of the Lumbar Spine Annual Meeting. Annual Meeting. 2023. Poster presentation.

Zein, K, Pashaj X, Bell K, Lee JY, Sowa GA, Vo N. Validation of a high throughput bioreactor compression chamber for small animal spine mechanobiology. Philadelphia Spine Research Society. 2023. Poster presentation.

Wood P, Clark K, Alexander P. Assaying extracellular matrix gene expression by vertebral endplate chondrocytes in 3D hydrogel culture. Philadelphia Spine Research Society. 2023. Poster presentation.

Wang D, Zou T, Lee JY, Sowa GA, Vo N. Perturbation of histone lactylation on gene expression in rat nucleus pulposus cells. ORS Annual Meeting. 2024. Poster presentation.

Ansari M, Moncher J, Ellis A, Husein M, Alvarex M, Vo N, Wang D. Terminal uridylyl transferase 7 deletion suppressed interleukin-6 expression and reduced the severity of intervertebral disc degeneration in a mouse model. ORS Annual Meeting. 2024. Poster presentation.

Wang D, Lee JY, Sowa GA, Vo N. Evidence of histone lactylation and its role in MMP-13 epigenetic regulation of intervertebral discs. ORS Annual Meeting. 2023. Poster presentation.

Tang MY, Kritschil R, Wang D, Zhou C, Qong Q, Guo D, Lee JY, Sowa GA, Vo N. Rapamycin ameliorates age-associated intervertebral disc degeneration in marmosets with sex specific effects. ORS Annual Meeting. 2023. Poster presentation.

Zhou H, Clark K, Lin H, Alexander P. The effect of mechanical loading on engineered cartilage constructs derived from human bone marrow-derived mesenchymal stromal cells of early or late passage. ORS Annual Meeting. 2023. Poster presentation.

Zou T, Wang D, Tang MY, Lee JY, Sowa GA, Vo N. Effects of lactate and histone lactylation on aggrecan expression in rat nucleus pulposus cells. ORS Annual Meeting. 2023. Poster presentation.

Zou T, Wang D, Tang MY, Lee JY, Sowa GA, Vo N. Role of MOF-mediated histone lactylation in nucleus pulposus (NP) cell function and survival.

INTRAOPERATIVE NEUROPHYSIOLOGICAL MONITORING AS A PREDICTOR FOR FUNCTIONAL RECOVERY FOLLOWING SPINAL CORD INJURY

Adida S[1,3,4], Calcaterra M[1,3,4], Como CJ[1,3,4], Tang MY[1,3,4], Bodo E[2,3], Valentino I[2,3], Thirumala PD[2,3], Shaw JD[1,3,4], Lee JY[1,3,4]

[1]Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.
[2]Department of Neurology and Clinical Neurophysiological Laboratory, University of Pittsburgh, Pittsburgh, Pa.
[3]Pittsburgh Orthopaedic Spine Research Group, Pittsburgh, Pa.
[4]Orland Bethel Family Musculoskeletal Research Center, Pittsburgh, Pa.

INTRODUCTION

The capability of patients to recover following traumatic spinal cord injury (SCI) is not well understood. The American Spinal Injury Association (ASIA) Impairment Scale is the most widely utilized predictor for functional recovery, with ASIA-A injuries exhibiting the lowest recovery levels.[1] Postoperative somatosensory-evoked potentials (SSEPs) and motor-evoked potentials (MEPs) are commonly utilized neurophysiological modalities recorded throughout the course of spinal surgery and correlate to functional recovery after SCI.[2-3] However, the prognostic value of intraoperative SSEPs and MEPs on long-term outcomes has not previously been investigated.[2] This study aimed to determine the neurophysiologic profiles of SCI patients stratified by postoperative predischarge ASIA scores. Patients with worse postoperative deficits (ASIA-A/ASIA-B) are hypothesized to have more absent or abnormal intraoperative neurophysiological modalities than patients with less severe postoperative deficits (ASIA-D/ASIA-E).

METHODS

The researchers conducted a retrospective review of 927 patients who underwent surgery for traumatic SCI at a level 1 trauma center (2017–2022). Patients who were younger than 18 years, underwent revision, or did not receive ASIA exams were excluded. Patient characteristics were recorded. Upper-extremity (UE) and lower-extremity (LE) SSEPs and MEPs were collected continuously throughout the procedure. Baselines, significant changes, and improvements to the amplitude of signals were recorded. After stratifying patients by ASIA score, one-way analyses of variance and χ^2 tests were performed to compare continuous and categorical variables, respectively. Post-hoc Bonferroni corrections were used to determine differences in neurophysiologic modalities between groups.

RESULTS

Of 927 patients, 205 (22.2%) met the inclusion criterion. Patients were assigned to ASIA-A (24.7%), ASIA-B (12.6%), ASIA-C (14.1%), ASIA-D (46.0%), and ASIA-E (2.5%) groups. There were no differences in sex ($p = 0.523$) or body mass index ($p = 0.585$) amongst the groups. Patients in the ASIA-A and ASIA-B groups were younger than patients in the ASIA-D group ($p = 0.003$ and $p < 0.001$, respectively). Within the ASIA-A and ASIA-B groups, 21 patients (28.4%) had a normal UE SSEP signal and one patient (1.4%) had a normal LE SSEP signal. Patients in the ASIA-A group had more abnormal LE SSEP signals compared to patients in the ASIA-D ($p < 0.001$) and ASIA-E ($p < 0.001$) groups (see Table 1). Additionally, patients in the ASIA-B group had more abnormal LE SSEP signals than patients in the ASIA-E group ($p < 0.001$). There were no differences in abnormal UE SSEP responses ($p = 0.938$) or changes in SSEP signals ($p = 0.182$) among all five groups. As for MEP signals, the researchers found no differences when comparing baseline UE signals ($p = 0.182$), baseline LE signals ($p = 0.134$), or changes in MEP signals ($p = 0.884$).

DISCUSSION

Patients with ASIA-A and ASIA-B scores were found to have more abnormal SSEP signals when compared to patients with ASIA-D and ASIA-E scores. This study reaffirms the prognostic value of the ASIA classification system, as quantifiable differences in intraoperative SSEPs and MEPs among ASIA groups were determined.

SIGNIFICANCE

Utilization of the ASIA classification system, along with intraoperative SSEPs and MEPs, may have useful prognostic value for functional recovery following spinal cord injury.

REFERENCES

1. Spiess MR et al. *Clinical Neurophysiology*. 2008;119(5):1051-61.
2. Costa P et al. *Spinal Cord*. 2014;52:749-57.
3. Eck JC et al. *J Clin Monit Comput*. 2013;27:93-6.

Score	ASIA-A	ASIA-B	ASIA-C	ASIA-D	ASIA-E	*P value*
Number of Patients	49	25	28	91	5	
Age (years)	49.1 ± 20.8	41.1 ± 19.6	53.3 ± 17.4	61.0 ± 16.9	46.0 ± 18.5	**<0.001**
Sex						
Male	36 (73.5%)	17 (68.0%)	24 (85.7%)	70 (76.9%)	3 (60.0%)	0.523
Female	13 (26.5%)	8 (32.0%)	4 (14.2%)	21 (23.1%)	2 (40.0%)	
BMI (kg/m²)	28.4 ± 7.4	26.0 ± 6.5	28.4 ± 7.5	28.4 ± 6.5	26.7 ± 2.9	0.585
UE SSEP Abnormal Response	33 of 47 (70.2%)	16 of 23 (69.6%)	18 of 27 (66.7%)	60 of 86 (69.8%)	2 of 4 (50.0%)	0.938
LE SSEP Abnormal Response	46 of 47 (97.9%)	22 of 22 (100.0%)	23 of 27 (85.2%)	66 of 86 (76.7%)	2 of 4 (50.0%)	**<0.001**
Significant SSEP Change	6 of 45 (13.3%)	0 of 24 (0.0%)	4 of 28 (14.3%)	9 of 90 (10.0%)	0 of 5 (0.0%)	0.182
UE MEP Baseline Absent	5 of 7 (71.4%)	2 of 3 (66.7%)	5 of 6 (83.3%)	6 of 16 (37.5%)	None recorded	0.182
LE MEP Baseline Absent	5 of 7 (71.4%)	2 of 2 (100%)	5 of 6 (83.3%)	6 of 15 (40%)	None recorded	0.134
Significant MEP Change	1 of 7 (14.2%)	1 of 3 (33.3%)	1 of 6 (16.7%)	4 of 16 (25%)	None recorded	0.884

deviation (median [range]) or number (%)

ASIA, American Spinal Injury Association; **BMI,** body mass index; **SSEP,** somatosensory-evoked potential; **LE,** lower extremity; **UE,** upper extremity

Table 1. Patient Demographics and Intraoperative Neuromonitoring Signals for the 198-Patient Cohort

CHARACTERIZING NEGATIVE ONLINE REVIEWS OF SPINE SURGEONS

Artz N[1,2], Dalton JF[1,2,3], Ramanathan R[1,2,3], Lin RT[1,2], Sadhwani S[1,2], Li V[1,2], Nwankwo J[1,2], Como CJ[1,2,3], Oyekan AA[1,2,3], Tang MY[1,2,3], Lee JY[1,2,3], Shaw JD[1,2,3]

[1]Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.
[2]Pittsburgh Orthopaedic Spine Research Group, Pittsburgh, Pa.
[3]Orland Bethel Family Musculoskeletal Research Center, Pittsburgh, Pa.

INTRODUCTION

Physician rating websites significantly influence the selection of doctors by other patients.[1-3] Negative experiences are impacted by various factors, both clinical and nonclinical aspects, geography, and practice structure. The purpose of this study was to evaluate and categorize negative reviews of spine surgeons in the United States, with a focus on surgical versus nonsurgical reviewers.

METHODS

Spine surgeons were selected from available online directories of professional society memberships. The researchers conducted a search for reviews on Healthgrades.com, Vitals.com, and RateMDs.com for the past 10 years. Free-response reviews were coded by complaint, and qualitative analysis was performed. Chi-square and Fisher exact tests were used to compare categorical variables, and multiple comparisons were adjusted with Benjamini-Hochberg correction. A binary logistic regression model was performed for the top three most mentioned nonclinical and clinical complaint labels. A p value < 0.05 was considered statistically significant.

RESULTS

A total of 16,695 online reviews were evaluated, including 1,690 one-star reviews (10.1%). Amongst one-star reviews, 64.7% were written by nonsurgical patients and 35.3% by surgical patients. Nonclinical and clinical comments constituted 54.9% and 45.1% of reviews, respectively (see Table 1). Surgeons in the south had more “bedside manner” comments (43.3%, $p < 0.0001$), whereas northeast surgeons had more “poor surgical outcome” remarks compared to all other geographic regions (14.4%, $p < 0.001$; see Table 2). Practicing in the south or northeast was an independent predictor of having complaints about “bedside manner” and “poor surgical outcome,” respectively.

DISCUSSION

Most one-star reviews of spine surgeons were attributed to nonsurgical patients, who tended to be unsatisfied with nonclinical factors, especially “bedside manner.” However, there was substantial geographic variation. Notably, patients in the south were significantly more likely to have “bedside manner” comments, and those in the northeast were more likely to complain of “poor surgical outcome” compared to all other regions.

SIGNIFICANCE

Spine surgeons could benefit from focusing on nonclinical factors such bedside manner, especially amongst their nonoperative patients. Additionally, there are important regional nuances that should be considered in delivering spine care.

REFERENCES

1. Ziemba JB et al. *JAMA Surg*. 2017;152:410-1.
2. Hanauer DA et al. *JAMA*. 2014;311:734-5.
3. Sculco PK et al. *Curr Rev Musculoskelet Med*. 2017;10:278-9.

	N	%
Total	1690	
Nonsurgical	1093	64.7%
Surgical	597	35.3%
Complaint reasons		
Nonclinical	928	54.9%
Bedside manner	563	33.3%
Unprofessional/Rude staff/Couldn't get ahold of office	105	6.2%
Time spent with provider	80	4.7%
Wait time	68	4.0%
Scheduling	56	3.3%
Workman's comp	38	2.2%
Billing/Insurance	18	1.1%
Clinical	762	45.1%
Disagreement with treatment plan/Unclear	229	13.6%
Uncontrolled pain	149	8.8%
Poor surgical outcome	131	7.8%
Complication	104	6.2%
Reoperation	54	3.2%
Misdiagnosis	50	3.0%
Delay in care	45	2.7%
Practice Structure		
Private	1411	83.5%
Academic	279	16.5%
Website		
Vitals	813	48.1%
Healthgrades	693	41.0%
RateMDs	184	10.9%
Region		
West	525	31.1%
Northeast	464	27.5%
Midwest	380	22.5%
South	321	19.0%

Table 1. Aggregate Statistics of the Entire Cohort

	Midwest	Northeast	South	West
	N (%)	N (%)	N (%)	N (%)
Total	380 (22.5)	464 (27.5)	321 (19)	525 (31.1)
Nonsurgical	257 (67.6)	332 (71.6)	151 (47)	353 (67.2)
Surgical	123 (32.4)	132 (28.4)	170 (53)	172 (32.8)
Nonclinical Complaints				
Nonclinical	182 (47.9)	251 (54.1)	208 (64.8)	287 (54.7)
Bedside manner	127 (33.4)	142 (30.6)	139 (43.3)	155 (29.5)
Scheduling	5 (1.3)	23 (5)	10 (3.1)	18 (3.4)
Time spent with provider	15 (3.9)	31 (6.7)	14 (4.4)	20 (3.8)
Billing/Insurance	2 (0.5)	8 (1.7)	4 (1.2)	4 (0.8)
Unprofessional/Rude staff/Couldn't get ahold of office	12 (3.2)	23 (5)	19 (5.9)	51 (9.7)
Wait time	17 (4.5)	15 (3.2)	22 (6.9)	14 (2.7)
Workman's comp	3 (0.8)	9 (1.9)	0	26 (5)
Clinical Complaints				
Clinical	198 (52.1)	213 (45.9)	113 (35.2)	238 (45.3)
Poor surgical outcome	28 (7.4)	67 (14.4)	13 (4)	23 (4.4)
Disagreement with treatment plan/Unclear	59 (15.5)	65 (14)	45 (14)	60 (11.4)
Reoperation	19 (5)	14 (3)	3 (0.9)	18 (3.4)
Delay in care	10 (2.6)	17 (3.7)	4 (1.2)	14 (2.7)
Complication	17 (4.5)	13 (2.8)	18 (5.6)	56 (10.7)
Uncontrolled pain	55 (14.5)	24 (5.2)	29 (9)	41 (7.8)
Misdiagnosis	11 (2.9)	13 (2.8)	1 (0.3)	25 (4.8)

Table 2. Sub-Group Analysis of Surgical Patients Versus Nonsurgical Patients by Healthgrades.com, Vitals.com, RateMDs.com, Geographic Region, and Practice Setting

THE CLINICAL SIGNIFICANCE OF DISTAL SCREW RADIOLUCENCY IN POSTERIOR CERVICAL FUSION

Chang A[1,3], Whaley JD[1,3,4], Como CJ[1,3,4], Dalton JF[1,3,4], Tang MY[1,3,4], Croft A[2,3], Canton S[1,3,4], Oyekan AA[1,3,4], Black K[1,3,4], Shaw JD[1,3,4], Lee JY[1,3,4]

[1]Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.
[2]Department of Orthopaedic Surgery, Vanderbilt University, Nashville, Tenn.
[3]Pittsburgh Orthopaedic Spine Research Group, Pittsburgh, Pa.
[4]Orland Bethel Family Musculoskeletal Research Center, Pittsburgh, Pa.

INTRODUCTION

Screw lucency is a known complication of spinal instrumentation. Lucency may be identified on radiographs at various timepoints in the postoperative period, presenting a dilemma: Operate or leave it alone? There is a paucity of clinical research evidence to support either decision.[1-4] Posterior cervical fusion constructs are commonly utilized in the management of cervical spondylotic myelopathy. The selection of lower instrumented vertebra (LIV) in these constructs with lateral mass screws in the cervical spine or pedicle screws in the upper thoracic spine is the subject of controversy.[5] To date, no studies have evaluated the clinical significance, if any, of screw radiolucency at the LIV for posterior cervical fusion constructs. The purposes of this study were to:

- Determine the incidence of radiologist-reported distal (LIV) screw radiolucency (computed tomography [CT] or x-ray criteria of radiolucent zone adjacent to screw ≥ 1 mm) in patients undergoing posterior cervical laminectomy and fusion
- Identify any potential differences in the rate of reoperation for patients with screw radiolucency as compared to those without screw radiolucency

METHODS

The authors conducted a retrospective review of data collected from two academic centers. Charts were reviewed for patients older than 18 years who underwent posterior cervical laminectomy and fusion for trauma or degenerative indications from August 2012 to August 2019. Patients who underwent posterior cervical surgery for tumor or infection, as well as revision procedures, were excluded. Distal screw radiolucency was determined by radiologist-reported CT or x-ray radiolucent zone adjacent to screw ≥ 1 mm, at multiple postoperative time points: seven days, 30 days, 90 days, one year, and latest films. Radiolucency was identified by chart review of radiologist x-ray reports. The researchers collected and compared reoperation rates between the two groups using chi-square test. Significance was set at $p < 0.05$.

RESULTS

A total of 235 patients underwent posterior cervical fusion during the study period. Of those patients, 44 had zero- to seven-day CT or x-ray, none of which demonstrated radiologist-reported cervical screw lucency. There were 82 patients with 30-day imaging, 2.4% of whom had reported lucency at 30 days, whereas 1.3% of the 228 patients had lucency at the 90-day interval, and 3.3% of the 181 had radiologist-reported lucency at the one-year mark. At time of latest imaging, 4.7% of the 235 patients had radiologist-reported lucency. The overall rate of reoperation was 5.1%. Only three patients with radiologist-reported lucency underwent revision surgery; two were attributed to trauma sustained more than one year after index surgery. In contrast, nine patients without radiologist-reported lucency underwent revision surgery, with adjacent segment disease as the most common indication.

DISCUSSION

Radiolucency at the LIV of posterior cervical fusion constructs increased over time during the postoperative course. However, radiolucency did not lead to increases in reoperation rate, and screw lucency was not often cited as an indication for reoperation. Further studies are needed to understand whether this trend continues over time, as well as the significance of screw lucency in reoperation and patient satisfaction outcomes following posterior cervical fusion.

REFERENCES

1. Goldstein et al. *Interdisciplinary Neurosurgery*. 2017.
2. Galbusera et al. *European Spine Journal*. 2015;24(5):1005-16.
3. Sandén et al. *Journal of Bone and Joint Surgery (British Vol)*. 2004;86(3):457-61.
4. Kanematsu et al. *Neurologia Medico-Chirurgica*. 2021;61(1):40-6.
5. Couch et al. *Global Spine Journal*. 2022;13(8):2379-86.

HOSPITAL EXPERIENCE SCORES POORLY CORRELATE WITH PATIENT-REPORTED OUTCOME MEASURES AFTER ELECTIVE SPINE SURGERY

Chang AY[1,2,3], Tang MY[1,2,3], Como CJ[1,2,3], Chang F[4], Ma Y[4], Calcaterra M[1,2], Adida S[1,2], Oyekan AA[1,2,3], Dalton JF[1,2,3], Donaldson WF[1,2,3], Lee JY[1,2,3], Shaw JD[1,2,3]

[1]Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.
[2]Pittsburgh Orthopaedic Spine Research Group, Pittsburgh, Pa.
[3]Orland Bethel Family Musculoskeletal Research Center, Pittsburgh, Pa.
[4]Department of Biostatistics, University of Pittsburgh, Pittsburgh, Pa.

INTRODUCTION

Patient experience is an important component of healthcare quality. Patient experience surveys, including the Hospital Consumer Assessment of Healthcare Providers and Systems (HCAHPS) score, have been used to justify changes in Medicare reimbursement.[1-2] Despite the increasing impact of these metrics, the factors that influence patient experience scores are not fully understood. The purpose of this study was to correlate hospital experience scores as measured by HCAHPS after cervical and thoracolumbar spine surgery with postoperative patient-reported outcome measures (PROMs) up to five years after surgery.

METHODS

The authors conducted a retrospective analysis approved by the Institutional Review Board on adults who underwent elective inpatient spine surgery from January 2010 to December 2019. Postoperative PROM data, including the Neck Disability Index (NDI), Oswestry Disability Index, Patient-Reported Outcomes Measurement Information System Global-10 Mental/Physical Health scores (PROMIS-10 Mental/Physical), and Patient Acceptable Symptom State Neck/Back were collected. Patients completed the HCAHPS hospital experience survey via text message within 24–48 hours of discharge, in which they rated the hospital on a Likert scale from 0–10, with 0 the "worst hospital possible" and 10 the "best hospital possible." Correlation analysis and longitudinal data analysis were used to assess relationships between PROMs and HCAHPS scores.

RESULTS

A total of 397 patients with recorded PROMs were included (see Tables 1 and 2). For cervical patients, NDI at 6 months ($r = -0.20$; $p = 0.016$) had a small significant correlation and PROMIS-10 Mental scores at six months ($r = 0.30$; $p = 0.003$) had a medium significant correlation with hospital experience scores (see Table 1). However, this correlation did not persist two years after surgery. No significant relationship was observed between HCAHPS and any postoperative PROM following thoracolumbar surgery (see Table 2).

DISCUSSION

In this study, hospital experience scores correlated poorly with patient-reported outcomes at various time points up to five years following elective spine surgery. Despite the emphasis in current reimbursement models as an indicator of the quality of hospital care, HCAHPS metrics appear to be a poor metric to reflect patient-reported outcomes following spine surgery.

SIGNIFICANCE

HCAHPS scores poorly correlate with PROMs after spine surgery and may not be an appropriate hospital metric for hospital reimbursement.

REFERENCES

1. Centers for Medicare and Medicaid Services. Hospital Value-Based Purchasing Program. 2021.
2. Centers for Medicare and Medicaid Services. CMS.gov. 2021.

Patient Reported Outcome Measure (PROM)	Correlation Coefficient (PROM vs HCAHPS)	P-Value
Neck Disability Index (NDI)	6 mo (n=86): -0.20 2y (n=43): -0.080 5y (n=22): -0.20	**6 mo: 0.016** 2y: 0.52 5y: 0.23
Patient-Reported Outcome Measurement Information System10-Physical (PROMIS10-Physical)	6 mo (n=60): 0.17 2y (n=48): 0.010 5y (n=41): 0.19	6 mo: 0.10 2y: 0.93 5y: 0.13
Patient-Reported Outcome Measurement Information System10-Mental (PROMIS10-Mental)	6 mo (n=60): 0.30 2y (n=48): 0.040 5y (n=41): 0.15	**6 mo: 0.003** 2y: 0.75 5y: 0.21
Patient Acceptable Symptom State (PASS)-Neck (PASS-Neck)	6 mo (n=58): 0.12 2y (n=31): 0.040 5y (n= 21): 0.040	6 mo: 0.30 2y: 0.80 5y: 0.80
Patient Acceptable Symptom State (PASS)-Back (PASS-Back)	6 mo (n=6): 0.20 2y (n=16): -0.10 5y (n=18): -0.30	6 mo: 0.60 2y: 0.70 5y: 0.14

Table 1. Correlation of Cervical Patient-Reported Outcome Measures and Hospital Experience Scores

Patient Reported Outcome Measure (PROM)	Correlation Coefficient (PROM vs HCAHPS)	P-Value
Oswestry Disability Index (ODI)	6 mo (n=232): -0.080 2y (n=136): 0.060 5y (n=61): 0.030	6 mo: 0.080 2y: 0.30 5y: 0.80
Patient-Reported Outcome Measurement Information System 10-Physical (PROMIS10-Physical)	6 mo (n=141): 0.080 2y (n=138): -0.060 5y (n=85): 0.10	6 mo: 0.20 2y: 0.40 5y: 0.20
Patient-Reported Outcome Measurement Information System10-Mental (PROMIS10-Mental)	6 mo (n=141): 0.12 2y (n=138): 0.050 5y (n=85): 0.019	6 mo: 0.060 2y: 0.50 5y: 0.80
Patient Acceptable Symptom State (PASS)-Neck (PASS-Neck)	6 mo (n=5): -0.13 2y (n=9): 0.23 5y (n=11): 0.33	6 mo: 0.80 2y: 0.50 5y: 0.30

Table 2. Correlation of Thoracolumbar Patient-Reported Outcome Measures and Hospital Experience Scores

FOCUSED PERIOPERATIVE NUTRITIONAL SUPPLEMENTATION REDUCES WOUND COMPLICATIONS IN PATIENTS UNDERGOING SPINAL FUSION SURGERY

Como CJ[1,2,3], Setliff JC[1,2,3], Dalton JF[1,2,3], Tang MY[1,2,3], Oyekan AA[1,2,3], Hua K[1,2,3], Byrne K[1,2,3], Spitnale M[1,2,3], Russell KL[1,2,3], Wawrose R[1,2,3], Russavage JM[4], Lee JY[1,2,3], Shaw JD[1,2,3]

[1]Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.
[2]Pittsburgh Orthopaedic Spine Research Group, Pittsburgh, Pa.
[3]Orland Bethel Musculoskeletal Research Center, Pittsburgh, Pa.
[4]University of Pittsburgh Medical Center, Department of Plastic Surgery, Pittsburgh, Pa.

BACKGROUND

Malnutrition is associated with unfavorable outcomes in spine surgery,[1-2] with multifactorial causes such as poor diet, advanced age, chronic pain, and extended bed rest.[3] Suboptimal nutritional status increases mortality and predisposes patients to complications.[4] Although perioperative nutritional supplementation has shown promise, its explicit impact on spinal fusion surgery outcomes remains unexplored.[5-6] The purpose of this study was to evaluate the impact of focused postoperative nutritional supplementation on outcomes in spinal fusion surgery.

METHODS

A retrospective cohort study (2019–2022) at a tertiary academic spine center assessed spinal fusion patients. Data included demographics, surgical variables, preoperative prealbumin (PAB), and postoperative plastic and reconstructive surgery supplemental diet. The supplemental diet consisted of once-daily administration of a multivitamin tab, vitamin A, vitamin C, and zinc sulfate, Juven nutrition powder, Arginaid, and either Ensure or Glucerna.[7] The primary endpoint was rate of complications (reoperation, surgical site infection, and wound complications. Secondary outcomes included Oswestry Disability Index and Patient-Reported Outcome Measurement Information System Physical Health scores. Analyses compared patients with and without the supplemental diet and subgroups based on malnutrition status. Significance was set at $p < 0.05$.

RESULTS

Of 281 patients meeting inclusion criteria (mean age: 61.7 ± 12.5 years, mean body mass index: 30.4 ± 6.3), those on the supplemental diet had significantly lower rates of wound complications ($p < 0.001$), reoperations ($p = 0.002$), and surgical site infections ($p = 0.002$) compared to patients not on the supplemental diet (see Table 1). In the low PAB subgroup, patients without the diet had higher rates of wound complications (39% versus 15%, $p = 0.013$, Table 1).

DISCUSSION

Patients receiving the supplemental diet had lower rates of wound complications, surgical site infections, and reoperations, emphasizing its beneficial impact. This effect was particularly notable in malnourished patients (low PAB subgroup), highlighting the significance of targeted nutritional support in mitigating adverse outcomes associated with malnutrition in spinal fusion surgery.

SIGNIFICANCE

This study underscores the potential of a specialized postoperative diet in improving patient outcomes, particularly in malnourished patients.

REFERENCES

1. Debono B et al. *Spine J.* 2021;21:729-52.
2. Tempel Z et al. *Neurol Surg A Cent Eur Neurosurg.* 2015;76:139-43.
3. He Z et al. *J Orthop Surg Res*. 2020.
4. Sugumar D et al. *Asian Spine Journal*. 2021.
5. Bisson EF et al. *Neurosurgery*. 2021.
6. Khalooeifard R et al. *Clin Spine Surg.* 2022.
7. Knackstedt R et al. *Plast Reconstr Surg.* 2020.

	Supplement (229)	No Supplement (52)	p-value
Reoperation – n (%)	9 (4%)	9 (17%)	**0.002**
Surgical site infection – n (%)	5 (2%)	5 (10%)	**0.022**
Wound complication – n (%)	18 (8%)	14 (27%)	**<0.001**
Preoperative PROMIS PH – mean (SD)	11.2 (4.2) (n=130)	11.5 (2.2) (n=33)	0.720
Preoperative ODI – mean (SD)	38.5 (16.9) (n=158)	35.0 (18.1) (n=33)	0.276
Postoperative PROMIS PH – mean (SD)	13.2 (6.3) (n=104)	12.7 (4.3) (n=30)	0.699
Postoperative ODI – mean (SD)	30.1 (20.7) (n=155)	32.0 (17.3) (n=36)	0.603

n.s., not significant; SD, standard deviation; PH, physical health; ODI, Oswestry disability index

Table 1. Postoperative Complication Rates and Patient-Reported Outcomes

PREVENTION OF ILEUS USING A STANDARDIZED BOWEL REGIMEN AFTER SPINE SURGERY: A RETROSPECTIVE COHORT STUDY

Dalton JF[1,2,3], Lin RT[1,2], Oyekan AA[1,2,3], Ridolfi D[1,2], Zheng A[1,2], Chang AY[1,2], Carlos NB[1,2], Como CJ[1,2,3], Couch B[1,2,3], Shaw JD[1,2,3], Lee JY[1,2,3]

[1]Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.
[2]Pittsburgh Orthopaedic Spine Research Group, Pittsburgh, Pa.
[3]Orland Bethel Family Musculoskeletal Research Center, Pittsburgh, Pa.

INTRODUCTION

Postoperative ileus (POI) is a prevalent complication following spine surgery, often leading to significant postoperative morbidity, prolonged hospitalization, and increased healthcare expenses.[1-3] Given the current lack of consistency in guidelines for managing POI, there exists a critical need for efficacious prophylaxis and treatment. This study investigated the impact of a standardized bowel regimen on POI incidence among adult spine surgery patients.

METHODS

Following Quality Improvement Review Committee approval, the researchers performed a retrospective cohort analysis on all elective adult spine surgeries performed between July 2020 and July 2021. Bowel-regimen standardization was implemented in January 2021 and included standing admission of naloxegol, bisacodyl, docusate, and polyethylene glycol. Additional medications were administered sequentially for each subsequent day without a bowel movement, including a bisacodyl suppository; lactulose; magnesium hydroxide; mineral oil; and a saline, mineral oil, and glycerin enema (see Figure 1). Patients were stratified into three groups based on bowel-regimen completion during postoperative hospitalization. The primary endpoint was the incidence of documented bowel movements. Secondary endpoints included the I-Feed score for POI (not yet validated in spine surgery), length of stay, and hospital readmission. Statistical analysis included chi-square, Fischer's exact test, analysis of variance, and binary logistic regression to adjust for confounding variables. A p value < 0.05 was considered significant.

RESULTS

The analysis included 527 patients (272 male and 255 female; mean age = 61 ± 12 years). The standardized bowel regimen was employed in 109 patients (20.6%), a partial bowel regimen in 345 patients (65.5%), and a substandard bowel regimen in 73 patients (13.9%). The prevalence of documented bowel movement in the postoperative course was significantly higher in patients receiving the standardized bowel regimen (99.1%) compared to those receiving the partial (56.8%) or substandard bowel regimens (9.6%, $p < 0.001$). Binary logistic regression analysis confirmed that this trend persisted even after the study controlled for demographic factors, surgical variables, and length of hospital stay. There were no significant differences in I-Feed score or hospital readmission among patients receiving standardized, partial, or substandard bowel regimens (all $p > 0.1$).

DISCUSSION

The implementation of a standardized perioperative bowel regimen may effectively improve the incidence of POI in spine surgery patients. This study demonstrated that a standardized protocol decreased the incidence of POI in spine surgery patients. Thus, healthcare providers managing postoperative spine surgery patients should consider integrating a standardized bowel regimen into their practice to mitigate and manage POI effectively.

SIGNIFICANCE

The use of a standardized bowel regimen decreases the incidence of POI in spine surgery patients, but further research is required to investigate the financial implications of the diet.

REFERENCES

1. Swong et al. *World Neurosurg.* 2019;122:e512-5.
2. Khan et al. *Neurosurgical Review.* 2022;45:275-83.
3. Mandl et al. *HSS J.* 2020;16:272-9.

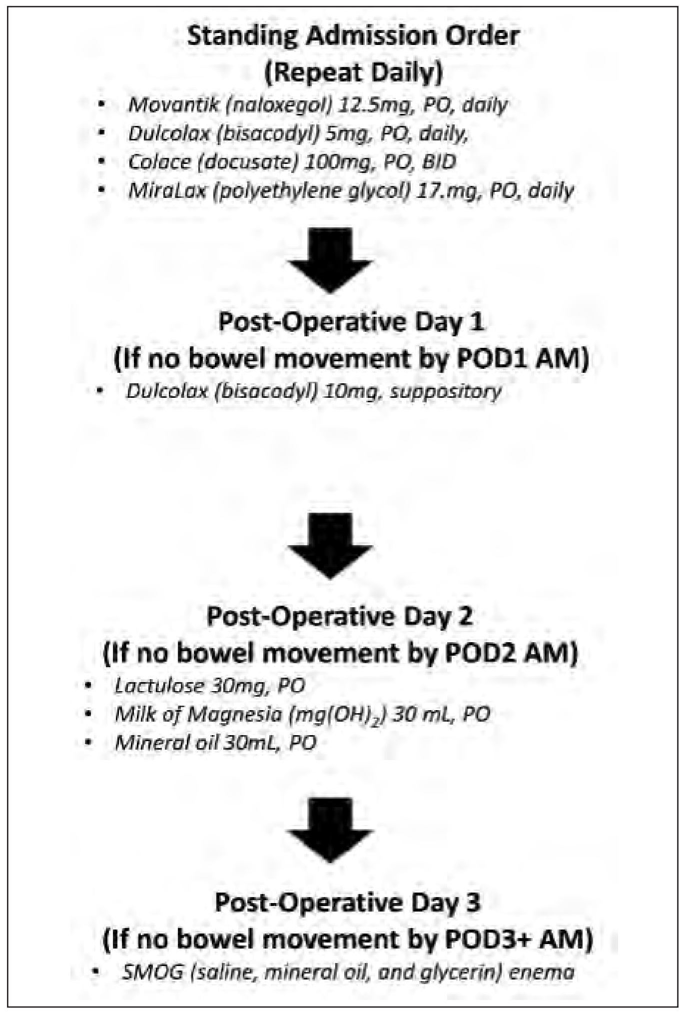


Figure 1. Flow diagram of bowel regimen administration: For each subsequent postoperative day without a bowel movement, patients are administered a standardized set of medications. A patient who has not defecated by postoperative day 2 is administered standing medications with postoperative day 2 medications.

FORMAL RADIOLOGIST INTERPRETATIONS OF INTRAOPERATIVE SPINE RADIOGRAPHS HAVE LOW CLINICAL VALUE

Lin RT[1,2], Dalton JF[1,2,3], Como CJ[1,2,3], Chang AY[1,2], Tang MY[1,2,3], Oyekan AA[1,2,3], Sadhwani S[1,2], Wawrose RA[1,2], Lee JY[1,2,3], Shaw JD[1,2,3]

[1]Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.
[2]Pittsburgh Orthopaedic Spine Research Group, Pittsburgh, Pa.
[3]Orland Bethel Family Musculoskeletal Research Center, Pittsburgh, Pa.

INTRODUCTION

Due to rising healthcare costs, spine surgery is under scrutiny to maximize value-based care. Formal radiographic analysis remains a potential source of unnecessary healthcare costs, especially for intra-operative radiographs.[1-3] The aim of this study was to evaluate the clinical relevance, usefulness, and financial implications of intraoperative radiograph interpretation by radiologists in spine surgery.

METHODS

The researchers conducted a retrospective cohort analysis on all adult elective spine surgeries at a single institution between July 2020 and July 2021. Demographic and radiographic data were collected, including intraoperative localization and post-instrumentation radiographs. Financial data were obtained through the institution's price estimator. Radiographic characteristics included time from radiographic imaging to completion of radiologist interpretation report, completion of radiologist interpretation report prior to the conclusion of surgical procedure, clinical relevance, and clinical usefulness. Reports were considered clinically relevant if spinal level of the procedure was described and clinically useful if completed prior to conclusion of the procedure and deemed clinically relevant.

RESULTS

The study found that 481 intraoperative localization and post-instrumentation radiographs from 360 patients revealed a median delay of 128 minutes between imaging and completion of interpretive report. Only 38.9% of reports were completed before conclusion of surgery. There were 79.4% deemed clinically relevant and only 33.5% clinically useful (see Table 1). Localization reports were completed more frequently before conclusion of surgery (67.2% versus 34.4%) but with lower clinical relevance (90.1% versus 98.5%) and clinical usefulness (60.3% versus 33.6%) than post-instrumentation reports (see Table 2). Each patient was charged \$32–\$34 for interpretation fee, cumulating a minimum total cost of \$15,392.

DISCUSSION

Given the increased cost, variable clinical relevance, and slow report-completion time, formal radiologist reads are of low clinical utility for spine surgeons in the operating room. Institutions should consider optimizing radiology workflows to improve timeliness and clinical relevance or evaluate the necessity of reflexive consultation to radiology for intraoperative imaging interpretation to ensure that value-based care is maximized during spine surgeries.

SIGNIFICANCE

Formal radiographic interpretation of intraoperative spine radiographs is of low clinical utility for spine surgeons, and institutions should consider optimizing workflows and assess necessity of reflexive radiology consultation.

REFERENCES

1. Barnett M et al. *Arch Intern Med*. 2012;172:163-70.
2. Phillip LR et al. *Global Spine J*. 2021;11:14s-22s.
3. Weber MH et al. *J Neurosurg Spine*. (2017;27:578-83.

Total Radiographs (n = 481)	
Average time to report, mean (SD), min	302.9 (700.9)
Average time to report, median (range), min	128 (10-13207)
Filed before completion of surgery, n (%)	187 (38.9)
Clinically relevant, n (%)	382 (79.4)
Clinical usefulness, n (%)	161 (33.5)
Localization Radiographs (n = 291)	
Average time to report, mean (SD), min	352.5 (866.8)
Average time to report, median (range), min	153 (10-13207)
Filed before completion of surgery, n (%)	128 (44.0)
Clinically relevant, n (%)	197 (67.7)
Clinical usefulness, n (%)	103 (35.4)
Post-Instrumentation Radiographs (n = 190)	
Average time to report, mean (SD), min	227.1 (292.0)
Average time to report, median (range), min	100.5 (10-1255)
Filed before completion of surgery, n (%)	59 (31.1)
Clinically relevant, n (%)	185 (97.4)
Clinical usefulness, n (%)	58 (30.5)

Table 1. Baseline Radiograph Characteristics

	Localization Radiograph (n = 131)	Post-Instrumentation Radiograph (n = 131)	p-value
Average time to report, mean (SD), min	165.1 (227.4)	178.3 (231.0)	p = 0.510
Filed before completion of surgery, n (%)	88 (67.2)	45 (34.4)	**p < 0.001**
Clinically relevant, n (%)	118 (90.1)	129 (98.5)	**p < 0.001**
Clinical usefulness, n (%)	79 (60.3)	44 (33.6)	**p < 0.001**

Table 2. Localization Versus Post-Instrumentation Radiographs

MODIFIED CLAVIEN-DINDO-SINK CLASSIFICATION SYSTEM FOR OPERATIVE COMPLICATIONS IN ADULT SPINE SURGERY

Ridolfi D[1,2,3], Oyekan AA[1,2,3], Tang MY[1,2,3], Chen SR[1,2,3], Como CJ[1,2,3], Dalton JF[1,2,3], Gannon EJ[2,4], Jackson II KL[5], Bible JE[6], Kowalski C[1,2], de Groot SJ[1,2,3], Donaldson III WF[1,2,3], Lee JY[1,2,3], Shaw JD[1,2,3]

[1] Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.
[2]Pittsburgh Orthopaedic Spine Research Group, Pittsburgh, Pa.
[3]Orland Bethel Family Musculoskeletal Research Center, Pittsburgh, Pa.
[4]Department of Orthopaedic Surgery, University of Nebraska Medical Center, Omaha, Neb.
[5] Department of Orthopaedic Surgery, U.S. Army, Augusta, Ga.
[6]Department of Orthopaedic Surgery, Penn State Hershey Medical Center, Hershey, Pa.

INTRODUCTION

Complications are an inevitable aspect of spine surgery, and the lack of a validated complication grading system has hindered our ability to facilitate comparison of complications.[1] The Clavien-Dindo-Sink Classification System was designed to standardize complication reporting.[2] The system has been validated in general orthopaedics but has not yet been adapted for use in spine surgery. Thus, the purpose of the present study was to modify and validate the Clavien-Dindo-Sink Classification System for applications in spine surgery.

METHODS

The Clavien-Dindo-Sink Complication System was evaluated and modified for spine surgery using a consensus process by four fellowship-trained spine surgeons. A distinct group of three fellowship-trained spine surgeons completed a randomized electronic survey grading 71 real clinical case scenarios. The survey was repeated two weeks after initial completion. Fleiss' and Cohen's kappa (k) statistics were used to evaluate inter-rater and intra-rater reliabilities, respectively.

RESULTS

Overall, inter-observer reliability during the first round and second rounds of grading was excellent, with a kappa of 0.847 (confidence interval [CI]: 0.785–0.908) and 0.852 (CI: 0.791–0.913), respectively. In round one, inter-rater reliability ranged from good to excellent, with k for grade I of 0.778 (CI: 0.644–0.912), grade II of 0.698 (CI: 0.564–0.832), grade III of 0.861 (CI: 0.727–0.996), grade IV-A of 0.845 (CI: 0.711–0.979), grade IV-B of 0.962 (CI: 0.828–1.097), & grade V of 0.960 (CI: 0.826–1.094). Similar reliabilities were seen in round two. Intra-observer reliability testing for all three independent observers was excellent, with k of 0.971 (CI: 0.944–0.999) for rater one, 0.963 (CI: 0.926–1.001) for rater two, and 0.926 (CI: 0.869–0.982) for rater three.

DISCUSSION

The modified Clavien-Dindo-Sink Classification System demonstrated excellent inter-rater and intra-rater reliability in adult spine surgery cases. Grade I exhibited good agreement; Grade II exhibited moderate to good agreement; and Grades III, IV-A, IV-B, and V exhibited excellent agreement.

SIGNIFICANCE

The modified Clavien-Dindo-Sink Classification System provides a reliable and objective method to communicate the severity of spine-related complications and is most reliable in stratifying more serious complications.

REFERENCES

1. Bortz et al. *Clin Spine Surg*. 2019;32(6):263-8.
2. Sink et al. *Clin Orthop Relat Res*. 2012;470(8):2220-6.

Grade	Definition	Examples
Grade I	A complication that does not result in deviation from routine follow-up in the postoperative period and has minimal clinical relevance and requires minimal treatment (e.g., antiemetics, antipyretics, analgesics, diuretics, electrolytes, antibiotics, and physiotherapy) or no treatment.	Postoperative fever; Nausea; Constipation; Uncomplicated UTI; Wound issue not requiring a change in postoperative care; **Transient dysphagia, hoarseness, or dysphonia; Transient weakness of an extremity; Disorientation or confusion; Pain at bone graft donor site and sequelae.**
Grade II	A deviation from the normal postoperative course (including unplanned clinic/office visits) that requires outpatient treatment, either pharmacological or close monitoring as an outpatient.	**Durotomy, with or without bedrest, not requiring subsequent procedures;** Superficial wound infection; Transient neurapraxia due to positioning or surgical retraction that resolves under close observation; Nerve palsy requiring close observation and/or bracing **(e.g., C5 palsy); Medical complication that resolves but requires minor intervention (e.g.,** DVT/PE treated with anticoagulation, **pneumonia treated with antibiotics, ileus not requiring NG tube, complex UTI); Proximal junctional kyphosis (PJK); Dysphagia, hoarseness, dysphonia requiring ENT scope or laryngeal EMG but without intervention.**
Grade III	A complication that is treatable but requires an invasive procedure such as additional surgery, interventional radiology procedure(s), or unplanned hospital readmission.	**Durotomy, requiring subsequent procedures;** Deep infection, requiring treatment with IV antibiotics **or I&D procedure**; Postoperative hematoma or **seroma**, requiring I&D procedure; **Hardware malposition requiring surgical intervention; Proximal junctional failure; Dysphagia, hoarseness, or dysphonia, requiring ENT intervention (e.g., vocal fold augmentation, NG tube, etc.); Medical complication requiring invasive procedure (e.g., pulmonary embolus requiring embolectomy); Ileus requiring readmission and/or a GI procedure.**
Grade IV-A	A complication that is life-threatening and/or requires ICU admission, a complication with potential for permanent disability but treatable, a complication that may require organ resection/replacement. No long-term disability.	**Neurological (Transient paralysis or paresis,** Permanent nerve injury treatable with tendon transfers, TIA, **Meningitis [without permanent cognitive dysfunction], or Sensory nerve dysfunction); Respiratory (Pulmonary embolus requiring ICU admission with full recovery or Mechanical ventilation >48 hours); Renal** (Kidney failure requiring temporary dialysis); **Cardiovascular (Cardiac arrest, Myocardial infarction, or Major vascular injury); Gastrointestinal (Ileus requiring prolonged hospital stay); Systemic sepsis;** No long-term disability.
Grade IV-B	A complication that is life-threatening and/or requires ICU admission, a complication that is not treatable, a complication that requires organ resection or salvage surgery. With long-term disability.	**Iatrogenic paralysis; Permanent irreparable nerve injury (e.g., not treatable with transfer);** Major vascular injury; **Central Nervous System (**Stroke or **Meningitis [with permanent cognitive dysfunction]); Spinal cord injury (Peripheral Nervous System or Motor nerve dysfunction** [e.g., permanent foot drop]); **Respiratory (ARDS); Renal** (Kidney failure requiring permanent dialysis); **Cardiovascular (Cardiac arrest or Myocardial infarction);** With long-term disability.
Grade V	Death	

Legend: Six grades for the modified Clavien-Dindo complication system are presented on left with definitions for the grades. To the right are case examples with consensus adaptions highlighted in bold. If more than one grade was applicable to the complication, only the highest applicable grade is considered—e.g., uncomplicated UTI (Grade I) + infection I&D (Grade III) = Grade III. Note that grading strictly applies to the treatment required to manage a complication in the postoperative period (e.g., durotomy intra-op repair without postoperative sequelae would be considered a Grade I complication, but a durotomy intra-op repair which leads to infection requiring irrigation and debridement without ICU admission is a grade III complication).

Table 1. Modified Clavien-Dindo-Sink Grading System for Spine Operative Complications

	Kappa (k)	Lower Bound 95% CI	Upper Bound 95% CI
Inter-Rater Reliability – Rating #1			
Overall	**0.847**	**0.785**	**0.908**
Grade I	0.778	0.644	0.912
Grade II	0.698	0.564	0.832
Grade III	0.861	0.727	0.996
Grade IV-A	0.845	0.711	0.979
Grade IV-B	0.962	0.828	1.097
Grade V	0.960	0.826	1.094
Inter-Rater Reliability – Rating #2			
Overall	**0.852**	**0.791**	**0.913**
Grade I	0.746	0.612	0.881
Grade II	0.595	0.461	0.730
Grade III	0.945	0.810	1.079
Grade IV-A	0.922	0.788	1.057
Grade IV-B	0.962	0.828	1.097
Grade V	0.960	0.826	1.094

Legend: CI = Confidence Interval; Grade I-V = Grade on Modified Spine Clavien-Dindo-Spine Classification System; Overall = Summative value for Grade I-V classifications corresponding to sub-headers. Fleiss' Kappa coefficients for the Modified Spine Clavien-Dindo System are presented with bounds of 95% confidence intervals for given sub-headers: 1) Inter-Rater Reliability – Rating #1 and 2) Inter-Rater Reliability – Rating #2. P-value significance was set to <0.05.

Table 2. Inter-Observer Reliability–Fleiss Kappa for Modified Spine Clavien-Dindo-Sink Grading System

DIVISION OF SPORTS MEDICINE

Volker Musahl, MD
Chief

Albert Lin, MD
Associate Chief

The 2023 academic year was very successful for the Division of Sports Medicine at UPMC. We have improved access for patients at the UPMC Rooney Sports Complex (UPMC Freddie Fu Sports Medicine Center) and UPMC Lemieux Sports Complex. Our surgical services are provided with community outreach in mind. And our diverse group of sports medicine fellows are absolutely outstanding, as they excel both academically and clinically. Every year, our report says the same with respect to research output, because it is true: "In research, we have had the busiest year, including many large-scale randomized, controlled, multicenter studies, as well as national and international collaborations." We are top 10 among sports medicine fellowships! We are No. 1 in anterior cruciate ligament (ACL) research worldwide!

In June, we will host once again the Panther Sports Medicine Symposium. Many thanks to the outstanding organizing committee, with James Irrgang, PT, PhD, Jonathan Hughes, MD, PhD, Bryson Lesniak, MD, and Stephen Rabuck, MD, on the program side and Andrea Badway, Barbara Moore, Lisa Arrisher-Brown, Amber Kramer, and Amy Gee on the organizational side. More than 60 faculty from around the world have committed to the meeting, and we expect more than 100 attendees. The conference will feature a "who's who" in knee surgery and will cover topics from ACL reconstruction and multi-ligament knee injury to meniscus, cartilage, and knee preservation with a focus on knee osteotomy. We will have a sports rehabilitation specialty day. Many of our industry partners will also be present, and new technologies will be highlighted to help improve outcomes for patients. A special ceremony will take place in dedication to our mentor and friend Dr. Freddie Fu!

Volker Musahl, MD, was named consultant on the Executive Committee of the International Society of Arthroscopy, Knee Surgery, and Orthopaedic Sports Medicine (ISAKOS), and he is also first vice president of the ACL study group. Dr. Musahl was an invited guest speaker in Castrocaro, Italy, with Professor Giuseppe Porcellini and Professor Fabio Catani. He Musahl moderated a very well-attended knee osteotomy instructional course lecture at the American Academy of Orthopaedic Surgeons (AAOS) annual meeting in San Francisco this year, with faculty Michael Alaia, MD, of New York University; David Dejour of Lyon, France; and Stefano Zaffagnini of Bologna, Italy. For the third year running, we held a surgical master course with the residents at Rizzoli Institute in Bologna. Professor Zaffagnini performed several complex knee surgeries, and Dr. Musahl delivered an invited guest lecture both at Rizzoli and Isokinetic.

Albert Lin, MD, was promoted to full professor and became a founding and board member of the Rotator Cuff Study Group, which held its international inaugural meeting in Gubbio, Italy. Dr. Lin received several awards, including the Excellence in Research Award and Fellow Research Award in Clinical Science (Ting Cong, mentee) from the American Orthopaedic Society for Sports Medicine (AOSSM); the Hawkins Award from the American Shoulder and Elbow Surgeons; and the Phillip Troen, MD, Excellence in Medical Student Research Mentoring Award and the Medical Student Research Mentoring Award at the University of Pittsburgh Medical School. He also was recently named associate editor of the *Journal of Bone and Joint Surgery* Case Connector and editor-in-chief of *Annals in Joint*, a journal founded by Dr. Fu. Dr. Lin also gave invited guest lectures at the University of Vermont as a grand-rounds speaker and at the New England Shoulder and Elbow Society and Miami Orthopaedic Society, and he recently performed a live cadaveric surgical demonstration with Andreas Imhoff of Munich, Germany, for the World Surgery Tour 2024 held in Cologne, Germany.

Dr. Hughes became associate member of the ACL Study Group and together with Enes Kayaalp won the prestigious AOSSM Young Investigator Award. He also won the Excellence in Research Award from the Arthroscopy Association of North America and was named associate editor of *Knee Surgery, Sports Traumatology, Arthroscopy*. In May 2024, Dr. Hughes successfully defended his PhD thesis at the prestigious Sahlgrenska Academy in Gothenburg, Sweden, titled "Relationship of Surgical Technique and Bony Morphology on ACL Reconstruction Failure." Congratulations!

Dr. Lesniak won the Richard J. O'Connor, MD, Research Award. Dr. Rabuck is a principal reviewer of the *American Journal of Sports Medicine*.

Many of our international academic collaborations have led to fantastic research projects, promotions of young clinician-scientists, and most of all improvements in outcomes for patients. The UPMC Sports Surgery Clinic in Dublin, Ireland, was successfully onboarded to our international, multicenter, randomized, controlled trial STABILITY II. When concluded, this trial will have studied more than 1,200 young athletes and will help reduce the high rate of second ACL injury. The first patients were already randomized in Dublin—thank you Brian Devitt, PhD! UPMC International is also continuing its growth in Rome at UPMC Salvator Mundi International Hospital. The successful enterprise in Italy reflects not only clinical growth in providing orthopaedic care for patients in Rome and around Europe but also strong academic growth with collaborations with Professor Fabrizio Margheritini, University of Rome "Foro Italico," and Professor Gianluca Camillieri, Tor Vergarta University.

The collaboration with Sahlgrenska Academy in Gothenburg, Sweden, has been continuing to grow, leading to well more than 100 peer-reviewed publications thus far and many interesting future projects. The collaboration was started more than 12 years ago with Professor Jon Karlsson and Dr. Fu. Our current research fellow and PhD student is Janina Kaarre. Many excellent students have come to visit Pittsburgh and study with the Department of Orthopaedic Surgery.

This year, we also had wonderful and scientifically powerful exchanges with Kobe University (Chair Professor Ryosuke Kuroda) with fellows Tetsuya Yamamoto and Koji Nokuto; Nagoya University (Chair Professor Hideki Murakami) with fellow Jumpei Ionue; Nihon University (Chair Professor Kazuyoshi Nakanishi) with fellow Yoshiyuki Yahagi; the Pitt–European Society of Sports Traumatology, Knee Surgery, and Arthroscopy fellowship (President Professor Roland Becker) with fellows Enes Kayaalp (Istanbul, Turkey) and Efstathios Konstantinou (Larissa, Greece); Technische University Munich (Chair Professor Sebastian Siebenlist) with fellows Armin Runer, Svenja Hoeger, and Anja Wackerle; Isokinetic in Bologna, Italy (Professors Stefano Della Villa and Francesco Della Villa) with fellow Marco Vecchia; and Sao Paulo Catolica University (Professor Julio Gali) with fellow Camila Grandberg.

In research, we continue to lead the field, with 200 peer-reviewed publications published by our sports medicine faculty in 2023. Our faculty were involved in in-person instructional courses for the AAOS, American Orthopaedic Society for Sports Medicine, Arthroscopy Association of North America, American Shoulder and Elbow Surgeons, San Diego Shoulder Institute, and ISAKOS. The 2023 ISAKOS Congress in Boston was a huge success for our division, with numerous talks, posters, symposia, and courses given. Our faculty also delivered grand rounds, guest lectures, and webinars, in addition to many local, national, and international presentations, and they received rewards. We continue to serve in leadership positions in major societies. The annual Freddie Fu Visiting Professor was Professor Matthieu Ollivier from Marseille, France, who delivered an outstanding lecture on osteotomies around the knee.

The STaR (Surgical Timing and Rehabilitation) Trial for Multiple Ligament Knee Injuries is a 28-site, Department of Defense–funded clinical trial investigating how the timing of surgery and rehabilitation after a multiple-ligament knee injury affects a person's ability to successfully return to a preinjury level of activity. Pitt is the primary awardee of a $4.4 million grant from the Department of Defense to conduct two parallel, multicenter, randomized clinical trials to investigate the effects of timing of surgery (early versus delayed) and timing of postoperative rehabilitation (early versus delayed) for the treatment of multiple-ligament knee injuries. Overall, 28 military and civilian sites across the United States and Canada are enrolling participants (University of Pittsburgh, Duke University, Hospital for Special Surgery, Louisiana State University, Mayo Clinic, NYU Langone, Ochsner Health, Oregon Health and Science University, OrthoCarolina, Rhode Island Hospital, San Antonio Military Medical Center, St. Michael's Hospital, TRIA Orthopaedic, University of Calgary, University of Cincinnati, University of Kentucky, University of Maryland, University of Michigan, University of Minnesota, University of Missouri, University of New Mexico, University of Washington, Wake Forest University, Walter Reed National Military Medical Center, Washinton University in St. Louis, University of Western Ontario, William Beaumont, Yale University). As of March 2024, we have randomized more than 450 participants in the study.

The POETT (Predicting the Outcome of Exercise Therapy for Treatment of Rotator Cuff Tears) Trial is a National Institutes of Health (NIH)-funded trial collecting two-year clinical outcome data, and enrolment was successfully completed in February 2022 (n = 113). The long-term goal of this research is the development of individualized nonsurgical treatment plans for improving outcomes and establishing predictors of failure for nonoperative treatment. The findings from the study are being published in peer-reviewed journals.

The Stability II Trial is a collaboration between the University of Pittsburgh (co-principal investigators [PIs] Dr. Irrgang and Musahl) and Western University, London, Ontario (co-PIs Dianne Bryant, PhD, and Alan Getgood, MD), which has been awarded a $3.2 million grant from the NIH to conduct a prospective, randomized, international, multicenter clinical trial to determine whether the use of the quadriceps tendon versus patellar tendon, either with or without lateral extra-articular tenodesis, reduces the risk of reinjury of the ACL. This study includes 30 sites across the United States, Canada, and Europe (University of Pittsburgh, University of Western Ontario/ Fowler Kennedy Sport Medicine Clinic, Aarhus University Hospital, Banff Sport Medicine Clinic, Cologne-Merheim Medical Center, Dublin City University [UPMC Sports Surgery Clinic], Fraser Health Authority [UBC], Hospital for Special Surgery, Mayo Clinic, Med Center Health [Bowling Green], McMaster University, North Bristol Trust, Nova Scotia Health Authority/Dalhousie, Ochsner Clinic Foundation, Oslo University Hospital, Pan Am Clinic, Stanford University, St. Michael's Hospital, Stockholm South Hospital, University Hospital Coventry and Warwickshire NHS Trust, University Klinik Münster, University of Calgary, University of California, San Francisco, University of Kentucky, University of Michigan, University of Minnesota, University of New Mexico, University of Ottawa, University of Virginia, Wake Forest University School of Medicine). As of March 2024, almost 900 participants have been randomized.

The OASIS (Open Versus Arthroscopic Stabilization of Shoulder Instability with Subcritical Bone Loss) Trial is a collaboration between Pitt (PI Adam Popchak, PT, PhD; co-investigators Dr. Lin, Dr. Lesniak, Dr. Musahl, Dr. Hughes, Dr. Irrgang Charity Patterson, PhD, and Alexandra Gil, PT, PhD) and Duke University (PI Jon Dickens, MD). This is a $2 million multicenter, prospective, observational cohort study (formerly randomized) involving civilian and military sites funded by the Department of Defense. The goal of the study is to determine the optimal surgical treatment for anterior instability patients with subcritical bone loss (10%–20% glenoid bone loss) who undergo arthroscopic Bankart repair with or without remplissage versus open Bankart versus Latarjet reconstruction. Overall, there are eight recruiting sites across the Unites States (University of Pittsburgh, Duke University, Rhode Island Hospital/Lifespan, University of Connecticut, University of North Carolina at Chapel Hill, Wake Forest University, Steadman Clinic, and Ohio State University Wexner Medical Center). An additional eight U.S. sites are in the process of joining the study (Walter Reed National Military Medical Center, Evans Army Community Hospital, Naval Medical Center San Diego, U.S. Naval Academy, San Antonio Military Medical Center, Naval Medical Center Camp Lejeune, Vanderbilt University, and Mayo Clinic–Scottsdale).

Our current fellows are doing an excellent job, and each of our fellows has successfully committed to a job for next year: Nicholas Apseloff, MD, Ohio State University; Abigail Boduch, MD, Atlantic Orthopaedics, Maryland; Jaren LaGreca, MD, private practice in New Mexico; Ariana Lott, MD, NYU Langone Orthopedic Hospital; Stephen Marcaccio, MD, Brown University; Nahom Tecle, MD, private practice in Indianapolis. Congratulations to our fellows!

The 2022–2023 fellowship class produced numerous scholarly projects related to the knee, the shoulder, the elbow, the hip, sports medicine education, and quality improvement. The Annual Sports Medicine Fellowship Research Day was held in person on June 7, 2023, and Alexis Colvin, MD, (Pitt fellow '08) from Mount Sinai School of Medicine in New York City was the grand-rounds visiting professor and moderator. The title of her presentation was "Top 10 Pearls for the Early-Career Orthopaedic Sports Medicine Physician." Each of the six sports fellows presented on the exciting results of their yearlong projects. Liane Miller, MD, was selected as the winner for her work on the shoulder. Her presentation was titled "Poor Quality and Adequacy of Radiographic Imaging of Referral Patients in Shoulder Clinic."

The fellowship program again matched six outstanding candidates for the 2024–2025 fellowship year: Marsalis Brown from Case Western University, Tyler Hauer from University of Toronto, Matthew Kolevar from University of Maryland, Amalie Nash from Emory University, Elise Raney from University of Wisconsin, and Michael Rocca from University of Maryland.

We are pleased to provide you with this update from the Division of Sports Medicine. Please check out our website (www.upmcsportsmedicine.com) and the sports fellowship website (https://www.orthonet.pitt.edu/educationtraining/fellowships/sports-medicine) for additional information or if you would like to get more involved with our program. In the words of Dr. Fu, "Thank you, thank you, thank you!" to all who have come before us, those who are currently with us, and those we will be fortunate to work with in the future. We are looking forward to another productive and exciting academic year in the Division of Sports Medicine. Please continue to stay healthy and safe!

HIGHER ODDS OF MENISCECTOMY COMPARED TO MENISCUS REPAIR IN YOUNG PATIENT POPULATION WITH INCREASED NEIGHBORHOOD DISADVANTAGE

Dadoo S[1], Keeling LE[1], Engler ID[1,2], Chang AY[1], Runer A[1,3], Kaarre J[1,4], Irrgang JJ[5], Hughes JD[1], Musahl V[1,4]

[1]UPMC Freddie Fu Sports Medicine Center, Department of Orthopaedic Surgery, University of Pittsburgh Medical Center, Pittsburgh, Pa.
[2]Central Maine Healthcare Orthopaedics, Central Maine Medical Center, Auburn, Maine
[3]Department of Sports Orthopaedics, Klinikum rechts der Isar, Technical University of Munich, Munich, Germany
[4]Department of Orthopaedics, Institute of Clinical Sciences, Sahlgrenska Academy, University of Gothenburg, Gothenburg, Sweden
[5]Department of Physiotherapy, School of Health and Rehabilitation Sciences, University of Pittsburgh, Pittsburgh, Pa.

OBJECTIVES

The objectives of this study were to investigate the impact of demographic and socioeconomic factors on the management of isolated meniscus tears in young patients and to identify trends in surgical management of isolated meniscus tears, both overall and based on surgeon volume.

METHODS

The researchers analyzed data from a large healthcare system on patients aged 14–44 years who underwent surgical management for isolated meniscus tears from 2016–2022. They recorded patient demographics and socioeconomic factors, as well as surgeon volume. For analysis, patient age was categorized as 14–29 years and ≥ 30 years old. Patient area deprivation index (ADI), a measure of neighborhood disadvantage, with higher ADI corresponding to more disadvantage, was subdivided into quartiles and grouped as < 25th, 25–75th, and > 75th percentile. Comparisons were made between surgeon and procedure groups, and binary logistic regression was used to identify factors associated with receiving meniscectomy instead of meniscus repair.

RESULTS

The study included 1,552 patients (mean age = 31.2 years, standard deviation [SD] = 9.7 years, 29.6% female) treated by 84 orthopaedic surgeons. Of those, 77.8% underwent meniscectomy and 22.2% received meniscus repair. Patients of older age and with nonprivate insurance were more likely to undergo treatment by a lower-volume versus higher-volume knee surgeon. Age 30–44 years old (odds ratio [OR]: 3.82, 95% confidence interval [CI]: 2.94–4.96, $p < 0.001$), ADI 25th–75th percentile (OR: 1.57, 95% CI: 1.16–2.11, $p = 0.003$), and ADI > 75th percentile (OR: 1.48, 95% CI: 1.04–2.10, $p = 0.028$) were associated with increased odds of undergoing meniscectomy versus meniscus repair. Higher-volume knee surgeons performed significantly higher rates of meniscus repair compared to lower-volume knee surgeons, up to the year 2022. When the researchers controlled for surgeon volume, higher ADI remained a significant predictor of meniscectomy versus meniscus repair.

CONCLUSION

This study revealed significant associations between patient demographics, socioeconomic factors, and surgical choices for isolated meniscus tears in younger patients. Patients of older age and with increased neighborhood disadvantage were more likely to undergo meniscectomy versus meniscus repair. Although higher-volume knee surgeons favored meniscus repair, meniscus repair rates trended upward among lower-volume knee surgeons in more recent years.

LATERAL EXTRA-ARTICULAR TENODESIS IS MORE COST-EFFECTIVE THAN ANTEROLATERAL LIGAMENT RECONSTRUCTION: A SYSTEMATIC REVIEW AND ECONOMIC ANALYSIS

Giusto JD[1], Cohen D[2], Dadoo S[1], Grandberg C[1], Lott A[1], Hughes JD[1], Ayeni OR[2], Musahl V[1]

[1]Department of Orthopaedic Surgery, Freddie Fu Sports Medicine Center, University of Pittsburgh, Pittsburgh, Pa.
[2]Division of Orthopaedic Surgery, McMaster University, Hamilton, Ontario, Canada

INTRODUCTION

Anterolateral augmentation during primary anterior cruciate ligament (ACL) reconstruction (ACLR) may lower the risk of ACL graft failure. However, differences in costs between two common techniques, lateral extra-articular tenodesis (LET) and anterolateral ligament reconstruction (ALLR), are unclear. The purpose of this study was to perform a systematic review and subsequent cost-effectiveness analysis comparing LET versus ALLR in the setting of primary ACLR. The hypothesis was that anterolateral augmentation with LET is more cost-effective than ALLR.

METHODS

A systematic review was conducted on all studies in which patients underwent primary ACLR with a concomitant LET or ALLR with minimum 24 months' follow-up published between January 2013 and July 2023. Primary outcomes included ACL graft failure rates and Knee Injury and Osteoarthritis Outcome Survey-Quality of Life (KOOS-QoL) subscale scores, which were used to determine health utilities measured by quality-adjusted life years (QALYs) gained. A decision tree model with one-way and two-way sensitivity analyses compared the cost of primary ACLR with concomitant LET, autograft ALLR, or allograft ALLR. The researchers estimated costs and compared them with QALYs gained using a combination of institution prices, literature references, and a survey sent to 49 internationally recognized high-volume knee surgeons regarding operative times.

RESULTS

A total of 2,505 knees undergoing primary ACLR with concomitant LET (n = 1,162) or ALLR (n = 1,343) were identified from 22 studies. There were 77 total ACL graft failures, with comparable failure rates between patients receiving LET versus ALLR (2.9% versus 3.2%, $p = 0.690$). The average QALYs gained were slightly higher for those who received LET (0.77) compared to ALLR (0.75). Survey results revealed a five-minute longer median self-reported operative time for ALLR (20 minutes) than LET (15 minutes). The estimated costs for LET, autograft ALLR, and allograft ALLR were $1,015, $1,295, and $3,068, respectively.

DISCUSSION

Anterolateral augmentation during primary ACLR with LET is more cost-effective than both autograft and allograft ALLR given the lower costs and comparable clinical outcomes. Surgeons may utilize this information when determining the optimal approach to anterolateral augmentation during primary ACLR.

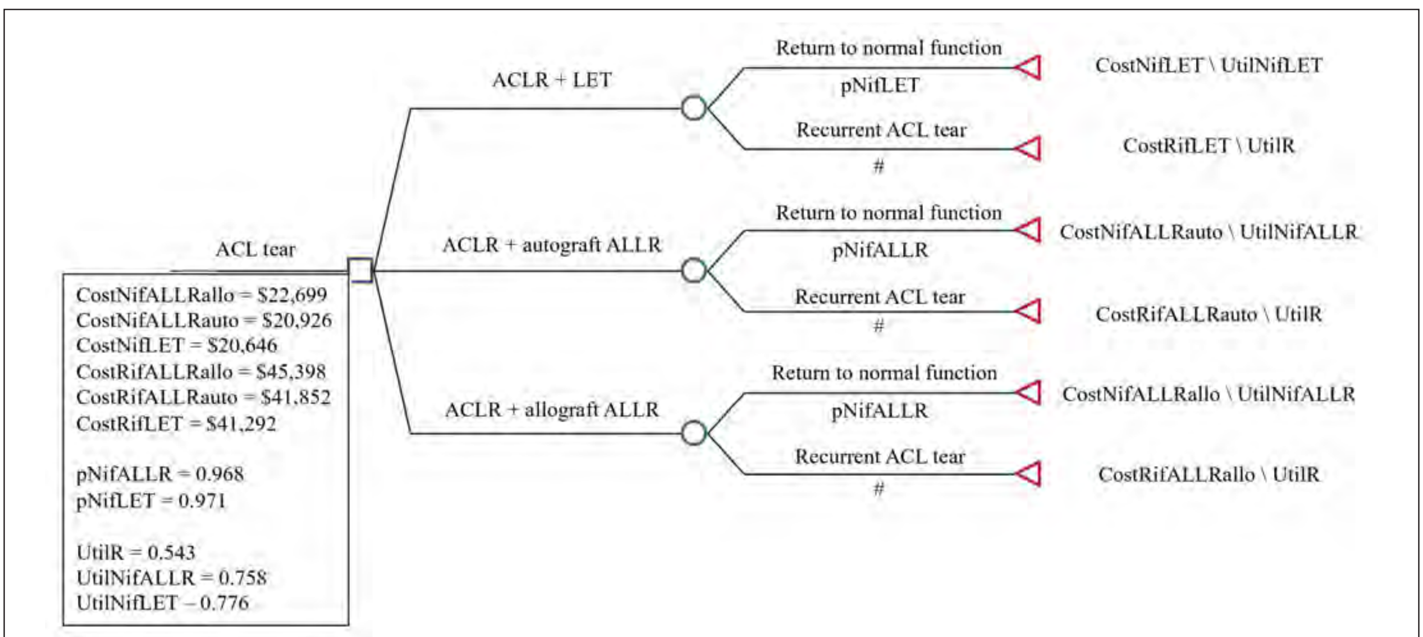


Figure 1. Decision Tree Model
Anterior cruciate ligament reconstruction (ACLR), lateral extra-articular tenodesis (LET), anterolateral ligament (ALL), autograft (auto), allograft (allo), probability of ACL graft failure (p), health utility in average quality adjusted life years gained (Util), no subsequent ACL graft failure (N), subsequent ACL graft failure (R)

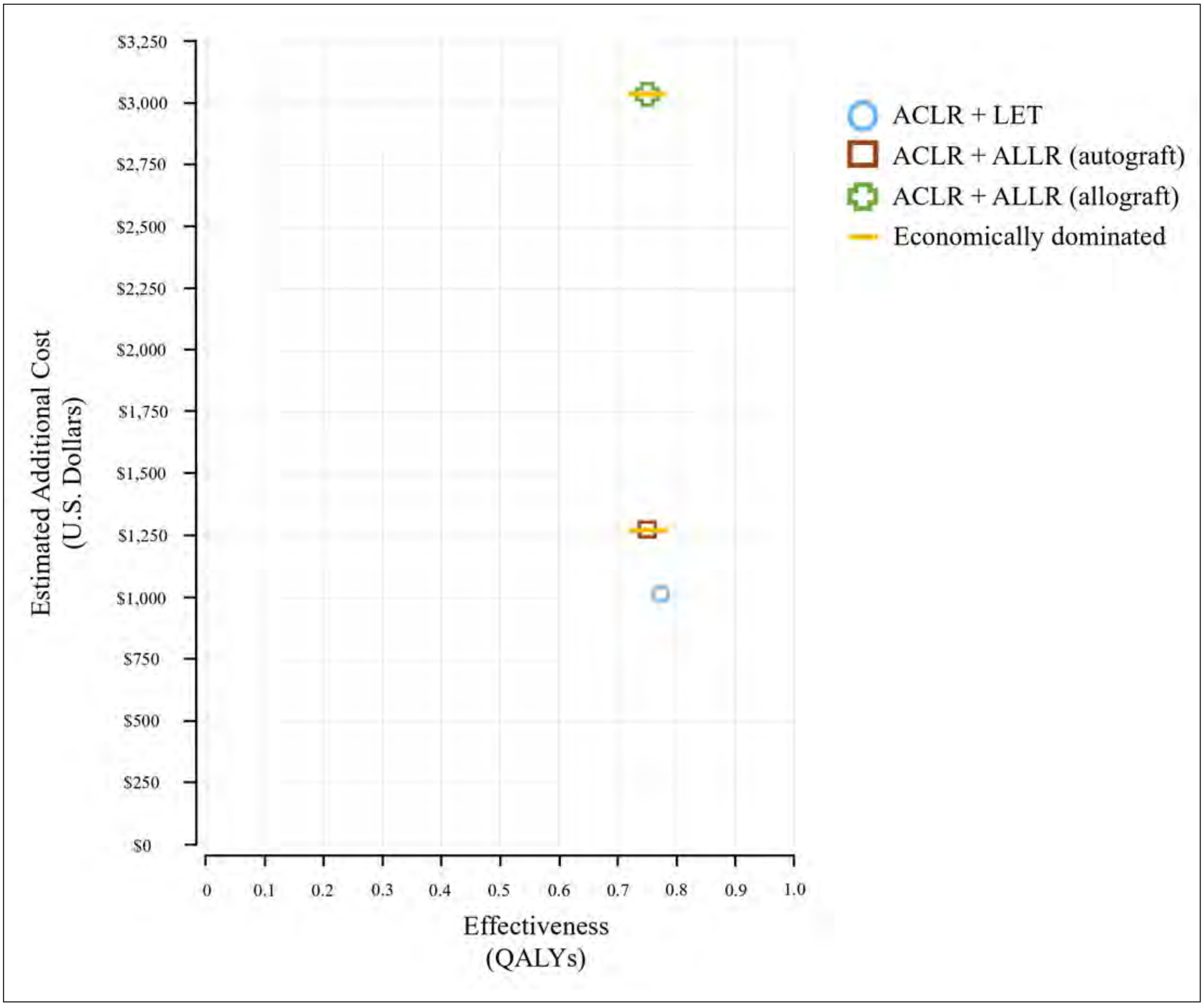


Figure 2: Cost-Effectiveness Analysis
Anterior cruciate ligament reconstruction (ACLR), lateral extra-articular tenodesis (LET), anterolateral ligament reconstruction (ALLR), quality-adjusted life years (QALYs). Data points labeled "dominated" indicate both higher costs and less effectiveness measured by health utiity as compared with ACLR with LET.

LOW REVISION RATE FOLLOWING ARTHROSCOPIC MANAGEMENT OF SHOULDER INSTABILITY IN DIVISION 1 COLLEGIATE AMERICAN FOOTBALL

Grandberg C[1], Engler ID[2], Benvegnu NA[1], Janina Kaarre J[1,3], Popchak AJ[1], Godshaw BM[4], Hughes JD[1], Musahl V[1,3]

[1]Department of Orthopaedic Surgery, UPMC Freddie Fu Sports Medicine Center, University of Pittsburgh Medical Center, Pittsburgh, Pa.
[2]Orthopedic Institute of Central Maine, Central Maine Medical Center, Auburn, Maine
[3]Department of Orthopaedics, Institute of Clinical Sciences, Sahlgrenska Academy, University of Gothenburg, Gothenburg, Sweden
[4]Ochsner Sports Medicine Institute, New Orleans, La.

PURPOSE
The purpose of this study was to perform a descriptive analysis of a cohort of Division 1 collegiate American football players after surgical management of shoulder instability.

METHODS
The study included Division 1 collegiate American football players undergoing surgical management of shoulder instability between 2017 and 2021 at a single institution. Demographics, imaging, surgical details, and postoperative outcomes, including revision surgery and Western Ontario Shoulder Instability Index (WOSI), were collected. Hill-Sachs lesions and glenoid bone loss were evaluated on magnetic resonance imaging. Categorical and continuous variables were analyzed with binary logistic regression and linear regression models, respectively, and Mann-Whitney U test or Kruskal-Wallis test was used for non-normally distributed variables.

RESULTS
The study included 17 shoulders of 16 male athletes, with mean age of 19.8 ± 1.1 years and mean follow-up of 1.9 ± 0.9 years. Twelve injuries were subluxations, and five were dislocations. Seven cases were posterior injuries, four were anterior, and six included anterior and posterior injuries. All patients underwent arthroscopic labrum repair, and two shoulders (11.8%) underwent concomitant open Bankart repair. A mean of 6.2 anchors were used in each shoulder, with anchors being placed in at least two quadrants. Hill-Sachs lesions were seen in seven shoulders (41.2%). Fourteen shoulders had no glenoid bone loss, one had < 15%, and two had > 15% glenoid bone loss. Two shoulders required revision surgery. Significant differences were found in postoperative WOSI scores between patients with and without recurrent instability (67.0% ± 11.5 versus 94.0% ± 5.3, $p = 0.02$) and between patients with and without Hill-Sachs lesions (84.1% ± 13.5 versus 94.5% ± 5.8, $p = 0.03$). Fifteen patients (93.8%) returned to play (RTP).

CONCLUSION
In Division 1 collegiate American football players with shoulder instability, low revision and high RTP rates were found despite no use of Remplissage and a low number of open Bankart repairs. These findings may be related to a large number and coverage of suture anchors. Concomitant Hill-Sachs lesions and recurrent shoulder instability yielded inferior outcomes.

"REAL WORLD" CLINICAL IMPLEMENTATION OF BLOOD FLOW RESTRICTION THERAPY DOES NOT INCREASE QUADRICEPS STRENGTH AFTER QUADRICEPS TENDON AUTOGRAFT ACL RECONSTRUCTION

Herman ZJ[1], Greiner JJ[2], Kaarre J[1,3], Drain NP[1], Hughes JD[1], Lesniak BP[1], Irrgang JJ[1,4], Musahl V[1]

[1]Department of Orthopaedic Surgery, UPMC Freddie Fu Sports Medicine Center, University of Pittsburgh Medical Center, Pittsburgh, Pa.
[2]University of Nebraska Medical Center, Omaha, Neb.
[3]Department of Orthopaedics, Institute of Clinical Sciences, Sahlgrenska Academy University of Gothenburg, Gothenburg, Sweden
[4]Department of Physical Therapy, School of Health and Rehabilitation Sciences, University of Pittsburgh, Pittsburgh, Pa.

PURPOSE
The purpose of this study was to retrospectively compare strength outcomes of individuals undergoing postoperative rehabilitation following quadriceps tendon (QT) autograft anterior cruciate ligament reconstruction (ACLR) with and without blood flow restriction therapy.

METHODS
The researchers conducted a retrospective review of consecutive patients undergoing ACLR with QT autograft with a minimum of two quantitative postoperative isometric strength assessments via an electromechanical dynamometer (Biodex). The researchers then compared demographics, surgical variables, and strength measurement outcomes between patients who had blood flow restriction therapy as part of postoperative rehabilitation versus those who did not.

RESULTS
Eighty-one patients met the inclusion criteria. No differences were found in demographic or surgical characteristics between those who received blood flow restriction compared to those who did not. Although both groups had improvements in quadriceps peak torque and limb symmetry index (LSI, defined as peak torque of the operative limb divided by the peak torque of the nonoperative limb [PKQT]) over the study period, the blood flow restriction group had significantly lower mean peak torque of the operative limb at first Biodex strength measurement (95.6 Nm versus 111.2 Nm, $p = 0.03$). Additionally, the blood flow restriction group had a significantly lower mean LSI than those with no blood flow restriction at the second Biodex measurement timepoint (81% versus 90%, $p = 0.02$). No other significant differences were found between the strength outcomes measured.

CONCLUSION
Results of this study show that the "real world" clinical implementation of blood flow restriction therapy to the postoperative rehabilitation protocol following QT autograft ACLR did not result in an increase in absolute or longitudinal changes in quadriceps strength measurements. Better understanding and standardization of the use of blood flow restriction therapy in the rehabilitation setting are necessary to delineate the true effects of this modality on strength recovery after QT autograft ACLR.

OUTCOMES OF BONE–PATELLAR TENDON–BONE AUTOGRAFT AND QUADRICEPS TENDON AUTOGRAFT FOR ACL RECONSTRUCTION IN AN ALL-FEMALE SOCCER PLAYER COHORT WITH MEAN 4.8-YEAR FOLLOW-UP

Herman ZH[1], Benvegnu Na[1], Dadoo S[1], Chang A[2], Scherer R[2], Nazzal EM[1], Özbek EA[1,3], Kaarre J[1,4], Hughes JD[1], Lesniak BP[1], Vyas D[1]

[1]Department of Orthopaedic Surgery, UPMC Freddie Fu Sports Medicine Center, University of Pittsburgh Medical Center, Pittsburgh, Pa.
[2]University of Pittsburgh School of Medicine, Pittsburgh, Pa.
[3]Department of Orthopedics and Traumatology, Ankara University, Ankara, Turkey
[4]Department of Orthopaedics, Institute of Clinical Sciences, Sahlgrenska Academy University of Gothenburg, Gothenburg, Sweden

OBJECTIVE
The purpose of this study was to compare functional outcomes, return-to-soccer rates, and revision rates in an all-female soccer player cohort undergoing quadriceps tendon (QT) autograft anterior cruciate ligament (ACL) reconstruction (ACLR) versus bone–patellar tendon–bone (BPTB) autograft ACLR.

METHODS
Female soccer players who sustained an ACL rupture and underwent primary anatomic, single-bundle ACLR with BPTB autograft or QT autograft were included. Demographic and surgical characteristics were collected. Outcomes of interest included Tegner score, International Knee Documentation Committee (IKDC) score, Marx score, return-to-soccer rates, and failure rates.

RESULTS
Data were available on 23 patients undergoing BPTB autograft ACLR and 14 undergoing QT autograft ACLR. Average age was 18.7 years, and average follow-up was 4.8 years. Overall, 76 % (28 of 37) returned to soccer and 5.4 % (2 of 37) underwent revision ACLR. No major significant differences were found in demographic or surgical characteristics. No differences were found in postoperative IKDC scores; preoperative, postoperative, or change from pre- to postoperative Marx activity scores; or pre- and postoperative Tegner scores between the groups. QT autograft ACLR patients had significantly less change in Tegner scores pre- to postoperatively compared to the BTPB autograft ACLR group (0.6 ± 1.2 versus 2.1 ± 1.8, $p = 0.02$). Both groups had similar rates of return to soccer (78 % [18 of 23] BPTB autograft ACLR versus 71 % [10 of 14] QT autograft ACLR, $p = 0.64$) and rates of revision (8.7 % [2 of 23] BPTB autograft ACLR; 0 % [0/14] QT autograft ACLR).

CONCLUSION
Results of this study suggest that BPTB autograft ACLR and QT autograft ACLR produce comparable, successful functional and return-to-soccer outcomes in this all-female soccer player cohort study. Larger, prospective studies are needed to improve the strength of conclusions and provide more information on the optimal graft choice for female soccer players. Surgeons can use the results of this study to counsel female soccer players on expected outcomes after ACLR.

LOWER PERCENTAGES OF PATIENTS REACH PASS FOR KNEE FUNCTION OUTCOMES AFTER REVISION ACLR COMPARED TO PRIMARY ACLR

Herman ZJ[1], Kaarre J[1,2,3], Grassi A[4], Senorski EH[2,5], Musahl V[1], Samuelsson K[2,3,6]

[1]Department of Orthopaedic Surgery, UPMC Freddie Fu Sports Medicine Center, University of Pittsburgh Medical Center, Pittsburgh, Pa.
[2]Sahlgrenska Sports Medicine Center, Gothenburg, Sweden
[3]Department of Orthopaedics, Institute of Clinical Sciences, Sahlgrenska Academy, University of Gothenburg, Gothenburg, Sweden
[4]IIa Clinica Ortopedica e Traumatologica, IRCCS Istituto Ortopedico Rizzoli, Bologna, Italy
[5]Unit of Physiotherapy, Department of Health and Rehabilitation, Institute of Neuroscience and Physiology, Sahlgrenska Academy, University of Gothenburg, Gothenburg, Sweden
[6]Department of Orthopaedics, Sahlgrenska University Hospital, Mölndal, Sweden

OBJECTIVES
The objectives of this study were: 1) to examine and compare the percentages of patients meeting patient acceptable symptom state PASS thresholds for Knee Injury and Osteoarthritis Outcome Score (KOOS) subscales one year postoperatively after primary anterior cruciate ligament reconstruction (ACLR) compared to revision ACLR (rACLR) and mrACLR and 2) to examine the predictors for reaching (PASS) for KOOS Quality of Life (QoL) and Function in Sport and Recreation (Sport/Rec) subscales after multiple-revision ACLR (mrACLR).

METHODS
The data utilized in this study were obtained from the Swedish National Ligament Registry and collected between 2005 and 2020. The study sample was divided into three different groups: 1) primary ACLR, 2) rACLR, and 3) mrACLR. Data on patients' demographic, injury, and surgical characteristics were obtained, as well as mean one-year postoperative scores for KOOS subscales and the percentage of patients meeting PASS for each subscale. Additionally, the predictors of reaching PASS for KOOS Sport/Rec and QoL subscales were evaluated in patients undergoing mrACLR. Alpha was set to 0.05.

RESULTS
Of the 22,928 patients included in the study, 1,144 underwent rACLR and 36 underwent mrACLR. Across all KOOS subscales, the percentage of patients meeting PASS thresholds was statistically lower for rACLR compared to primary ACLR (KOOS Symptoms 22.5% versus 32.9%, KOOS Pain 84.9% versus 92.9%, KOOS Activities of Daily Living 23.5% versus 31.4%, KOOS Sport/Rec 26.3% versus 45.6%, KOOS QoL 26.9% versus 51.4%), and percentages of patients reaching PASS thresholds for all KOOS subscales was comparable between patients undergoing rACLR versus mrACLR. No predictive factors were found to be associated with reaching PASS for KOOS QoL and KOOS Sport/Rec one year postoperatively after mrACLR.

CONCLUSION
Patients undergoing ACLR in the revision setting had lower rates of reaching acceptable symptoms states for functional knee outcomes than those undergoing primary ACLR.

OVERHEAD ATHLETES HAVE COMPARABLE INTRAOPERATIVE INJURY PATTERNS AND CLINICAL OUTCOMES TO NON-OVERHEAD ATHLETES FOLLOWING SURGICAL STABILIZATION FOR FIRST-TIME ANTERIOR SHOULDER INSTABILITY AT AVERAGE SIX-YEAR FOLLOW-UP

Herman ZJ[1], Nazzal EM[1], Engler ID[2], Kaarre J[1,3], Drain NP[1], Sebastiani R[1], Tisherman RT[1], Rai A[1], Greiner JJ[4], Hughes JD[1], Lesniak BP[1], Lin A[1]

[1]Department of Orthopaedic Surgery, University of Pittsburgh Medical Center, Pittsburgh, Pa.
[2]Central Maine Medical Center, Lewiston, Maine
[3]Department of Orthopaedics, Institute of Clinical Sciences, Sahlgrenska Academy, University of Gothenburg, Gothenburg, Sweden
[4]University of Nebraska Medical Center, Omaha, Neb.

BACKGROUND AND HYPOTHESIS

Anterior shoulder instability is a common problem affecting young, athletic populations and results in potential career-altering functional limitations. However, little is known regarding the differences in clinical outcomes after operative management of overhead versus non-overhead athletes presenting with first-time anterior shoulder instability. The authors hypothesized that overhead athletes would have milder clinical presentations, similar surgical characteristics, and diminished postoperative outcomes when compared with non-overhead athletes after surgical stabilization following first-time anterior shoulder instability episodes.

METHODS

Patients with first-time anterior shoulder instability events (subluxations and dislocations) undergoing operative management between 2013 and 2020 were included. The exclusion criteria included multiple dislocations and multidirectional shoulder instability. Baseline demographic characteristics, imaging data, examination findings, and intraoperative findings were retrospectively collected. Researchers contacted patients to collect postoperative patient-reported outcomes, including American Shoulder and Elbow Surgeons score, Western Ontario Shoulder Instability Index score, Brophy activity index score, and Subjective Shoulder Value, in addition to return-to-work and -sport, recurrent dislocation, and revision rates.

RESULTS

A total of 256 patients met the inclusion criteria, of whom 178 (70%) were non-overhead athletes. The mean age of the entire population was 23.1 years. There were no significant differences in concomitant shoulder pathology, preoperative range of motion, or preoperative strength between cohorts. A greater proportion of overhead athletes presented with instability events not requiring manual reduction (defined as subluxations; 64.1% versus 50.6%, $p < 0.001$) and underwent arthroscopic surgery (97% versus 76%, $p < 0.001$) compared with non-overhead athletes. A smaller proportion of overhead athletes underwent open soft-tissue stabilization compared with non-overhead athletes (1% versus 19%, $p < 0.001$). Outcome data were available for 60 patients, with an average follow-up period of 6.7 years. No significant differences were found between groups with respect to recurrent postoperative instability event rate (13.0% for overhead athletes versus 16.8% for non-overhead athletes), revision rate (13.0% for overhead athletes versus 11.1% for non-overhead athletes), American Shoulder and Elbow Surgeons score, Western Ontario Shoulder Instability Index score, Brophy score, Subjective Shoulder Value, or rates of return to work or sport.

CONCLUSION

Overhead athletes who underwent surgery after an initial instability event were more likely to present with subluxations compared with non-overhead athletes. With limited follow-up subject to biases, this study found no differences in recurrence or revision rates, postoperative patient-reported outcomes, or return-to-work or -sport rates between overhead and non-overhead athletes undergoing shoulder stabilization surgery following first-time instability events. Although larger prospective studies are necessary to draw firmer conclusions, the findings of this study suggest that overhead athletes can be considered in the same treatment pathway for first-time dislocation as non-overhead athletes.

NEAR-COMPLETE QUADRICEPS TENDON HEALING TWO YEARS FOLLOWING HARVEST IN ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

Inoue J[1], Dadoo S[1], Nukuto K[1], Lesniak BP[1], Sprague AL[2], Irrgang JJ[2], Musahl V[1]

[1]Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.
[2]Department of Physical Therapy, School of Health and Rehabilitation Sciences, University of Pittsburgh, Pittsburgh, Pa.

INTRODUCTION

Despite the recent increase in the use of quadriceps tendon (QT) autograft in anterior cruciate ligament reconstruction (ACLR), there remains a paucity of literature evaluating the postoperative morphology of the QT. The present study aimed to determine the postoperative morphologic change of the QT at a minimum of two years following harvesting for ACLR.

METHODS

Patients who underwent ACLR with QT autograft and magnetic resonance imaging (MRI) at least two years after harvesting were retrospectively included in the study. The anterior-to-posterior (A-P) thickness, medial-to-lateral (M-L) width, cross-sectional area (CSA), and signal/noise quotient (SNQ) of the QT were assessed at 5 mm, 15 mm, and 30 mm proximal to the superior pole of the patella on MRI (see Figure 1). The CSA was adjusted by the angle between the QT and the plane of the axial cut based on a cosine function (adjusted CSA). The A-P thickness, M-L width, adjusted CSA, and SNQ were compared pre- and postoperatively. In addition, defects or scar-tissue formation in the harvest site were investigated on postoperative MRI.

RESULTS

Thirty patients were recruited for the study. The mean duration between postoperative MRI and surgery was 2.8 ± 1.1 years. The mean A-P thickness was 10.3% and 11.9% larger postoperatively at 5 mm and 15 mm, respectively. The mean M-L width was 7.3% and 6.5% smaller postoperatively at 5 mm and 15 mm, respectively. There were no significant differences in the adjusted CSA between pre- and postoperative states. There was no significant difference in the postoperative change in the SNQ of the QT at all assessment locations (see Figure 2). Defect or scar-tissue formation at the harvest site was observed in four cases (13.3%) and five cases (16.6%), respectively.

DISCUSSION

At a minimum of two years following ACLR, the QT became slightly thicker and narrower, and defects or scar-tissue formation were observed in only 30% of cases at the harvest site. Harvest thickness did not affect the postoperative morphologic change of the QT. Given the normalized tendon morphology and postsurgical SNQ of the QT like pre-surgical state, re-harvesting the QT may be possible.

REFERENCES

1. Emerson CP. *Skeletal Radiol*. 2019;48:1685-96.
2. Tashiro Y. *AJSM*. 2017;45:1829-36.
3. Li H. *AJSM*. 2018;46:1892-900.

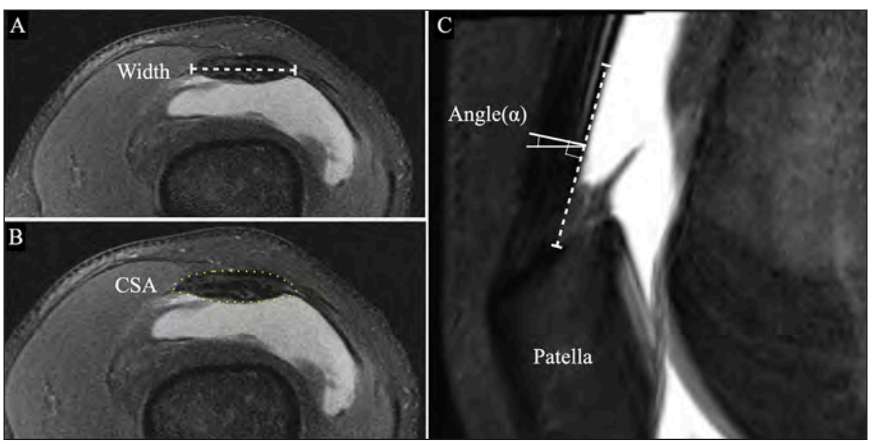


Figure 1. Measurement for the width, cross-sectional area (CSA), and thickness of the tendon on MRI. A. The width was measured on axial plane. B. CSA was measured on axial plane. C. The thickness was measured on sagittal plane.

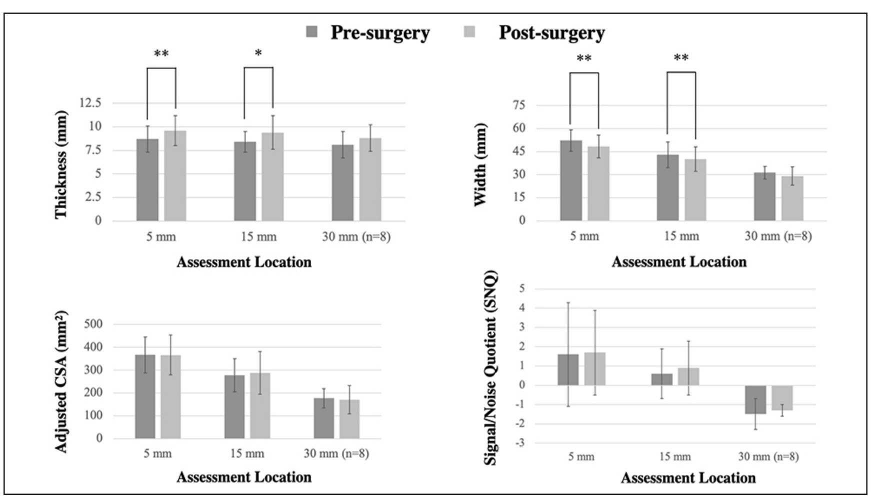


Figure 2. Comparison of thickness, width, adjusted cross-sectional area, and signal/noise quotient SNQ of the tendon between pre- and post-surgery.
*** Significant differences ($p < 0.05$)**
**** Significant differences ($p < 0.01$)**

DIFFERENCES IN CROSS-SECTIONAL AREA OF QUADRICEPS TENDON BASED ON HARVEST LOCATION IN ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

Inoue J[1], Takeuchi S[1], Dadoo S[1], Takaba K[1], Lesniak BP[1], Musahl V[1], Onishi K[2]

[1]Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.
[2]Department of Physical Medicine and Rehabilitation, University of Pittsburgh, Pittsburgh, Pa.

INTRODUCTION

Anterior cruciate ligament (ACL) reconstruction (ACLR) with quadriceps tendon (QT) has been gaining popularity. However, it is unknown how differences in harvest location of the QT affect its thickness and cross-sectional area (CSA). The present study aimed to clarify the differences in thickness and CSA of the QT based on location of tendon harvesting.

METHODS

Patients who were scheduled for or who underwent ACLR were prospectively recruited in the study. Preoperative patients were investigated with the ipsilateral QT, whereas post-operative patients were investigated with the contralateral QT. Patients with a history of injury or surgery in the investigated knee were excluded from the study. An 18-5 MHz linear-array transducer (Aplio i800; Canon Medica Systems) was used for assessment of participants, who were positioned supine and in 20° of knee flexion. A transducer was set from the anterior part of the knee perpendicular to the muscle fibers of the QT. The depth, frequency, and gain were set at 20 to 30 mm (depending on the patient), 17 MHz, and 80 dB, respectively. The short-axis images on ultrasound were used to assess the CSA of the QT at 30 and 60 mm proximal to the superior pole of the patella. The thickness and CSA with a 10 mm width of the QT were measured at three different locations: the center, medial one-third, and lateral one-third at the widest diameter of the QT (see Figure 1). Patients with less than 10 mm width of the QT at 60 mm proximal to the superior pole of the patella were excluded. One-way analysis of variance (ANOVA) was used to compare the thickness and CSA of the QT at the three locations. If a significant difference was found, a Bonferroni correction was used for post-hoc pairwise comparisons. Statistical significance was set at $p < 0.05$.

RESULTS

Thirty-seven patients were recruited for the study. The mean thickness and CSA were larger in the center of the QT compared to the lateral one-third at 30 mm proximal to the superior pole of the patella (thickness, 6.7 ± 1.3 mm versus 5.9 ± 1.3 mm; $p = 0.009$; CSA, 65.6 ± 11.4 mm^2 versus 58.8 ± 11.9 mm^2; $p = 0.036$). There were no significant differences in thickness or CSA of the QT among the three assessment locations at 60 mm proximal to the superior pole of the patella ($p > 0.05$).

DISCUSSION

The thickness and CSA of QT were greater in the center compared to the lateral one-third at 30 mm proximal to the QT insertion point. However, the difference in value was clinically nonsignificant; therefore, harvest location of the QT autograft may not meaningfully impact intraoperative graft diameter. As a result, surgeons may choose the harvest location without concern for resultant graft diameter as long as the enough length of QT is secured.

REFERENCES

1. Takeuchi S. *AJSM*. 2022;50:111-7.
2. Takeuchi S. *KSSTA*. 2022;30:52-60.
3. Xerogeanes JW. *AJSM*. 2013;41:2392-9.

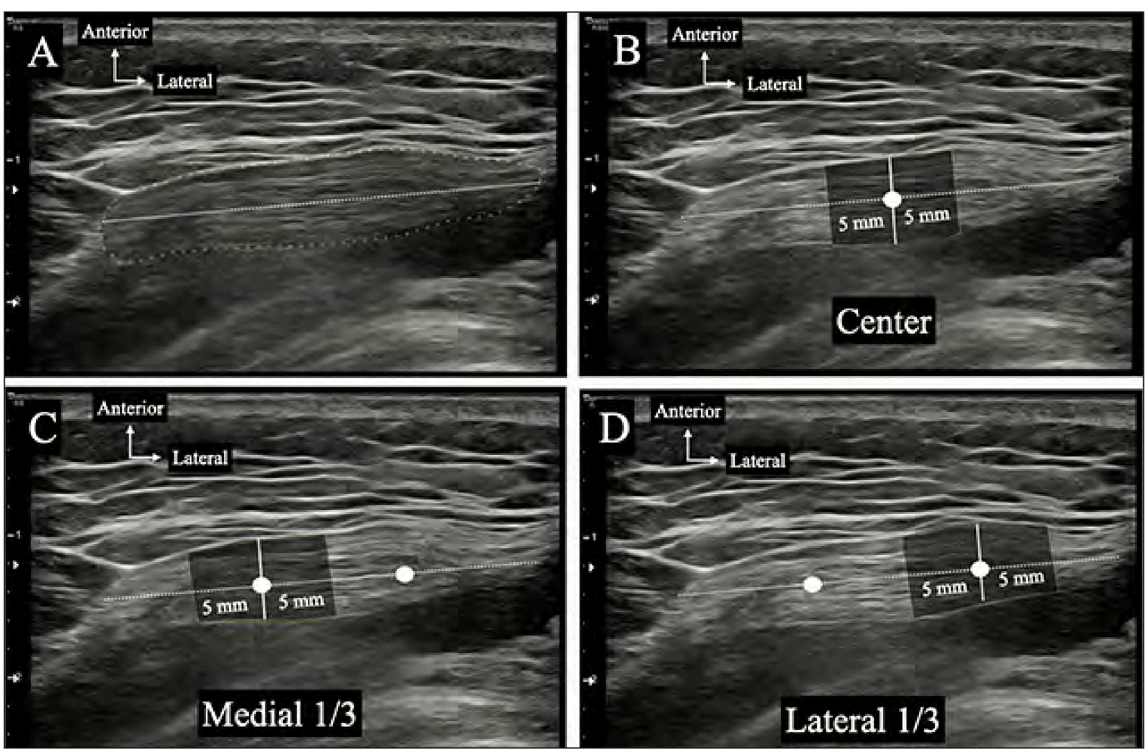


Figure 1. Ultrasonographic measurement of cross-sectional area (CSA) and thickness of quadriceps tendon (QT) at three different points. CSA was measured with a width of 10 mm. A. The width was measured parallel to the tendon at the widest diameter of the QT; B. The center of the QT; C. Medial one-third of the QT; D. Lateral one-third of the QT

COMPARISON OF IMPROVEMENT IN PATIENT-REPORTED KNEE FUNCTION AFTER REVISION AND MULTIPLE-REVISION ACL RECONSTRUCTION COMPARED WITH PRIMARY ACL RECONSTRUCTION

Kaarre J[1,2,3], Herman ZJ[3], Grassi A[4], Senorski EH[2,5], Musahl V[3], Samuelsson V[1,2,6]

[1]Department of Orthopaedics, Institute of Clinical Sciences, Sahlgrenska Academy, University of Gothenburg, Gothenburg, Sweden
[2]Sahlgrenska Sports Medicine Center, Gothenburg, Sweden
[3]Department of Orthopaedic Surgery, UPMC Freddie Fu Sports Medicine Center, University of Pittsburgh Medical Center, Pittsburgh, Pa.
[4]IIa Clinica Ortopedica e Traumatologica, IRCCS Istituto Ortopedico Rizzoli, Bologna, Italy
[5]Unit of Physiotherapy, Department of Health and Rehabilitation, Institute of Neuroscience and Physiology, Sahlgrenska Academy, University of Gothenburg, Gothenburg, Sweden
[6]Department of Orthopaedics, Sahlgrenska University Hospital, Mölndal, Sweden

BACKGROUND
Graft failure after anterior cruciate ligament reconstruction (ACLR) is a debilitating complication often requiring revision surgery. It is widely agreed upon that functional knee outcomes after revision ACLR (rACLR) are inferior compared with those after primary reconstruction. However, data are scarce on outcomes after multiple-revision ACLR (mrACLR).

PURPOSE
The purpose of the study was to compare patient-reported knee function in terms of Knee Injury and Osteoarthritis Outcome Score (KOOS) preoperatively and one year postoperatively after primary ACLR, rACLR, and mrACLR and evaluate the pre- to postoperative improvement in KOOS scores for each procedure.

METHODS
The researchers conducted a cohort study including patients from the Swedish National Knee Ligament Registry who underwent an index ACLR between 2005 and 2020. Participants had a minimum age of 15 years at the time of surgery. All patients had pre- and postoperative KOOS data. The one-year postoperative KOOS and the pre- to postoperative changes in KOOS were assessed between patients who underwent primary ACLR and those who underwent subsequent rACLR and mrACLR.

RESULTS
Of 20,542 included patients, 19,769 (96.2%) underwent primary ACLR, 760 (3.7%) underwent rACLR and 13 (0.06%) underwent mrACLR. Patients who underwent rACLR had significantly smaller pre- to postoperative changes on all KOOS subscales compared with patients undergoing primary ACLR ($p < 0.0001$ for all). Furthermore, patients in the mrACLR group had significantly smaller changes in the KOOS Pain subscale compared with patients in the rACLR group (–9 ± 23.3 versus 2.5 ± 18, $p = 0.024$).

CONCLUSION
The study results indicate that although improvement is seen after primary ACLR, rACLR, and mrACLR, the greatest improvement in functional outcomes is observed after primary ACLR. Patients who underwent at least one rACLR, specifically mrACLR, had lower postoperative outcome scores, indicating that primary ACLR may provide the best chance for recovery after ACL injury.

DIFFERENCES IN POSTOPERATIVE KNEE FUNCTION BASED ON CONCOMITANT TREATMENT OF LATERAL MENISCAL INJURY IN THE SETTING OF PRIMARY ACL RECONSTRUCTION

Kaarre J[1,2,3], Herman ZH[3], Persson F[1,2], Wållgren JO[1,2,4], Alentorn-Geli E[5,6,7], Senorski EH[2,8], Musahl V[3], Samuelsson K[1,2,9]

[1]Department of Orthopaedics, Institute of Clinical Sciences, Sahlgrenska Academy University of Gothenburg, Gothenburg, Sweden
[2]Sahlgrenska Sports Medicine Center, Gothenburg, Sweden
[3]Department of Orthopaedic Surgery, UPMC Freddie Fu Sports Medicine Center, University of Pittsburgh Medical Center, Pittsburgh, Pa.
[4]Department of Orthopaedics, the NU Hospital Group, Trollhättan, Sweden
[5]Instituto Cugat, Hospital Quironsalud Barcelona, Barcelona, Spain
[6]Mutualidad de Futbolistas Españoles - Delegación Catalana, Barcelona, Spain
[7]Fundación García Cugat, Barcelona, Spain
[8]Unit of Physiotherapy, Department of Health and Rehabilitation, Institute of Neuroscience and Physiology, Sahlgrenska Academy, University of Gothenburg, Gothenburg, Sweden
[9] Department of Orthopaedics, Sahlgrenska University Hospital, Mölndal, Sweden

BACKGROUND
Concomitant lateral meniscal (LM) injuries are common in acute anterior cruciate ligament (ACL) ruptures. However, the effect of addressing these injuries with various treatment methods during primary ACL reconstruction (ACLR) on patient-reported outcomes (PROs) is unknown. Therefore, the purpose of this study was to compare postoperative Knee Injury and Osteoarthritis Outcome Score (KOOS) at two, five, and 10 years after isolated primary ACLR to primary ACLR with various treatment methods to address concomitant LM injury.

METHODS
This study was based on data from the Swedish National Knee Ligament Registry. Patients 15 years of age or older who underwent primary ACLR between the years 2005 and 2018 and had data on postoperative KOOS were included in the study. The study population was divided into five groups: 1) isolated ACLR, 2) ACLR + LM repair, 3) ACLR + LM resection, 4) ACLR + LM injury left in situ, and 5) ACLR + LM repair + LM resection. Patients with concomitant medial meniscal or other surgically treated ligament injuries were excluded.

RESULTS
Of 31,819 included patients, 24% had LM injury. After post hoc comparisons, the researchers found significantly lower scores for the KOOS Symptoms subscale in the ACLR + LM repair group compared to the isolated ACLR group (76.0 versus 78.3, $p = 0.0097$) and the ACLR + LM injury left in situ group (76.0 versus 78.3, $p = 0.041$) at two-year follow-up. However, at 10-year follow-up, no differences were found between ACLR + LM repair and isolated ACLR, but ACLR + LM resection resulted in significantly lower KOOS Symptoms scores compared to isolated ACLR (80.4 versus 82.3, $p = 0.041$).

CONCLUSION
The results of this study suggest that LM injury during ACLR is associated with lower KOOS scores, particularly in the Symptoms subscale, at short- and long-term follow-up. However, this finding falls below minimal clinically important difference and therefore may not be clinically relevant.

EXPLORING THE POTENTIAL OF ChatGPT AS A SUPPLEMENTARY TOOL FOR PROVIDING ORTHOPAEDIC INFORMATION

Kaarre J[1,2], Feldt R[3], Keeling LE[1], Dadoo S[1], Zsidai B[2], Hughes JD[1], Samuelsson K[2,4], Musahl V[1]

[1]Department of Orthopaedic Surgery, UPMC Freddie Fu Sports Medicine Center, University of Pittsburgh, Pittsburgh, Pa.
[2]Department of Orthopaedics, Institute of Clinical Sciences, Sahlgrenska Academy, University of Gothenburg, Gothenburg, Sweden
[3]Department of Computer Science and Engineering, Chalmers University of Technology, Gothenburg, Sweden
[4]Department of Orthopaedics, Sahlgrenska University Hospital, Mölndal, Sweden

PURPOSE
The purpose of this study was to investigate the potential use of large language models (LLMs) in orthopaedics by presenting queries pertinent to anterior cruciate ligament (ACL) surgery to generative pretrained transformer (ChatGPT, specifically using its GPT-4 model of March 14, 2023). Additionally, this study aimed to evaluate the depth of the LLM's knowledge and investigate its adaptability to different user groups. It was hypothesized that ChatGPT would be able to adapt to different target groups due to its strong capabilities in language understanding and processing.

METHODS
ChatGPT was presented with 20 questions, and response was requested for two distinct target audiences: patients and non-orthopaedic medical doctors. Four board-certified orthopaedic sports medicine surgeons independently evaluated the responses generated by ChatGPT. Mean correctness, completeness, and adaptability to the target audiences (patients and non-orthopaedic medical doctors) were determined. A three-point response scale facilitated nuanced assessment.

RESULTS
ChatGPT exhibited fair accuracy, with average correctness scores of 1.69 and 1.66 (on a scale of 0, incorrect; 1, partially correct; and 2, correct) for patients and medical doctors, respectively. Three of the 20 questions (15.0%) were deemed incorrect by any of the four orthopaedic sports medicine surgeon assessors. Moreover, overall completeness was calculated to be 1.51 and 1.64 for patients and medical doctors, respectively, whereas overall adaptiveness was determined to be 1.75 and 1.73 for patients and doctors, respectively.

CONCLUSION
Overall, ChatGPT was successful in generating correct responses in approximately 65% of the cases related to ACL surgery. The findings of this study imply that LLMs offer potential as a supplementary tool for acquiring orthopaedic knowledge. However, although ChatGPT can provide guidance and effectively adapt to diverse target audiences, it cannot supplant the expertise of orthopaedic sports medicine surgeons in diagnosis and treatment planning due to its limited understanding of orthopaedic domains and its potential for erroneous responses.

METAL INTERFERENCE SCREW FIXATION COMBINATIONS SHOW HIGH REVISION RATES IN PRIMARY HAMSTRING TENDON ACL RECONSTRUCTION

Kaarre J[1,2,3], Benvegnu NA[3], Engler ID[4], Nazzal EM[3], Zsidai B[1,2], Senorski EH[1,2,5], Musahl V[3], Samuelsson K[1,2,6]

[1]Department of Orthopaedics, Institute of Clinical Sciences, Sahlgrenska Academy, University of Gothenburg, Gothenburg, Sweden
[2]Sahlgrenska Sports Medicine Center, Gothenburg, Sweden
[3]Department of Orthopaedic Surgery, UPMC Freddie Fu Sports Medicine Center, University of Pittsburgh, Pittsburgh, Pa.
[4]Central Maine Healthcare Orthopedics, Central Maine Medical Center, Auburn, Maine
[5]Department of Health and Rehabilitation, Institute of Neuroscience and Physiology, Sahlgrenska Academy, University of Gothenburg, Gothenburg, Sweden
[6]Department of Orthopaedics, Sahlgrenska University Hospital, Mölndal, Sweden

BACKGROUND
Different fixation methods in anterior cruciate ligament (ACL) reconstruction (ACLR) have been associated with different revision rates, specifically in the early postoperative period. However, most previous research has either grouped together different fixation types or evaluated femoral-sided fixation or tibial-sided fixation separately. Therefore, the purpose of this study was to determine ACL revision rates for specific combinations of femoral and tibial fixation methods within two years of primary hamstring tendon autograft ACLR based on data from the Swedish National Knee Ligament Registry (SNKLR).

METHODS
The study included patients who underwent primary hamstring tendon autograft ACLR between 2005 and 2018 and were recorded in the SNKLR. The collected data included patient characteristics (age, sex, body mass index), activity at time of injury, surgical information (concomitant injuries, time from injury to surgery, fixation types at the femur and tibia), and subsequent revision ACLR. The researchers chose revision rate within two years of the index procedure, as ACLR fixation is most likely to contribute to ACLR revision within the first two years, during graft maturation.

RESULTS
Of the 23,238 included patients undergoing primary hamstring ACLR, 581 (2.5%) underwent revision ACLR within two years of the index procedure. Among the combinations used for more than 300 patients, the femoral metal interference screw/tibial metal interference screw fixation combination had the highest revision rate, followed by metal interference screw/resorbable screw and endobutton/AO screw fixation combinations, with respective revision rates of 4.0, 3.0, and 3.0%. The lowest revision rate within two years of ACLR was found in the endobutton/metal interference screw with backup osteosuture fixation combination, used in 433 cases, with a failure rate of 0.9%.

CONCLUSION
Different early ACL revision rates were found across different combinations of femoral and tibial fixation devices within two years of primary hamstring tendon autograft ACLR. Metal interference screw fixation, particularly when performed on both the femoral and tibial sides, most frequently resulted in revision ACLR. These findings may be helpful for surgeons in selecting appropriate fixation devices for hamstring ACLR.

ARTHROSCOPIC ROTATOR CUFF REPAIR WITH SIDE-TO-SIDE SUTURES FOR FULL-THICKNESS TRANSTENDINOUS SUPRASPINATUS TEARS YIELDS EXCELLENT OUTCOMES AND LOW RE-TEAR RATES SIMILAR TO TRADITIONAL TENDON-TO-BONE FIXATION AT MEAN FOLLOW-UP OF FOUR YEARS

Karimi A, Steuer F, McMahon S, Reddy R, Njoku-Austin C, Gilbert R, Lin A

University of Pittsburgh, Pittsburgh, Pa.

INTRODUCTION
Full-thickness, transtendinous supraspinatus tears involve a large portion of the tendon that remains attached to the footprint that often leaves insufficient medial tissue for tension-free footprint restoration with traditional suture anchor repair. The aim of this study was to compare outcomes and failure rates for arthroscopic side-to-side (STS) suture repair for transtendinous tears to traditional double-row repair for more common tendon avulsions. The authors hypothesized poorer objective and subjective outcomes as well as higher re-tear rates for STS suture repair.

METHODS
This was a retrospective cohort study of 18 consecutive patients with full-thickness, transtendinous supraspinatus tears repaired with arthroscopic STS sutures compared to 36 matched controls with classic tendon avulsion from the footprint repaired with double-row knotless transosseous equivalent (TOE) repairs. All procedures were performed by a single surgeon with a minimum of two years' follow-up. Demographics and prospectively collected patient-reported outcomes (PROs) were collected, including postoperative active range of motion (AROM), American Shoulder and Elbow Surgeons (ASES) score, visual analog scale (VAS) for pain, and Subjective Shoulder Value (SSV). Failure (defined as a symptomatic re-tear diagnosed on magnetic resonance imaging (MRI) or need for revision surgery) was also determined. Preoperative tear size and Goutallier stage were recorded from MRI.

RESULTS
There were no significant differences between the STS and TOE repair groups regarding mean follow-up (48.2 ± 18.5 months versus 47.8 ± 19.8 months, p = 0.73) and age (64.6 ± 7.2 versus 64.8 ± 7.7, p = 0.95). With respect to clinical outcomes and PROs, there were no differences in postoperative VAS pain score (0.94 ± 1.5 versus 1.17 ± 2.2, p = 0.63), SSV score (88.8 ± 15.0 versus 92.4 ± 8.9, p = 0.75), or ASES score (90.8 ± 9.7 versus 90.6 ± 14.6, p = 0.23). No differences were identified for postoperative AROM forward flexion (154.2 ± 13.3 versus 159.3 ± 11.4, p= 0.10), external rotation (53.3 ± 6.2 versus 51.3 ± 10.1, p= 0.70), or internal rotation score (6.4 ± 1.8 versus 7.2 ± 1.2, p = 0.244). Regarding preoperative tear characteristics, fatty infiltration of the supraspinatus (1.24 ± 1.03 versus 1.72 ± 0.81, p = 0.08) and the infraspinatus (0.35 ± 0.6 versus 0.63 ± 0.7, p = 0.21) was similar. Although there were larger anteroposterior tear sizes in the STS group (21.4 ± 9.3 versus 16.6 ± 8.4, p = 0.049), there was no statistically significant difference in failure rates between cohorts (11% versus 11%, p = 1.0).

DISCUSSION
Arthroscopic STS suture repair for supraspinatus tears yields excellent outcomes with low failure rates comparable to tendon-to-bone double-suture anchor repair for typical avulsion type tears. Retention of the large tendon stump on the greater tuberosity with STS repair also allows restoration of anatomy without undue tension in this uncommon scenario.

THE COST OF LAST-MINUTE CANCELLATION: ANALYSIS OF TIMING, REASON, AND THE BLOCK TIME YOU WON'T GET BACK

McMahon S, Steuer F, Ahrendt G, Marcaccio S, Lin A

University of Pittsburgh, Pittsburgh, Pa.

INTRODUCTION

Last-minute cancellation of elective surgeries occurs for medical and non-medical reasons and can affect operating room availability. According to existing literature, the average cost of shoulder surgery is \$16,568 ± \$8,457. Cost contributors include the procedure type, the level of invasiveness, the procedure time, the cost of implants utilized, and the use of assistive adjuncts. The additional costs associated with securing an operating room, including the personnel costs of surgeons, nurses, surgical technicians, and other team members required for safe and efficient case execution, must also be considered.

This study aimed to determine whether there is an inflection time point at which a cancellation becomes more costly. The authors hypothesized that cancellations are more costly when they occur within one week of the scheduled date, due to an inability to fill the operating room time, and that failure to obtain medical clearance would be a common reason for cancellation.

METHODS

The researchers conducted a retrospective review of 878 consecutive scheduled surgeries at one surgery center for one orthopaedic shoulder surgeon. The cases included arthroscopic rotator cuff repair, arthroscopic-assisted coracoclavicular ligament reconstruction, and complex procedures such as superior capsular reconstruction and anterior cable reconstruction. Additionally, the surgeon performs anatomic and reverse total shoulder arthroplasty, with a total case volume of approximately 750 cases annually.

Elective arthroscopic procedures and elective shoulder arthroplasty are scheduled six to eight weeks and 10 to 12 weeks in advance, respectively. All cancellations within two weeks of surgery that occurred between January 1, 2023, to December 31, 2023, were recorded, including the date and reason for cancellation. A timeslot was considered filled when a new case was scheduled for the procedure time made available by the cancellation. The rate and percentage of cancellations that could be filled were analyzed based on the number of days before the scheduled surgery the cancellation occurred: within one week compared to one to two weeks of the scheduled surgery.

Reasons for cancellation were categorized as elective or non-elective. Non-elective reasons included medical reasons, family emergencies, and insurance difficulties, with further analysis of an additional subgroup: lack of preoperative medical clearance. Estimated revenue losses were calculated by the average cost of shoulder surgery found in existing literature. Descriptive statistics were calculated, and significance was determined via Fisher's exact test and linear regression analysis.

RESULTS

There were 79 total cancellations, 52 within two weeks of the scheduled surgery. The average cancellation time was 4.83 ± 3.92 days before surgery. For surgeries canceled within two weeks, 54.0% of the timeslots (28 of 52) were filled. When canceled within one week of surgery, 42.5% (17 of 40) of timeslots were filled, a significant reduction compared to cancellations that occurred eight to 14 days prior, when 91.67% (11 of 12) of timeslots were filled ($p = 0.003$). Linear regression showed a statistically significant ($p = 0.03$) linear relationship between fill rate per day and day of cancellation. For cancellations occurring zero to seven days before surgery, the average fill rate per day was 49.0%. For cancellations occurring eight to 14 days before surgery, the average fill rate per day was 87.5%.

Cancellations were considered elective for 26.9% (14 of 52) of those canceled within two weeks of the scheduled date and for 32.5% (13 of 40) of those canceled within one week. The rate of elective and non-elective cancellations did not differ between the one- and two-week mark ($p = 0.470$). Unfilled elective cancellations accounted for five cancellations, \$82,840, whereas unfilled non-elective cancellations accounted for 19 cancellations, \$314,792. More specifically, non-elective cancellations related to lack of clearance contributed 17.5% (7 of 40), and those occurring within one week and left unfilled accounted for \$115,976. Approximately \$463,904 of revenue was lost due to unfilled timeslots.

DISCUSSION

The data support the authors' hypothesis that there was an inflection point, observed at one week prior to scheduled surgery, at which there was a statistically significant decrease in the rate of filling available surgical timeslots. Although most cancellations were unavoidable due to non-elective reasons, about one-third were found to be elective. This information may guide practice policies to minimize costly elective cancellations that result in unfilled operating room availability and to streamline preoperative workup for elective surgeries to prevent last-minute cancellations.

EFFECT OF CONCOMITANT LATERAL MENISCAL MANAGEMENT ON ACL RECONSTRUCTION REVISION RATE AND SECONDARY MENISCAL AND CARTILAGINOUS INJURIES

Persson F[1,2], Kaarre J[1,2,3], Herman ZJ[3], Wållgren JO[1,2], Senorski EH[2,4], Musahl V[3], Samuelsson K[1,2,5]

[1]Department of Orthopaedics, Institute of Clinical Sciences, Sahlgrenska Academy, University of Gothenburg, Gothenburg, Sweden
[2]Sahlgrenska Sports Medicine Center, Gothenburg, Sweden
[3]Department of Orthopaedic Surgery, UPMC Freddie Fu Sports Medicine Center, University of Pittsburgh Medical Center, Pittsburgh, Pa.
[4]Unit of Physiotherapy, Department of Health and Rehabilitation, Institute of Neuroscience and Physiology, Sahlgrenska Academy, University of Gothenburg, Gothenburg, Sweden
[5]Department of Orthopaedics, Sahlgrenska University Hospital, Mölndal, Sweden

BACKGROUND

Simultaneous meniscal tears are often present with anterior cruciate ligament (ACL) injuries, and in the acute setting, the lateral meniscus (LM) is more commonly injured than the medial meniscus.

PURPOSE

The purpose of this study was to investigate how a concomitant LM injury—repaired, resected, or left in situ during primary ACL reconstruction (ACLR)—affects the ACL revision rate and cartilaginous and meniscal status at the time of revision within two years after primary ACLR.

METHODS

The cohort study used data for 31,705 patients with primary ACLR, extracted from the Swedish National Knee Ligament Registry. The odds of revision ACLR, and cartilaginous as well as meniscal injuries at the time of revision ACLR, were assessed between the unexposed comparison group (isolated ACLR) and the exposed groups of interest (ACLR + LM repair, ACLR + LM resection, ACLR + LM repair + LM resection, or ACLR + LM injury left in situ).

RESULTS

In total, 719 (2.5%) of the included 29,270 patients with two-year follow-up data underwent revision ACLR within two years after primary ACLR. No significant difference in revision rate was found between groups. Patients with concomitant LM repair (odds ratio [OR], 3.56; 95% confidence interval [CI], 1.57–8.10; $p = 0.0024$) or LM resection (OR, 1.76; 95% CI, 1.18–2.62; $p = 0.0055$) had higher odds of concomitant meniscal injuries (medial or lateral) at the time of revision ACLR than patients undergoing isolated primary ACLR. Additionally, higher odds of concomitant cartilage injuries at the time of revision ACLR were found in patients with LM resection at index ACLR compared with patients undergoing isolated primary ACLR (OR, 1.73; 95% CI, 1.14–2.63; $p = 0.010$).

CONCLUSION

The results of this study demonstrated higher odds of meniscal and cartilaginous injuries at the time of revision ACLR within two years after primary ACLR + LM resection and higher odds of meniscal injury at the time of revision ACLR within two years after primary ACLR + LM repair compared with isolated ACLR. Surgeons should be aware of the possibility of concomitant cartilaginous and meniscal injuries at the time of revision ACLR after index ACLR with concomitant LM injury, regardless of the index treatment type received.

REVERSING CHRONIC PSEUDOPARESIS SECONDARY TO MASSIVE, IRREPARABLE ROTATOR CUFF TEAR: SUPERIOR CAPSULAR RECONSTRUCTION VERSUS REVERSE TOTAL SHOULDER ARTHROPLASTY

Reddy RP,. Herman ZJ, Como M, James MG, Steuer FW, Adida S, Singh-Varma A, Njoku-Austin C, Karimi A, Lin A

Department of Orthopaedic Surgery, UPMC Freddie Fu Sports Medicine Center, Pittsburgh, Pa.

INTRODUCTION

Recent studies have defined pseudoparesis as limited active forward elevation less than 90° and maintained passive range of motion in the setting of a massive rotator cuff tear (RCT). Although pseudoparesis can be reliably reversed with reverse total shoulder arthroplasty (RSA) or superior capsular reconstruction (SCR), the optimal treatment for this indication remains unknown. The purpose of this study was to compare the clinical outcomes of RSA to SCR in patients with pseudoparesis secondary to massive, irreparable rotator cuff tear (miRCT).

METHODS

This was a retrospective cohort study of consecutive patients aged 40–70 years with pseudoparesis secondary to miRCT who were treated with either RSA or SCR by a single fellowship-trained shoulder surgeon from 2016–2021 with a minimum 12-month follow-up. Multivariate linear regression modeling was utilized to compare active range of motion, visual analog pain scale (VAS), Subjective Shoulder Value (SSV), and American Shoulder and Elbow Surgeons score between RSA and SCR while controlling for confounding variables.

RESULTS

Twenty-seven patients were included in the RSA cohort and 23 patients were included in the SCR cohort, with similar mean follow-up times (26.2 ± 21.1 versus 21.9 ± 14.7 months, respectively). The patients in the RSA group were significantly older than those in the SCR group (65.2 ± 4.4 versus 54.2 ± 7.8 years, $p < 0.001$) and had more severe arthritis (1.8 ± 0.9 versus 1.2 ± 0.5 per the Samilson-Prieto classification, $p = 0.019$).

The pseudoparesis reversal rates among the RSA and SCR cohorts were 96.3% and 91.3%, respectively. On univariate analysis, the RSA cohort demonstrated significantly greater mean improvement in active forward flexion (FF) (89 ± 26 versus 73 ± 30 change in degrees, $p = 0.048$), greater postoperative SSV ($91 \pm 8\%$ versus $69 \pm 25\%$, $p < 0.001$), lower postoperative VAS pain scores (0.6 ± 1.2 versus 2.2 ± 2.9, $p = 0.020$), and less postoperative internal rotation (4.6 ± 1.6 versus 6.9 ± 1.8, $p = 0.004$) compared to the SCR cohort.

On multivariate analysis controlling for age and osteoarthritis, RSA remained a significant predictor of greater SSV ($\beta = 21.5$, $p = 0.021$) and lower VAS scores ($\beta = -1.4$, $p = 0.037$), whereas SCR was predictive of greater internal rotation ($\beta = 3.0$, $p = 0.043$).

CONCLUSION

Although both RSA and SCR effectively reverse pseudoparesis, patients with RSA have higher SSV and lower pain scores but less internal rotation, according to analysis after controlling for age and osteoarthritis. The results of this study may inform surgical decision making for patients who are suitable candidates for either procedure.

CRITERIA-BASED RETURN-TO-SPORT TESTING AFTER OPEN LATARJET REVEALS RESIDUAL DEFICITS AND CAN BE UTILIZED FOR SPORTS CLEARANCE WITH EXCELLENT OUTCOMES AT MEAN 3.6-YEAR FOLLOW-UP: A SMALL CASE SERIES OF COMPETITIVE ATHLETES

Reddy RP, Charles S, Como M, Herman Z, Nazzal E, Como C, Popchak A, Lin A

Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.

INTRODUCTION

Return-to-play criteria after open Latarjet remain heterogenous. Thus, the purpose of this study was to evaluate the use of a criteria-based return-to-sport (CBRTS) testing protocol in competitive athletes who underwent open Latarjet to assess their ability to return to play.

METHODS

Ten subjects (eight male, mean age = 19.9 ± 4.9 years) who underwent open Latarjet procedure from 2016–2020 at a single institution were referred during postoperative rehabilitation for functional testing at a minimum of five months postoperatively to evaluate their readiness for return to play. The testing consisted of four sections: isometric strength testing, isokinetic strength testing, endurance testing, and functional testing.

Isometric strength testing was performed in external rotation (ER) and internal rotation (IR) with a handheld dynamometer at 0 and 90 degrees. Isokinetic strength testing of ER and IR was evaluated with a Biodex isokinetic dynamometer. Functional testing was performed with the Closed Kinetic Chain Upper Extremity Stability Test and Unilateral Seated Shot Put Test. Posterior rotator cuff endurance was evaluated with a repetition-to-failure technique. A passing score was considered achieving 90% of the nonoperative shoulder.

Patients who passed all sections of the CBRTS test were cleared to return to play. Patients who failed only one section were given four to six weeks delayed clearance to return to play after focusing on the specific deficit identified during testing. Patients who failed multiple components of the test underwent additional deficit-based formal rehabilitation for four to six weeks, then repeated the test before final clearance. The 10 subjects were followed for a minimum of two years to assess for recurrent instability and return to sport.

RESULTS

All 10 subjects were competitive high school or college athletes. Five of them (50%) were contact athletes and six (60%) were overhead athletes. CBRTS testing occurred at a mean of 5.3 months postoperatively. Of the 10 patients who tested, three passed the CBRTS test without failing any sections (30%), and one passed the CBRTS test while failing one section (10%). The remaining six patients failed two or more sections and thus failed their CBRTS test, requiring repeat testing before full return to play.

Only three patients (30%) met all of the expected goals for strength, endurance, and functional testing. Seven patients (70%) failed at least one portion of the strength testing, two patients (30%) failed endurance testing, and two patients (20%) did not pass both functional tests.

At final follow-up (mean 3.6 ± 1.2 years), one patient had recurrent subluxations (10%) and nine patients returned to sport (90%).

CONCLUSION

The majority of athletes in this cohort did not meet the expected goals for the operative shoulder during return-to-sport testing at around five months postoperatively, with 70% demonstrating residual deficits in strength and more than 20% demonstrating deficits in endurance or function. Overall, CBRTS testing could provide more reliable evidence for return to play than time-based clearance after open Latarjet procedure.

DUAL-PLATE FIXATION OF MIDSHAFT CLAVICLE FRACTURES DEMONSTRATES FEWER HEALING COMPLICATIONS BUT SIMILAR LONG-TERM PATIENT-REPORTED OUTCOMES COMPARED TO NONOPERATIVE MANAGEMENT: A COHORT STUDY WITH MEAN 3.4-YEAR FOLLOW-UP

Reddy RP, Charles S, Njoku-Austin C, Como M, Okundaye O, Singh-Varma A, Fogg D, Karimi A, Lin A

Freddie Fu Sports Medicine Center, UPMC Department of Orthopaedic Surgery, Pittsburgh, Pa.

INTRODUCTION

Although open reduction and internal fixation (ORIF) is the gold-standard treatment for displaced midshaft clavicle fractures, recent studies have advocated for nonoperative management, citing high rates of reoperation associated with operative intervention. However, many of these studies utilized single-plate fixation for the operative arm, which has been shown to have high rates of symptomatic hardware. Very few studies have compared nonoperative management to ORIF with dual-plate fixation, which may be associated with lower rates of reoperation.

Thus, the purpose of this study was to compare the long-term complications and patient-reported outcomes of dual-plate fixation to nonoperative management for displaced midshaft clavicle fractures. The authors hypothesized that dual-plate fixation would result in fewer healing complications and greater patient satisfaction compared to nonoperative management.

METHODS

This was a retrospective cohort study of all patients who presented with a displaced midshaft clavicle fracture between January 1, 2010, and December 31, 2021, at a level one trauma center and who had minimum 12-month follow-up. Patients were separated into two cohorts: 1) those treated with orthogonal dual mini-fragment plate fixation and 2) those in which surgery was deemed a treatment option but nonoperative management with sling immobilization was chosen by the patient. Data on patient demographics, injury characteristics, and fracture pattern were collected. Outcomes included healing complications (non-union, delayed union, symptomatic malunion) and patient-reported outcomes such as visual analog pain scale (VAS) and subjective shoulder value (SSV), which were compared between cohorts with univariate and multivariate analyses. A final multivariate logistic regression model controlling for confounders was utilized to determine the relationship between treatment and healing complications.

RESULTS

The study identified 111 patients (mean age = 41.6 ± 16.7 years) with average follow-up of 3.4 ± 2.2 years. Of those, 62 underwent dual-plate fixation and 49 underwent nonoperative management. There were no significant differences in age, sex, body mass index, tobacco use, diabetes, and follow-up time. There were also no differences between groups in fracture morphology, displacement, shortening, comminution, and high-energy mechanism.

With regard to complications, there were zero non-unions, one delayed union, and zero symptomatic malunions in the dual-plate cohort compared to four non-unions ($p = 0.035$), one delayed union ($p = 1.00$), and three symptomatic malunions ($p = 0.083$) in the nonoperative cohort. There was one reoperation in the dual-plate cohort for symptomatic hardware. At final follow-up, there were no differences between the dual-plate and nonoperative cohorts with regard to VAS (1.2 ± 2.2 versus 1.5 ± 2.4, $p = 0.559$) and SSV (90 ± 16 versus 92 ± 15, $p = 0.671$).

In the final multivariate model controlling for confounders, patients who underwent nonoperative management were more than 14 times more likely to develop a healing complication ($\beta = 14.3$; $p = 0.019$) compared to patients who underwent dual-plate fixation.

CONCLUSION

Dual-plate fixation of displaced midshaft clavicle fractures results in a significantly lower rate of healing complications compared to nonoperative management, but without the high risk of reoperation associated with single-plate fixation. However, at long-term follow-up, both treatments demonstrate similar pain scores and subjective shoulder function.

CONVERSION TO KNEE ARTHROPLASTY IS MORE COMMON AFTER MENISCECTOMY THAN MENISCUS REPAIR IN PATIENTS OLDER THAN AGE 40

Runer A[1,2], Özbek A[1,3], Dadoo S[1], Keeling L[1], Grandberg C[1], Engler I[1,4], Irrgang JJ[1,5], Hughes JD[1], Musahl V[1]

[1]Department of Orthopaedic Surgery, UPMC Freddie Fu Sports Medicine Center, University of Pittsburgh Medical Center, Pittsburgh, Pa.
[2]Department of Sports Orthopaedics, Klinikum rechts der Isar, Technical University of Munich, Munich, Germany
[3]Department of Orthopedics and Traumatology, Ankara University, Ankara, Turkey
[4]Central Maine Healthcare Orthopedics, Central Maine Medical Center, Lewiston Maine
[5]Department of Physical Therapy, School of Health and Rehabilitation Sciences, University of Pittsburgh, Pittsburgh, Pa.

PURPOSE
The purpose of this study was to describe rates of conversion to unicompartmental or total knee arthroplasty (KA) in patients older than 40 years (at initial surgery) after partial meniscectomy (ME) or meniscal repair (MR).

METHODS
Patients older than 40 years undergoing isolated ME or MR between 2016 and 2018 were extracted from a single healthcare provider database. Data on patient characteristics, type of initial surgery, number of returns to the operating room, and performed procedures, including conversion to KA, were recorded. Comparative group statistics and Kaplan-Meier survival rate analysis were performed.

RESULTS
A total of 3,638 patients (47.8% female) were included, with 3,520 (96.8%) undergoing ME and 118 (3.2%) MR. Overall, 378 (10.4%) patients returned to the operating room at an average of 22.7 ± 17.3 months postoperatively. Conversion to KA was more frequent in patients after primary ME (n = 270, 7.7%) compared to MR (2.5%, n = 3, OR: 3.2, p = 0.03). Compared to ME (2.3%, n = 82), twice as many patients undergoing MR returned for subsequent meniscus surgery (MR: 5.9%, n = 7, odds ratio: 2.6, p = 0.02,). Time from primary surgery to KA (ME: 22 ± 17 months, MR: 25 ± 15 months, p = 0.96) did not differ between the treatment groups. Survivorship was 95% for ME and 98.2% for MR after 24 months (p = 0.76) and 92.5% and 98.2% after 60 months (p = 0.07), respectively.

CONCLUSION
The overall reoperation rate after meniscal surgery was 10.4% in patients older than 40 years. Patients treated with primary meniscectomy have more than three times higher odds to undergo subsequent KA compared to those treated with meniscal repair. However, patients with primary meniscal repair have a higher rate of subsequent meniscus surgery compared to those undergoing primary meniscectomy. This information is important when considering and treating a patient older than 40 years who has meniscal injury.

MRI OFFERS GREATER RELIABILITY FOR ASSESSMENT OF GLENOID TRACK CONCEPT THAN CT

Steuer F, Tecle N, Karimi A, Reddy R, Lin A

University of Pittsburgh, Pittsburgh, Pa.

INTRODUCTION
The objective of this study was to assess the reliability of glenoid track measurements by computed tomography (CT) and magnetic resonance imaging (MRI). The authors hypothesized that CT and MRI would have equivalent reliability.

METHODS
The researchers collected a cohort of 46 patients with Hill-Sachs lesions following anterior shoulder dislocations. Inclusion criteria included both CT and MRI preoperative scans. Exclusion criteria included imaging of prior surgery, non-reduced dislocations, or those without Hill-Sachs lesions. Glenoid circumference using a best-fit circle, anterior bone loss, and Hill-Sachs interval were assessed by a sports medicine fellow and an orthopaedic surgeon. The measurements were used to determine the glenoid track, defined as GT = 0.83*D-d, with D representing the diameter of the glenoid best-fit circle and d representing the width of anterior glenoid bone loss. Distance to dislocation (DTD), defined as DTD = GT-HSI, was determined and thus whether the lesion was on track (DTD ≥ 10 mm), near track (0 mm < DTD < 10 mm), or off track (DTD ≤ 0 mm). Statistical analysis was carried out with Cohens kappa and interclass correlation coefficient (ICC).

RESULTS
A total of 44 patients met the inclusion criteria. The mean age of patients was 25.5 years (range = 16–40). Assessment of whether the lesion was on, near, or off track via MRI showed moderate agreement between raters (70%, k = 0.47), whereas assessment via CT showed fair agreement between raters (56%, k = 0.28). On-track, near-track, and off-track agreement between CT and MRI ranged from fair to almost perfect (59%–86%, k = 0.29–0.72). The ICC for glenoid track width via MRI was moderate (ICC = 0.51), and via CT was poor (ICC = 0.22). The ICC for Hill-Sachs interval via MRI was moderate (ICC = 0.70) and via CT was moderate (ICC = 0.53). The ICC for distance to dislocation via MRI was moderate (ICC = 0.57) and via CT was moderate (ICC = 0.50).

DISCUSSION
CT and MRI do not demonstrate similar reliability regarding measurements of the glenoid track. Based on the results of this study, MRI showed a higher interrater reliability across multiple measurements. This may be due to the lower number of slices per MRI for raters to assess. The larger number of slices available for analysis in CT may lead to lower reliability between raters. The additional measurement of Hill-Sachs interval (HSI) may have contributed to decreased reliability when compared to current literature on measurement reliability of anterior glenoid bone loss. Poor reliability between CT measurements of the glenoid track may potentially affect clinical decisions. Although MRI demonstrated better interrater reliability, the discrepancy between CT and MRI in the same individual implies that the modalities are not equivalent for calculating the glenoid track.

COMPARISON OF OPERATIVE VERSUS NON-OPERATIVE OUTCOMES OF POSTERIOR SHOULDER INSTABILITY

Scherer R[1], Chang A[1], Marcaccio S[2], Vyas D[2]

[1]University of Pittsburgh School of Medicine, Pittsburgh, Pa.
[2]Department of Orthopaedic Surgery, University of Pittsburgh Medical Center, Pittsburgh, Pa.

BACKGROUND
Posterior shoulder instability, described as the posterior subluxation or dislocation of the shoulder joint, is a common cause of pain and functional limitations in athletes.[1,2] It accounts for roughly 10% of all shoulder instability cases and 24% of all operative shoulder instability cases.[1-3] Currently, the two primary methods of intervention for posterior shoulder instability are nonoperative measures and surgical intervention. Nonoperative management usually consists of rest and physical therapy to help the shoulder recover. Alternatively, the patient may opt for operative management of the shoulder. Surgery is performed either arthroscopically or open to repair the labrum tear and capsular laxity that contributed to dislocation or subluxation.[1,3-4]

HYPOTHESIS
The authors hypothesized that patients who undergo operative management of posterior shoulder instability will have better patient-reported outcomes than patients who undergo nonoperative management.

METHODS
The researchers developed a database of approximately 300 patients with posterior shoulder instability. All patients were seen by the orthopaedic surgery department at University of Pittsburgh Medical Center (UPMC) between 2015 and 2020. Patients were excluded if they had multidirectional instability.

In addition to patient demographics, pre-intervention and post-intervention Kim, Jerk, and D-Pitt test results will be recorded from patient charts. Information from magnetic resonance imaging and x-rays were collected, such as o'clock position of labrum tear to assess size, posterior humeral head subluxation index, glenoid version, and posterior labral height. Surgical interventions and findings were recorded through reviewing surgical notes on EPIC. Lastly, the patients will record patient-reported outcomes. Patients will be contacted and asked to fill out surveys consisting of the Single Assessment Numeric Evaluation (SANE) and Western Ontario Shoulder Instability index (WOSI). SANE and WOSI are used to put numerical values on functionality of the shoulder. All patient-reported outcomes will be reported at least two years after the date of either the surgical or non-surgical intervention. The scores of the patient-reported outcomes will be compared between groups. T-test, chi-square test, and multivariable regression will be utilized to determine statistical significance. Results will be compared to the minimal clinically important difference and patient acceptable symptom state to determine clinical significance.

RESULTS
This study is currently contacting approximately 300 patients with posterior shoulder instability. A database of patients who were managed both operatively and conservatively was built and is being used to complete the study. A proposal has been both completed and approved by the Institutional Review Board. Preliminary chart review has been completed and is awaiting statistical analysis after the patient-reported outcomes have been recorded.

CONCLUSIONS
Pending the statistical analysis of patient responses, the authors will be able to determine whether surgical and conservative management of posterior shoulder instability yields different outcomes. They hope this will help guide clinical decision making regarding posterior shoulder instability.

REFERENCES
1. Antosh IJ, Tokish JM, Owens BD. Posterior shoulder instability. *Sports Health*. 2016;8(6):520-6. doi: 10.1177/1941738116672446.
2. Tannenbaum E, Sekiya JK. Evaluation and management of posterior shoulder instability. *Sports Health*. 2011;3(3):253-63. doi: 10.1177/1941738111400562.
3. Goldenberg BT, Goldsten P, Lacheta L, Arner JW, Provencher MT, Millett PJ. Rehabilitation following posterior shoulder stabilization. *Int J Sports Phys Ther*. 2021;16(3):930-40. doi: 10.26603/001c.22501.
4. Cruz-Ferreira E, Abadie P, Godenèche A, Mansat P, Clavert P, Flurin P; French Arthroscopy Society. Posterior shoulder instability: prospective non-randomised comparison of operative and non-operative treatment in 51 patients. *Orthop Traumatol Surg Res*. 2017;103(8S):S185-8. doi: 10.1016/j.otsr.2017.08.004.

FIX THE OTHER SHOULDER: CONTRALATERAL ROTATOR CUFF REPAIR YIELDS SIMILAR FUNCTION AND PATIENT-REPORTED OUTCOMES

Steuer F, Marcaccio S, McMahon S, Njoku-Austin C, Findlay G, Mirvish A, Fox M, Lin A

University of Pittsburgh, Pittsburgh, Pa.

INTRODUCTION

Following rotator cuff repair, patients sustaining a rotator cuff tear requiring surgical intervention in the contralateral shoulder is a common clinical scenario for orthopaedic shoulder surgeons, though the incidence and outcomes of these contralateral repairs remain unclear.

This study aimed to identify the incidence of patients undergoing contralateral rotator cuff repair and to compare the surgical outcomes of the first arthroscopic rotator cuff repair to the subsequent contralateral repair. The authors hypothesized that postoperative outcomes would be better with the subsequent contralateral repair and that tear shapes would be similar between the first and contralateral tears.

METHODS

This was a retrospective study of 1,300 consecutive rotator cuff repairs (1,223 patients) over five years. The inclusion criteria were primary arthroscopic rotator cuff repair followed by a subsequent primary rotator cuff repair to the contralateral side. Exclusion criteria included lack of appropriate follow-up documentation, open rotator cuff repair, lack of both operative reports, and development of unrelated neuropathic pain. Pre- and postoperative range of motion (ROM) and strength measurements including forward flexion (FF), external rotation (ER), and internal rotation (IR) were recorded from electronic medical records. Preoperative and postoperative patient-reported outcomes (PROs) including American Shoulder and Elbow Score (ASES), Subjective Shoulder Value (SSV), and visual analog score (VAS) were also collected. To account for follow-up differences, an algorithm calculated the maximum duration of follow-up after the contralateral procedure and matched the index shoulder follow-up to this time interval, labeled as matched follow-up outcomes. Intraoperative characteristics were recorded for both surgeries, including rotator cuff involvement, tear thickness, tendon involvement, tear shape, anterior posterior (AP) dimension of tear, and degree of retraction.

RESULTS

After the researchers applied inclusion and exclusion criteria, the cohort was comprised of 76 patients. The average age at time of first and contralateral surgery was 59 ± 7.9 and 61 ± 8.0, respectively. The average time between surgeries was 1.64 ± 1.2 years. The incidence of bilateral rotator cuff repair was 6.87 of 100 patients per year. The preoperative ASES score of the first shoulder statistically significantly differed from the preoperative score for the contralateral shoulder but did not exceed most cited minimal clinically important difference (MCID) (first, 43.1 ± 19.6; contralateral, 50.5 ± 20.3; $p = 0.045$). Other preoperative PROs did not significantly differ, including the following: SSV (first, 49.6±24.3, contralateral, 45.9 ± 23.5; $p = 0.405$), and VAS (first 6.9 ± 1.9, contralateral, 6.6 ± 2.6, $p = 0.358$). No significant differences were found between the first and contralateral preoperative FF, ER ROM and FF, ER, IR strength. The tear characteristics did not significantly differ regarding AP tear size (1.3 ± 0.9, 1.2 ± 0.7, $p = 0.436$) or supraspinatus tear shape (kappa = 0.119).

The matched postoperative PROs did not differ between shoulders with ASES (first, 70.3 ± 22.3, contralateral, 72.9 ± 2.7; $p = 0.569$), SSV (first, 76.6 ± 25.22, contralateral 75.3 ± 25.7; $p = 0.884$), and VAS (first, 4.6 ± 14.3, contralateral, 2.1 ± 2.5; $p = 0.146$). No significant difference was found between the first and contralateral postoperative FF, ER ROM and FF, ER, IR strength. This remained true when comparing the unmatched PROs, except for SSV, which showed less improvement in patient-reported shoulder function in the contralateral shoulder with uneven follow-up ($p = 0.03$).

For patients whose operations took place within a year, the contralateral postoperative ER strength and IR strength statistically differed (ER, 4.8 versus 5, $p =0.017$; IR, 4.8 versus 5, $p = 0.047$). No other contralateral outcomes were found to differ statistically when divided by surgical time interval.

DISCUSSION

Patients who undergo bilateral primary arthroscopic RCR have similar PROs, ROM, and strength after their second, contralateral procedure compared to the first shoulder. Additionally, this study quantifies the incidence of patients undergoing contralateral repair: nearly 7 per 100 patients. The preoperative difference in ASES between first and contralateral repairs, although not meeting MCID, may result from patients picking the "worse" shoulder to repair first. Interestingly, the postoperative ER and IR strength of the contralateral side differed when the second surgery was done within one year, suggesting that allowing for full recovery from the first surgery may affect postoperative outcomes of the second. These data will better inform discussions of risks and benefits of contralateral rotator cuff repair.

INCIDENTAL TERES MINOR ATROPHY IN PATIENTS UNDERGOING ARTHROSCOPIC ROTATOR CUFF REPAIR OF THE SUPRASPINATUS OCCURS FREQUENTLY AND IS ASSOCIATED WITH WORSE POSTOPERATIVE OUTCOMES WITHOUT HIGHER FAILURE RATES

Steuer F[1], Okundaye O[2], McMahon S[1], Fox M[1], Lesniak B[1], Musahl V[1], Rodosky M[1], Lin A[1]

[1]University of Pittsburgh, Pittsburgh, Pa.
[2]Temple University, Philadelphia, Pa.

INTRODUCTION

Fatty infiltration and rotator cuff atrophy have been associated with poor clinical outcomes during rotator cuff repairs. Compared to supraspinatus and infraspinatus atrophy, there has been minimal research on the effect of teres minor atrophy on surgical outcomes and failure rates in rotator cuff repairs. The purpose of this study was to assess the incidence and outcomes of arthroscopic rotator cuff repair (ARCR) for partial- and full-thickness supraspinatus tears in patients with incidentally identified teres minor fatty infiltration.

METHODS

The researchers reviewed a consecutive series of 272 shoulders from 256 patients who underwent arthroscopic, double-row transosseous equivalent repair by one of three fellowship-trained surgeons (with minimum one-year follow-up) for partial- or full-thickness tear of the supraspinatus tendon. Revision repairs and concomitant subscapularis repairs were excluded. The researchers reviewed preoperative MRI to classify teres minor fatty infiltration using the modified Goutallier classification. They also collected preoperative and postoperative range of motion, strength, visual analog scale, subjective shoulder value (SSV), Patient-Reported Outcomes Measurement Information System (PROMIS) mental physical health subscales, American Shoulder and Elbow Surgeons Shoulder Score (ASES), and Brophy shoulder activity score. In addition, they collected rates of failure, defined as a symptomatic retear identified on postoperative MRI or need for revision surgery. Paired t-tests, Chi-squared tests, and Fisher's exact tests were utilized for continuous and binary variables, respectively. Statistical significance was at $p < 0.05$.

RESULTS

A total of 106 patients met the inclusion criteria, with 47 partial-thickness tears and 59 full-thickness tears. The average age of was 67 years and average follow-up was 30 months (range = 10–92) were included. Tear size (16.37 versus 13.62, p = 0.30) and Goutallier classification of supraspinatus (0.51 versus 0.62, p = 0.41) and infraspinatus (0.42 versus 0.47, p = 0.81) did not differ between the two groups. Incidental teres minor fat infiltration was present in 53% of cases, with an overall frequency in Goutallier stage as follows: 47% grade 0, 38% grade 1, 14% grade 2, 1% grade 3, and 0% grade 4. For partial tears, postoperative PROMIS mental and physical scores were significantly better in those without teres minor fatty infiltration versus those without (16.7 versus 14.3, p = 0.01; 15.5 versus 13.5, p = 0.02), whereas ROM, strength, and patient-reported outcome measurements (PROs) were not statistically significant. For full tears, those without fat infiltration had statistically significantly better PROs on PROMIS physical (16.25 versus 14.07, p = 0.01), ASES (83 versus 63, p = 0.02), Brophy (8.3 versus 5.2, p = 0.02), and SSV scores (94 versus 83, p = 0.046). No other differences in ROM, strength, or other PROs were identified. No differences were identified for retear and revision rates among patients regardless of fatty infiltration (partial: retear, 7.7% versus 9.5%, p = 0.59; revision, 7.7% versus 9.5%, p = 0.59; revision, 12.5% versus 5.7%, p = 0.18).

CONCLUSION

This study demonstrates that incidentally noted teres minor fatty infiltration occurs in more than 50% of patients undergoing arthroscopic rotator cuff repair for full-thickness supraspinatus tears and is associated with worse postoperative outcome scores without higher failure rates. Compared to full-thickness tears, teres minor atrophy in partial-thickness tears showed a lesser effect on outcome scores, with worse postoperative scores on only the PROMIS mental and physical subscales. Identification of these patients preoperatively with strategies to optimize may be necessary to improve outcomes.

DIVISION OF ORTHOPAEDIC TRAUMA

Dr. George V. Russell, MD, MBA
Professor of Orthopaedic Surgery
Chief, Division of Orthopaedic Trauma

I would like to offer an expression of gratitude for the opportunity to present a synopsis of the Orthopaedic Trauma Division as the newest member of the team. It has been an exciting six months, as the following paragraphs illustrate. It is a challenge to work out of two level 1 trauma centers, but we are coming together as a team, focusing on optimizing our trauma service.

In the past six months, we have taken a hard look at our strengths and weaknesses. We are celebrating our strengths, examining our weaknesses, and making significant strides to improve. Highlights of our efforts at improvement include: a weekly fracture conference with the UPMC Mercy and UPMC Presbyterian faculty and staff. As well, we have instituted a combined monthly journal club. Other operational improvements have also been initiated, which will set up the division to best care for patients, to educate our residents and fellows, and to expand the knowledge base of orthopaedic trauma through basic science and clinical research.

Perhaps the most enriching part of my new position at Pitt Orthopaedics is an opportunity to partner with the faculty to support their interests while focusing intently on the refinement of the division. Below are highlights of our faculty, written by two proud Pitt Ortho graduates: Gele Moloney, MD, and Peter Siska, MD.

UPMC Mercy
UPMC Mercy continues to thrive as a level 1 trauma center as well as burn center for the city. Orthopaedic trauma volumes remain robust, and general fracture care is provided primarily by Aaron Taylor, MD, Deniz Olgun, MD, and Dr. Moloney. In addition to the typical mix of high-energy fractures seen at most level 1 trauma centers, system initiatives continue to direct geriatric fracture volume to UPMC Mercy, creating an opportunity to create a geriatric center of excellence. Significant and ongoing effort has gone into creating geriatric care pathways to improve outcomes. This year has seen the formalization of a fracture liaison service, a combined effort with endocrinology to ensure patients are receiving appropriate pharmacologic treatment for osteoporosis following fragility fracture.

UPMC Mercy serves as a core site for resident trauma education with the postgraduate year (PGY)-5 chief residents each spending three months on the trauma service and PGY-4 residents spending six weeks.

Dr. Taylor continues to provide top-notch orthopaedic trauma care for the most complex of problems. He is valued by the residents as a dedicated educator, working most closely with the PGY-4 residents. His annual trauma lectures are widely regarded as some of the best. He has also taken an active role in medical student education, serving as the preceptor for the newly formed MS3 orthopaedic trauma rotation, encouraging early exposure to the field. He actively teaches the MS1 and MS2 musculoskeletal courses and small-group discussions.

Dr. Moloney serves as site principal investigator for the Major Extremity Trauma Research Consortium, as the trauma division is actively involved in some of the largest prospective, multicenter studies in the field of orthopaedic trauma. Drs. Moloney and Taylor are actively enrolling patients in a randomized, controlled trial evaluating the effects of early weightbearing following ankle fractures, which has the potential to broadly change practice. Dr. Moloney is also actively teaching resident courses on a national level through AO North America and the Orthopaedic Trauma Association (OTA).

Dr. Olgun adds a unique skillset to the group, as she is dual-fellowship-trained in both pediatric orthopaedics and orthopaedic trauma surgery, allowing her to care for complex trauma in patients of all ages. As evidence of her commitment to training residents, she received the Golden Apple Award at last year's resident graduation.

UPMC Presbyterian
The Orthopaedic Trauma Division at UPMC Presbyterian Hospital has undergone an exciting period of growth this past year, allowing for enhanced delivery of orthopaedic trauma care. Recognizing the need for consistent and timely communication with other medical and surgical services, the Department of Orthopaedic Surgery has added Lindsay Smell, PA-C, Minday Johns, CRNP, and Priscilla Mosesso, DNP, CRNP, to the trauma team. All have proven to be invaluable in this capacity. Furthermore, our division has added two new faculty members.

George V. Russell, MD, MBA, is our new chief of trauma. He comes to us from the University of Mississippi, where he served as the James L. Hughes Chair of Orthopaedic Surgery and the chief executive officer of University Physicians. Dr. Russell is a very well-known academic orthopaedic trauma surgeon, having served on many influential committees, including a board appointment from the OTA, and he has been active in the AO, with a commitment to educating the next generation of surgeons. He has received numerous academic awards, including University of Mississippi Medical Center, Department of Orthopaedic Surgery Professor of the Year in 2001, 2003, and 2014. Dr. Russell's specific area of interest is in pelvic and acetabular surgery, and he has authored numerous articles within this field of study. With his leadership, our trauma faculty will strive to carve out an enhanced national academic presence.

Dr. Russell has brought his commitment to education with him to UPMC, as highlighted by our weekly fracture conference, where the residents and faculty review the week's fracture cases in an in-depth and instructional way. Dr. Russell's historical perspective as to why our current practice patterns have developed has been much appreciated. Moreover, there has been a renewed focus on the quality of the operative experience for the younger residents, and this will pay huge dividends as they advance through their training.

Tyler Petersen, DO, has also joined as full-time trauma faculty at UPMC Presbyterian. He completed his orthopaedic trauma fellowship at UPMC last year and has continued to thrive as a surgeon and educator. He has become a favorite of the orthopaedic residents, as he has a unique gift of explaining the complexities of orthopaedic trauma in a way that is practical and relatable. Dr. Petersen is an expert in the care of polytraumatized patients and works closely with general surgery and critical care medicine to optimize patient outcomes. He is a clinical workhorse, providing timely care and throughput. We are delighted to have Dr. Petersen as part of our team.

Dr. Siska continues his very busy clinical practice in both orthopaedic trauma and adult reconstruction. With a focus on acute fracture care and arthroplasty, as well as complex post-traumatic reconstruction, Dr. Siska provides comprehensive orthopaedic trauma care at UPMC

Presbyterian Hospital. This "Traumaplasty" experience remains a highlight of the UPMC Orthopaedic Trauma Fellowship. Dr. Siska continues to collaborate with various medical and surgical services at UPMC Presbyterian to ensure comprehensive and timely care for the most complex patients. Furthermore, over this past academic year, Dr. Siska has worked closely with a multidisciplinary team to improve the Operative Hip Fracture Pathway at UPMC Presbyterian, as well as develop a compassionate Non-Operative Hip Fracture Pathway for optimal patient care.

The division would also like to recognize Dr. Moloney for her appointment to the OTA's Publications Committee. Additionally, we would like to celebrate the appointment of Stephen Chen, MD, as resident member of the OTA Disaster Management Committee and Stephen Canton, MD, as resident member of the OTA Classification and Outcomes Committee.

Finally, we would like to extend our most sincere thank you to Gary S. Gruen, MD, who retired this past year following an academic career that has spanned more than three decades. Dr. Gruen was influential in the development of a robust orthopaedic trauma service at UPMC Presbyterian. Generations of people in western Pennsylvania and beyond owe their lives and limbs to the talented hands of Dr. Gruen. Perhaps most importantly, Dr. Gruen has educated countless students, residents, and fellows. Many of us have chosen the field of orthopaedic trauma because of his teaching and passion. As such, his influence will continue to extend far beyond him and far beyond the time during which he practiced. Thank you, Dr. Gruen.

MARKERS OF IMMUNE FUNCTION AND TISSUE DAMAGE ARE ASSOCIATED WITH OPERATIVE DELAY AND MORTALITY AMONG ORTHOPAEDIC POLYTRAUMA PATIENTS

Canton SP[1], Brown JB[3,4], Guyette FX[2], Vodovotz Y[3,4], Johansson PI[5], Stensballe J[5], Billiar TR[5], Gruen GS[1], Sperry JL[3,4], Gruen DS[3,4]

[1]Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.
[2]Department of Emergency Medicine, University of Pittsburgh, Pittsburgh, Pa.
[3]Department of Surgery, University of Pittsburgh, Pittsburgh, Pa.
[4]Pittsburgh Trauma and Transfusion Medicine Research Center, Pittsburgh, Pa.
[5]Rigshospitalet, Copenhagen University Hospital, Denmark

INTRODUCTION

Optimizing surgical timing for severely injured orthopaedic polytrauma patients is challenging, and the decision to delay definitive surgical fixation may impact outcomes. Markers of immune function and tissue damage may inform the need for resuscitation and operative delay. The authors sought to evaluate the association among inflammatory mediators, orthopaedic fixation time, and mortality in a cohort of severely injured polytrauma patients.

METHODS

The researchers included severely injured polytrauma patients enrolled in the Prehospital Air Medical Plasma Trial who sustained orthopaedic fractures and were transported to University of Pittsburgh Medical Center. They sampled circulating markers of immune function and tissue damage at hospital admission and 24 and 72 hours after admission. They assessed patient and injury characteristics, surgical interventions, and marker values among patients who received orthopaedic fixation and those who died prior to definitive orthopaedic surgery. They modeled the association between inflammatory mediator trends over 72 hours and orthopaedic fixation time using linear mixed-effects models, controlling for injury characteristics and operative procedures.

RESULTS

Forty-six patients met inclusion criteria: 24 received early fixation (< 72 hours), 11 received delayed fixation (> 72 hours), six died prior to definitive orthopaedic surgical intervention, and four were deemed to have non-operative injuries. Patients were mostly male (78%) with blunt injuries (100%) and had a median Injury Severity Score (ISS) of 22. Although ISS was similar between surgical patients and non-survivors (22 [17, 30] versus 22 [17, 33], $p = 0.98$), several markers of immune function and tissue damage measured upon hospital admission stratified patients who died before orthopaedic fixation. Compared to similarly injured patients who received orthopaedic fixation, patients with pelvis or femur fractures who died prior to definitive surgery had significantly higher levels of interleukin (IL)-6, IL-8, monocyte chemoattractant protein-1, syndecan-1, and vascular endothelial growth factor and significantly lower levels of IL-2 and IL-7. Among patients who received early orthopaedic fixation, every hour of delay in definitive surgery was associated with a 5.3 pg/mL decrease in IL-6 ($p = 0.036$), even after the researchers controlled for injury and surgical characteristics.

DISCUSSION

Among severely injured orthopaedic polytrauma patients, circulating immune and tissue-damage markers measured upon admission were associated with mortality prior to definitive surgery. These markers may inform the timing of operative interventions or reveal the burden of a "second hit" to the body incurred by surgery following traumatic injury.

REFERENCES

1. Pape HC et al. *J of Orthopaedic Trauma*. 2005;19(8):551-62.
2. Sperry JL et al. *NEJM*. 2018;379(4):315-26.
3. McKinley TO et al. *J of Orthopaedic Trauma*. 2022;36(1):S14-20.

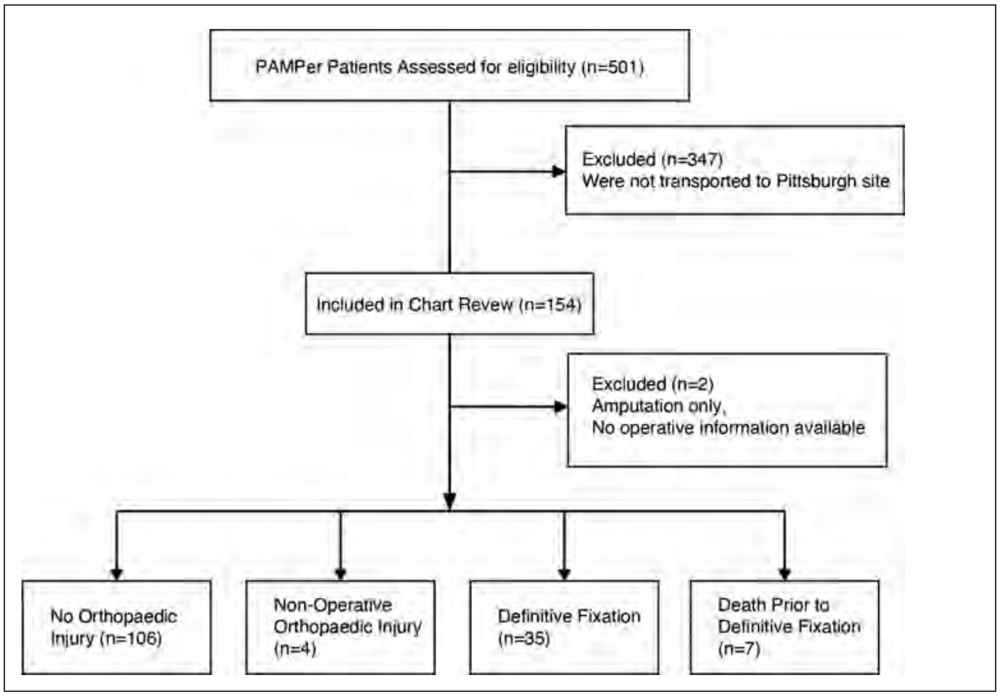


Figure 1. Events timeline

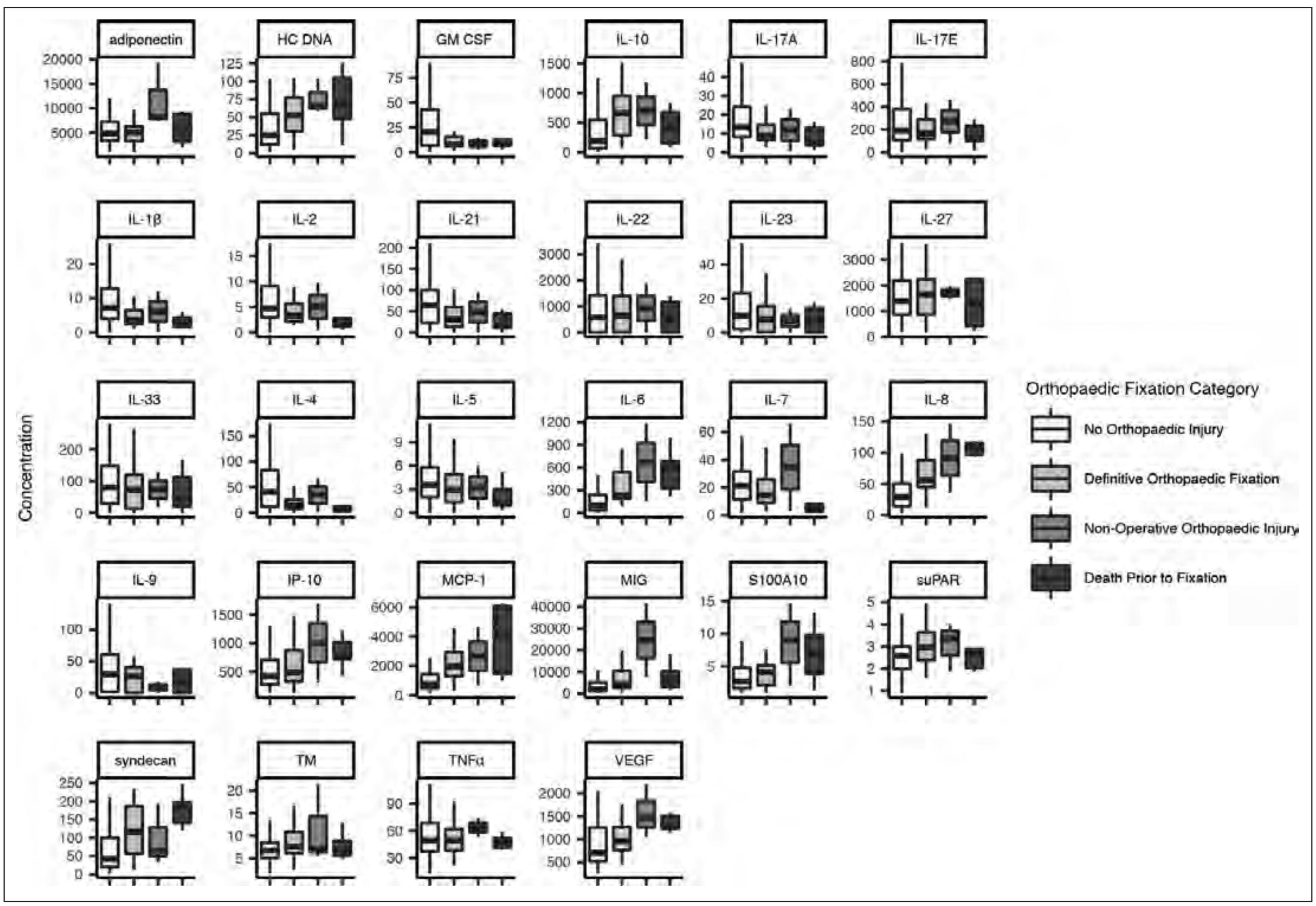


Figure 2. Admission biomarker values based on fixation status

DIVISION OF PEDIATRIC ORTHOPAEDIC SURGERY

W. Timothy Ward, MD
Professor of Orthopaedic Surgery
Chief, Division of Pediatric Orthopaedics

The physicians of the Division of Pediatric Orthopaedic Surgery at the University of Pittsburgh and UPMC Children's Hospital of Pittsburgh saw 36,361 patients and performed 1,809 surgeries in 2023. The academic offices and main clinic are located at the UPMC Children's Hospital of Pittsburgh (CHP) in Lawrenceville. Our physicians treat acute cases such as fractures and chronic diseases requiring long-term care for infants, adolescents, teens, and young adults. We offer regular scheduled clinics, same-day clinic, evening walk-in hours, and outpatient urgent care. Our physicians also travel to Shriners Hospitals for Children in Erie, Pennsylvania, and CHP satellite locations: north in Wexford, south in Bridgeville, and east in Monroeville. The division has been adding new clinical staff, including physician assistants, registered nurses, medical assistants, and schedulers to help make clinic visits more efficient and personable. Our physicians sincerely appreciate our clinical and surgical care teams.

Division Chief W. Timothy Ward, MD, professor of orthopaedic surgery, sees a variety of patients in his clinic, but one day a week is set aside for spine patients. A prevalent disease he sees in spine clinic is adolescent idiopathic scoliosis (AIS). Dr. Ward has many nonoperative and operative AIS patients. He is participating in a prospective, observational, multicenter international study of AIS long-term follow-up of greater than 20 years with sponsor, Setting Scoliosis Straight Foundation (SSSF) and the HARMS Study Group of San Diego, California.

Ozgur Dede, MD, associate professor of orthopaedic surgery, is medical director at Shriners Hospitals for Children in Erie. Dr. Dede is collaborating as coinvestigator with Senthil Senthilkumar, MD, in pediatric anesthesia and perioperative care for the U01 funded study titled "Perioperative Precision Medicine: Translating Science to Clinical Practice to Improve Safety and Efficacy of Opioids in Neonates, Children, and Nursing Mothers."

Stephen A. Mendelson, MD, assistant professor of orthopaedic surgery, is also coinvestigator on that study, He is director of the pediatric orthopaedic surgery fellowship program. Interviews for 2025–2026 fellowship year were held recently. Our 2022–2023 pediatric orthopaedic surgery fellow was Iara De Albuquerque Lacerda, MD. Our current fellow for 2023–2024 is Wasim Shihab, MD. The 2024–2025 fellow will be David Segal, MD. Former fellow Houssam Bouloussa, MD submitted an abstract to the Scoliosis Research Society, with Dr. Mendelson and Dr. Lacerda as co-authors, titled "The Amount of Curve Correction and Level Selection during Posterior Spinal Fusion for Adolescent Idiopathic Scoliosis Are Predictors of Distal Junctional Kyphosis."

Drs. Ward, Mendelson, and Dede focus on spine care, and they are pleased that the Spine Center at CHP continues in its seventh year. Patients receive surgical and nonsurgical care from our multidisciplinary on-site team of doctors, physical therapists, and orthotists, along with the state-of-the-art EOS 3D imaging.

Jan S. Grudziak, MD, PhD, is assistant professor of orthopaedic surgery and medical director of Children's Sports Medicine at CHP.

Z. Deniz Olgun, MD, assistant professor of orthopaedic surgery, is director of orthopaedic trauma at CHP. Dr. Olgun and colleagues' abstract titled "Radiation Knowledge and Safety in Orthopaedic Surgery" was accepted as an oral presentation for the J. Robert Gladden Orthopaedic Society Research Competition during the American Academy of Orthopaedic Surgeons annual meeting in San Francisco, California.

Michael P. McClincy, MD, was promoted to associate professor of orthopaedic surgery and remains the director of the Adolescent and Young Adult Hip Preservation Program at CHP. The program includes on-site physical therapy, surgical specialists, and nonoperative specialists with expertise in ultrasound imaging and interventions for treatment of hip pain. Ongoing research efforts are studying the impact of diseases such as femoroacetabular impingement and hip dysplasia, and biomechanical and patient-reported functional outcomes are an important part of the program. This year, Dr. McClincy received the St. Giles award grant at the 2023 Pediatric Orthopaedic Society of North America meeting for hip biomechanics cadaveric research titled "Evaluation of Hip Labral and Capsular Strain under Physiologic Loading," a collaborative study with Patrick Smolinski, PhD. The primary objective of the project is to develop a physiologic, weight-bearing cadaveric model for hip biomechanics. Dr. McClincy was also awarded a PInCH award from the University of Pittsburgh's Clinical and Translational Science Institute for further work in developing a remote shoulder-rehabilitation device alongside Kevin Bell, PhD, and ēlizur. Dr. McClincy recently applied for a National Institutes of Health R01 grant with William Anderst, PhD, to evaluate the effects of mild hip dysplasia on hip kinematics before and after surgery.

Amanda J. McCoy, MD, MPH, assistant professor of orthopaedic surgery, participated in the Lim Lengthening and Reconstruction Society pediatric traveling fellowship for five weeks in the summer of 2023. She completed analysis for a project involving incidence of slipped capital femoral epiphysis (SCFE) and the Child Opportunity Index (COI), and the manuscript will soon be submitted. Continuing with her interests in healthy equity and social determinants of health (SDoH), Dr. McCoy expanded her Institutional Review Board–approved protocol looking at the incidence SCFE and COI to "Common Pediatric Orthopaedic Surgical Conditions and SDoH Study," adding three more surgical conditions: supracondylar humerus fracture, femoral shaft fracture, and Blount disease.

Jessica L. Hughes, MD, assistant professor of orthopaedic surgery, continues with her clinical and research interests in hip deformity and neuromuscular diseases and the project "Pelvic Osteotomy in Older Children."

The division came together outside of work as well to participate in the Walk for Children's on June 3, 2023, benefiting the UPMC Children's Hospital Foundation. The walk started at 9 am near the Carnegie Library in Oakland. It was well attended by our team, "Hip-Hip Hooray." We had team T-shirts and a potluck lunch immediately following the walk. The walk celebrated a milestone of raising over $1 million at the event.

Selected 2023 Publications

Page BJ, Hughes JL, Walsh JM, Stimson LN, Hammonds KP, Brennan KL, Stahl DL, Brennan ML. Association of brain natriuretic peptide levels at time of injury with morbidity and mortality in patients with surgically treated hip fractures. *JBJS Open Access*. 2023;8(2):e22.00102. doi: 10.2106/JBJS.OA.22.00102.

Curley AJ, Engler ID, Ruh ER, Mauro CS, McClincy MP. Periacetabular osteotomy after failed hip arthroscopy demonstrates improved outcomes in a heterogenous patient population: a systematic review. *KSSTA*. 2023.

Grandberg C, Fox MA, Engler ID, Cong T, Musahl V, McClincy MP. Femoral physeal-sparing ACL Reconstruction with iliotibial band autograft over-the-top with associated lateral extra-articular tenodesis. *Video Journal of Sports Medicine*. 2023.

Özbek EA, Runer A, Dadoo S, Dalton J, McClincy M, Yen YM, Heyworth B. Introducing skeletally-mature anterior cruciate ligament reconstruction technique using reinforcement (SATURN) with iliotibial band autograft. *Arthrosc Tech*. 2023;12(11):e1867-72. doi: 10.1016/j.eats.2023.07.005.

Hughes JL, Fogleman SA, Chun L, Bomar JD, Edmonds EW. Comparing outcomes in the treatment of pediatric and adolescent intraarticular radial head fractures. *J Pediatr Orthop B*. 2023;32(6):593-8. doi: 10.1097/BPB.0000000000001049.

Özbek EA, Runer A, Dadoo S, DiNenna M, Linde M, Smolinski P, Musahl V, McClincy MP. The effect of lateral extra-articular tenodesis in an ACL-reconstructed knee with partial medial meniscectomy: a biomechanical study. *Am J Sports Med*. 2023;51(13):3473-9. doi: 10.1177/03635465231198856.

Disantis AE, Martin RL, Enseki K, Spaid V, McClincy M. Non-operative rehabilitation principles for use in individuals with acetabular dysplasia: a North American based Delphi study. *Int J Sports Phys Ther*. 2023;18(6):1331-45. doi: 10.26603/001c.89265.

Dr. McClincy at the Walk for Children's 2023 event wearing the Hip Hip Hooray team t-shirts

THE AMOUNT OF CURVE CORRECTION AND LEVEL SELECTION DURING POSTERIOR SPINAL FUSION FOR ADOLESCENT IDIOPATHIC SCOLIOSIS ARE PREDICTORS OF DISTAL JUNCTIONAL KYPHOSIS

Bouloussa H[1], Lacerda I[2], Maali R[1], Fourman M[2], Xi W[1], Cheng A[1], Mendelson SA[2]

[1]University of Missouri-Kansas City, Kansas City, Mo.
[2]Department of Orthopaedic Surgery, UPMC Children's Hospital of Pittsburgh, Pittsburgh, Pa.

HYPOTHESIS

Posterior spinal fusion (PSF) for adolescent idiopathic scoliosis (AIS) with a lowest instrumented vertebra (LIV) proximal to the last substantially touched vertebra (LSTV) and high Cobb angle corrections may lead to distal junctional kyphosis (DJK) and revision.

INTRODUCTION

A growing body of evidence is highlighting the role of level selection and sagittal balance in the development of distal junctional kyphosis (DJK). The purpose of this study is to identify new risk factors for developing DJK based on surgical strategy and sagittal balance in the coronal and sagittal planes.

METHODS

Patients with AIS who underwent PSF were included in a single-center, retrospective study. Mean follow-up was 3.9 years. Demographic data (age, sex, body mass index) and preoperative radiographic parameters, including Risser stage, Lenke type, Cobb angle, and spinopelvic sagittal parameters (SPP), were measured. Postoperatively, both coronal (distance from C7 plumb-line [C7PL] to LIV, central sacral vertical line [CSVL] to C7PL, CSVL to LIV) and sagittal (distance from LIV to sagittal stable vertebra, from LIV to LSTV, neutral vertebra, and stable vertebra) parameters were measured. SPP and curve correction were measured at last follow-up. Patients were stratified into DJK ($\geq$ 10°) and non-DJK groups. Bivariate analyses and logistic regression models were employed to estimate and examine the potential risk factors associated with DJK.

RESULTS

Overall, 116 patients met inclusion criteria (14.3 ± 1.77 years of age). The prevalence of DJK was 18% (n = 21). Demographics, Lenke types, and preoperative radiographic parameters did not differ between the DJK and non-DJK groups ($p > 0.05$). LSTV was on average 0.6 ± 1.2 vertebra proximal to LIV in the DJK group, but it was 0.1 ± 1.2 vertebra distal to LIV in the non-DJK group ($p < 0.05$). The curve correction was significantly higher in the DJK group versus the non-DJK group, respectively 68.7% versus 62% ($p < 0.05$). The DJK group was associated with a significantly higher pelvic tilt (PT) increase at last follow-up (+8.7 ± 13.2° versus +1.3 ± 8.0°; $p < 0.05$). There were six revisions (five for DJK or adding on and one infection).

CONCLUSION

Fusing short of the LSTV and high curve correction are predictors for predominantly asymptomatic DJK following PSFs for AIS.

Dependent: DJK		Yes	No	OR (univariable)	OR (multivariable)
AGE	Mean (SD)	13.7 (1.5)	14.5 (1.8)	1.31 (0.99-1.77, p=0.064)	1.09 (0.71-1.69, p=0.706)
BMI	Mean (SD)	23.6 (5.6)	21.7 (4.4)	0.92 (0.83-1.02, p=0.116)	0.94 (0.81-1.10, p=0.451)
LSTV	Mean (SD)	**-0.6 (1.2)**	**0.1 (1.2)**	1.64 (1.06-2.67, **p=0.033**)	2.19 (0.98-5.55, p=0.070)
SSV	Mean (SD)	0.1 (2.3)	-0.8 (2.2)	0.82 (0.65-1.02, p=0.082)	0.89 (0.58-1.30, p=0.569)
CSVL_C7	Mean (SD)	44.1 (25.8)	38.4 (26.8)	0.99 (0.97-1.01, p=0.378)	0.98 (0.94-1.01, p=0.152)
Cobb correction	Mean (SD)	**68.7 (16.3)**	**62.0 (12.5)**	0.96 (0.93-1.00, **p=0.048**)	0.91 (0.84-0.96, **p=0.006**)
PT Var	Mean (SD)	**8.7 (13.2)**	**1.3 (8.0)**	0.93 (0.87-0.97, **p=0.006**)	0.88 (0.80-0.95, **p=0.005**)

Table 1. Multivariate Logostic Regression

NONOPERATIVE REHABILITATION PRINCIPLES FOR USE IN INDIVIDUALS WITH ACETABULAR DYSPLASIA: A NORTH AMERICAN–BASED DELPHI STUDY

Disantis AE[1,2], Martin RL[2], Enseki K[3], Spaid V[4], McClincy M[1]

[1]Adolescent and Young Adult Hip Preservation Program, UPMC Children's Hospital of Pittsburgh, Pittsburgh, Pa.
[2]Rangos School of Health Sciences, Department of Physical Therapy, Duquesne University, Pittsburgh, Pa.
[3]UPMC Freddie Fu Center for Sports Medicine, UPMC Rehabilitation Institute, Pittsburgh, Pa.
[4]Department of Orthopaedic Surgery, UPMC Children's Hospital of Pittsburgh, Pittsburgh, Pa.

BACKGROUND

Acetabular dysplasia (AD) is defined as a structurally deficient acetabulum and is a well-recognized cause of hip pain in young adults. Although treatment of severe AD with a periacetabular osteotomy has demonstrated good long-term outcomes, a trial of nonoperative management is often recommended in this population. This may be especially true in patients with milder deformities. Currently, there is a paucity of research pertaining to nonoperative management of individuals with AD.

PURPOSE

The purpose of the study was to present expert-driven nonoperative rehabilitation guidelines for use in individuals with AD.

METHODS

A panel of 15 physiotherapists from North America who were identified as experts in nonoperative rehabilitation of individuals with AD in a high-volume hip-preservation program participated in the study. Panelists were presented with 16 questions regarding evaluation and treatment principles. A three-step Delphi method was utilized to establish consensus on nonoperative rehabilitation principles.

RESULTS

Total (100%) participation was achieved for all three survey rounds. Consensus, defined a priori as > 75%, was reached for 16/16 questions regarding evaluation principles, activity modifications, appropriate therapeutic exercise progression, return to activity/sport criteria, and indications for physician referral.

CONCLUSION

This North American–based Delphi study gathered expert-based consensus on nonoperative rehabilitation principles for use in individuals with AD. Establishing guidelines for nonoperative management in this population will help reduce practice variation and is the first step in stratifying individuals who would benefit from nonoperative management. Future research should focus on patient-reported outcomes and rate of subsequent surgical intervention to determine the success of the guidelines reported in this study.

FEMORAL PHYSEAL-SPARING ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION WITH ILIOTIBIAL BAND AUTOGRAFT OVER-THE-TOP TECHNIQUE WITH ASSOCIATED LATERAL EXTRA-ARTICULAR TENODESIS

Grandberg C, Fox MA, Engler ID, Cong T, Musahl V, McClincy MP

Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.

BACKGROUND

Injuries to the anterior cruciate ligament (ACL) in the pediatric population have been exponentially increasing over the years. However, surgical techniques typically employed for ACL reconstruction (ACL-R) in adults may injure the physes of skeletally immature patients, resulting in growth disturbances.

INDICATIONS

Currently, ACL-R is recommended for most patients, aiming to return them to their previous activities as well as reduce the risk of further instability, meniscal and chondral injuries, and early osteoarthritis. Pediatric ACL-R techniques may vary widely. The authors created a video demonstrating the over-the-top technique on the femur with a vertical tibial tunnel, in addition to lateral extra-articular tenodesis, using the iliotibial (IT) band as the graft.

TECHNIQUE DESCRIPTION

The patient is positioned in standard supine arthroscopic position. An incision is made over the lateral epicondyle and the IT band is exposed. A 2-cm-wide graft is harvested. The proximal aspect of the graft is truncated as high as possible, and the distal aspect is left attached to Gerdy tubercle. Arthroscopic portals are established, and the remanent ACL is debrided, exposing the posterior aspect of the lateral femoral condyle. The capsule is penetrated with a Schnidt tonsil to establish the over-the-top position, which is subsequently exchanged for a cardiac clamp. The graft sutures are grasped with the clamp and pulled into the joint. The tibial tunnel is drilled at the anatomic footprint of the ACL. The graft is threaded over the top of the lateral femoral condyle and through the tibial tunnel. Finally, femoral graft fixation is performed on the lateral femoral condyle with interrupted sutures through the IT band and periosteum, and tibial graft fixation is performed with standard interference fixation.

RESULTS

Previous literature shows low re-rupture rates, excellent postoperative patient-reported outcomes, and high return-to-sport rates.

CONCLUSION

In the pediatric population, there is still no ACL-R technique defined as the gold standard. The described technique is a valuable option for ACL-R in skeletally immature patients, with low revision rates and excellent postoperative outcomes. In addition, this technique minimizes the risk of growth disturbances and effectively stabilizes the knee, allowing patients to return to previous activities.

The video was published in the *Video Journal of Sports Medicine* in June 2023.

COMPARING OUTCOMES IN THE TREATMENT OF PEDIATRIC AND ADOLESCENT INTRA-ARTICULAR RADIAL HEAD FRACTURES

Hughes JL[1 2], Fogleman SA[1], Chun L[1], Bomar JD[1], Edmonds EW[1]

[1]Department of Orthopedics, Rady Children's Hospital, San Diego, Calif.
[2]Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.

BACKGROUND
Intra-articular radial head (IARH) fractures are uncommon pediatric injuries with unpredictable yet poor outcomes.

HYPOTHESIS
The aim of this study was to evaluate clinical outcomes of IARH fractures in pediatric and adolescent patients. The authors tested the hypothesis that surgically managed fractures would have less risk for unplanned second surgery and result in better elbow range of motion at final follow-up.

METHODS
The researchers performed a retrospective review of 53 IARH fractures. They documented demographic and clinical data, concomitant and associated injuries, initial management, and any attempted reduction in the emergency room. The primary outcome was the need for an unplanned second procedure. The researchers reviewed motion at final follow-up, presence of pain, and need for physical therapy. They carefully reviewed and analyzed radiographs for physeal status, displacement, angulation, and percentage of radial head involved.

RESULTS
The authors rejected their hypothesis because displaced fractures tended to require an unplanned change in treatment at a higher rate than nondisplaced fractures, regardless of index management with or without surgery. Fracture displacement on the lateral radiograph was a significant risk factor compared to the anteroposterior images, and younger patients, particularly those with open physis, were at higher risk of an unplanned second procedure. Moreover, 80% of displaced fractures had asymmetric elbow motion after healing was achieved.

CONCLUSION
It is important to counsel patients and families regarding the potential for suboptimal outcomes and elbow stiffness, regardless of treatment choice, in the setting of an initially displaced IARH fracture.

INCIDENCE OF SCFE IS ASSOCIATED WITH LOW CHILDHOOD OPPORTUNITY INDEX

McCoy AJ[1], Hughes JL[1], Olgun ZD[1], McClincy MP[1], Yahner K[2], Wittman SR[2], Ray KN[2]

[1]Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.
[2]Department of Pediatrics, UPMC Children's Hospital of Pittsburgh, Pittsburgh, Pa.

BACKGROUND
Slipped capital femoral epiphysis (SCFE) is a common adolescent hip condition that has historically been associated with certain demographic factors, obesity, and adverse social determinants of health (SDoH). The Child Opportunity Index 2.0 (COI) is an aggregate measure by ZIP code and census tract of 29 features of communities that can impact the life outcomes of children, including measures related to socioeconomic circumstances, educational resources, and built environment. The authors aimed to investigate the relationship between the incidence of SCFE and COI.

METHODS
The researchers retrospectively queried the surgical database of a tertiary referral children's hospital in a medium-sized metropolitan area by CPT code. They identified subjects who underwent index surgical fixation of SCFE from January 1, 2010, to December 31, 2022. They collected subject demographic data, body mass index (BMI), SCFE stability, and SCFE chronicity. Using residential address ZIP code, they determined the composite COI level, normalized at the national and metropolitan levels. They then calculated the incidence rate, stratified by COI level for the metropolitan area. They performed chi-square analysis to determine the associations of SCFE chronicity and stability with COI and obesity (defined as BMI > 95% on the Centers for Disease Control and Prevention growth charts).

RESULTS
The researchers reviewed 426 hips in 389 unique subjects. Focusing within the metropolitan area, they identified a total of 244 hips in 220 unique subjects for an annual incidence rate of 4.17 per 100,000 person-years. In the metropolitan area, communities in the lowest quintile of COI level had higher SCFE incidence rates (7.1 per 100,000 person-years), whereas communities in the highest quintile of COI levels had lower SCFE incidence rates (2.7 per 100,000 person-years). The relative risk of SCFE decreased by 11% for each increase in COI quintile (RR = 0.89, 95% confidence interval: 0.76–1.01). Unexpectedly, when the researchers stratified the analysis by race, they found that Black children trended to have higher rates of SCFE with increasing COI level ($p = 0.28$). The researchers identified a correlation between obesity and chronicity in the general analysis ($p = 0.012$) and in the metropolitan area analysis ($p = 0.005$).

CONCLUSION
This study demonstrated an inverse relationship between overall SCFE incidence and COI level, an aggregate measure of community resources that affect childhood outcomes, at a pediatric tertiary referral center. The direction and significance of this association differed when stratified by race.

SIGNIFICANCE
The effects of SCFE are long-lasting. Clarifying the relationship with SDoH and race may aid in developing early-detection and prevention programs.

INTRODUCING SKELETALLY MATURE ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION TECHNIQUE USING REINFORCEMENT (SATURN) WITH ILIOTIBIAL BAND AUTOGRAFT

Özbek EA[1,2], Runer A[1,3], Dadoo S[1], Dalton J[1], McClincy M[1], Yen Y[4], Heyworth B[4]

[1]Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.
[2]Department of Orthopaedics and Traumatology, Ankara University, Ankara, Turkey
[3]Department for Orthopaedic Sports Medicine, Klinikum rechts der Isar, Technical University of Munich, Munich, Germany
[4]Boston Children's Hospital, Harvard Medical School, Boston, Mass.

Anterior cruciate ligament (ACL) injuries are increasingly common in the adolescent age group. Recent literature has endorsed combining ACL reconstruction with lateral extra-articular procedures to minimize residual rotatory knee instability and reduce the risk of reinjury in this age group. This technique describes a single-bundle combined anatomical ACL reconstruction and lateral extra-articular reinforcement performed with a single iliotibial band autograft. Also, this technique allows for ACL reconstruction and lateral extra-articular stabilization to be performed through a single surgical incision while obtaining autograft tissue without disruption of the extensor or hamstring mechanisms.

SURGICAL TECHNIQUE

Graft Harvesting

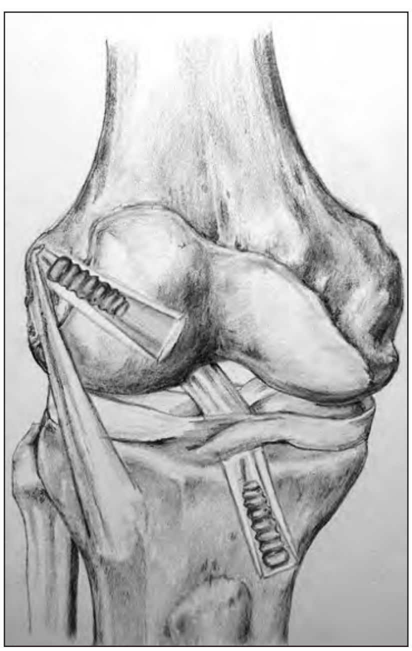
An oblique 5 cm lateral skin incision is created from just posterior to the lateral epicondyle. The ITB's anterior and posterior borders are identified, and the central 80% is harvested, achieving an ideal graft length of 15 cm from the lateral epicondyle for reconstruction. The ITB graft tissue is cut proximally with a curved meniscotome and distally, the ITB graft tissue is separated past the lateral epicondyle to the level of the lateral joint line, leaving the ITB insertion and joint capsules intact. The ITB graft is then sutured to be tubularized at a length of 2 to 3 cm from its proximal end, and graft thickness is measured, with a typical diameter of 7.5 to 9 mm.

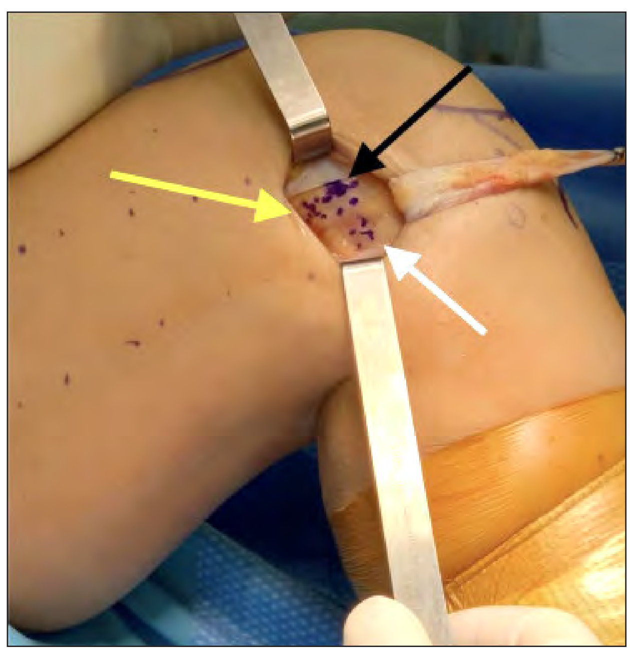
Tunnel Preparation

To begin the ACL-R, while viewing through the medial portal, a retrograde femoral aiming guide is inserted via the lateral portal and placed at the anatomic ACL femoral footprint. Once in place, a guidewire is passed across the lateral femur to connect the extra-articular (anterolateral ligament) and intra-articular (ACL) femoral footprints, and its position confirmed at both locations. The femoral tunnel is then created in a retrograde manner, and a looped suture is shuttled across the femoral tunnel to enable future graft passage. The tibial tunnel is then prepared, using an aiming arm introduced through the medial portal and centered at the tibial ACL footprint. After positioning of the drilling sleeve and creation of the tibial incision for tunnel creation and graft passage, the drilling sleeve is inserted to the tibial cortex and tunnel length measurements are made. A 2.4 mm pin is then introduced across the guide and into the joint, and its anatomic position is confirmed. After anatomic pin placement, an appropriately sized tibial tunnel is drilled using a rigid reamer. The passing stitch through the femoral tunnel is retrieved through the tibial tunnel.

Graft Passage and Fixation

The graft, still attached at Gerdy's tubercle, is passed through the femoral tunnel across the joint and through the tibial tunnel. This routes the ITB graft to span both the anterolateral ligament and ACL anatomy. Lateral extra-articular tenodesis fixation is then performed with the knee flexed between 70 to 80 degrees, and a bioabsorbable screw is inserted at the extra-articular aperture while applying maximal tension to the graft. The knee is then brought into a position of extension or slight flexion with a reverse-Lachman stress placed the proximal tibia. The ACL graft is then maximally tensioned and fixated with insertion of a bioabsorbable screw.





THE EFFECT OF LATERAL EXTRA-ARTICULAR TENODESIS IN AN ACL-RECONSTRUCTED KNEE WITH PARTIAL MEDIAL MENISCECTOMY: A BIOMECHANICAL STUDY

Özbek EA[1,2], Runer A[1,3], Dadoo S[1], DiNenna M[4], Linde M[1], Smolinski P[1,4], Musahl V[1], McClincy MP[1]

[1]Department of Orthopaedic Surgery, University of Pittsburgh Medical Center, Pittsburgh, Pa.
[2]Department of Orthopaedics and Traumatology, Ankara University, Ankara, Turkey
[3]Department for Orthopaedic Sports Medicine, Technical University of Munich, Munich, Germany
[4]Department of Mechanical and Materials Science, Swanson School of Engineering, University of Pittsburgh, Pittsburgh, Pa.

BACKGROUND
Knee laxity increases with medial meniscectomy in anterior cruciate ligament (ACL)-reconstructed knees; however, the biomechanical effect of an additional lateral extra-articular tenodesis (LET) is unknown.

PURPOSE/HYPOTHESIS
The purpose of this study was to determine the kinematic effect of LET in knees that underwent combined ACL reconstruction (ACL-R) and partial medial meniscus posterior horn (MMPH) meniscectomy. The authors hypothesized that the addition of LET would reduce laxity after ACL-R.

METHODS
The controlled laboratory study tested 10 fresh-frozen human cadaveric knees (mean age, 41.5 years) with a robotic system under three loads: (1) 89.0 N of anterior tibial (AT) load, (2) 5 Nm of internal rotation (IR) tibial torque, and (3) a simulated pivot shift: a combined valgus of 7 Nm and IR torque of 5 Nm at 0°, 15°, 30°, 45°, 60°, and 90° of knee flexion. Kinematic data were acquired in four states: (1) intact, (2) ACL-R, (3) ACL-R plus partial MMPH meniscectomy (MMPH group), and (4) ACL-R plus partial MMPH meniscectomy + LET (MMPH+LET).

RESULTS
In response to AT loading, there was a significant increase in AT translation (ATT) in the MMPH state at all knee flexion angles compared with the ACL-R state, with the highest increase at 90° of knee flexion (mean difference, 3.1 mm) ($p < 0.001$). Although there was a significant decrease in ATT at 15° of knee flexion with MMPH + LET ($p = 0.022$), no significant differences were found at other knee flexion angles ($p > 0.05$). In MMPH with IR torque, a significant increase was observed in IR at all knee flexion angles except 90° compared with the ACL-R state (range = 2.8°–4.9°), and this increase was significantly decreased at all flexion angles with the addition of LET (range = 0.7°–1.6°) ($p < 0.05$).

CONCLUSION
Performing a partial MMPH meniscectomy increased ATT and IR in response to AT and IR loads compared with the isolated ACL-R state in a cadaveric model. However, when the LET procedure was performed after partial MMPH meniscectomy, a significant decrease was seen at all knee flexion angles except 90° in response to IR and torque, and a significant decrease was seen at 15° of knee flexion in response to AT load.

CLINICAL RELEVANCE
LET may be a useful adjunct procedure after ACL-R with partial MMPH meniscectomy to reduce knee laxity.

ANTEROINFERIOR ILIAC SPINE OSTEOPLASTY AT THE TIME OF PERIACETABULAR OSTEOTOMY HELPS PRESERVE PREOPERATIVE RANGE OF MOTION

Shihab W, Luck C, Dalton J, Disantis A, Oakley J, McClincy M

UPMC Children's Hospital of Pittsburgh, Pittsburgh, Pa.

INTRODUCTION

Iatrogenic femoroacetabular impingement (FAI) following periacetabular osteotomy (PAO) is a well-documented cause of early failure and poor results. The anterior inferior iliac spine (AIIS) is an increasingly recognized source of extra-articular FAI, and previous studies have documented AIIS morphologic subtypes at risk for FAI in patients undergoing PAO for hip dysplasia. The typical reorientation maneuver to increase anterior and lateral hip coverage during PAO theoretically increases the likelihood of subspine impingement. To the authors' knowledge, no studies have evaluated the effects of PAO with concomitant AIIS osteoplasty on range of motion (ROM) and function.

METHODS

The authors performed a retrospective study of 63 consecutive hips in 55 patients who underwent PAO with concomitant AIIS osteoplasty between the years 2019 and 2023. All patients underwent pelvic computed tomography (CT) with 3D reconstruction including condylar cuts. AIIS was classified with 3D reconstruction, and femoral version was measured on axial CT imaging. ROM of hip internal rotation (IR) at 90 degrees was systematically recorded during preoperative exam, intraoperatively following PAO (pre-osteoplasty and post-osteoplasty), and at six months postoperatively. Merle d'Aubigné (MDA) scores were calculated preoperatively and postoperatively. IR motion changes across timepoints were compared with repeated-measures analyses of variance with post-hoc comparisons using a Bonferroni correction. Regression analyses were performed to evaluate the impact of femoral version on motion parameters before and after AIIS osteoplasty. MDA scores were compared with a pairwise t-test.

RESULTS

Significant clinical improvements in MDA scores were noted at the latest follow-up. Repeated-measures analyses of variance showed significant changes in hip internal rotation following PAO with concomitant AIIS osteoplasty ($F = 10.9$, $p < 0.01$). Table 1 shows hip IR motion across multiple timepoints. IR motion loss was noted following acetabular reorientation, but addition of an AIIS osteoplasty significantly improved IR intraoperatively, and this motion was preserved at long-term follow-up. No differences were noted in hip IR comparing preoperative to postoperative motion. The impact of IR restoration with AIIS osteoplasty correlated significantly with femoral version, with greater motion improvement noted in patients with lower femoral version ($t = 3.3$, $p < 0.01$).

CONCLUSION

When planning PAO for hip dysplasia, careful appreciation of motion parameters is critical. Regardless of AIIS morphology, consideration of an intraoperative AIIS osteoplasty should occur in cases where IR is decreased following acetabular reorientation.

SIGNIFICANCE

Future work to better understand the potential sources of FAI following PAO, including acetabular position and femoral morphology, is important to improve our ability to prevent impingement and improve function.

Timepoint	Mean	SD	Pre-Op	Pre-Osteoplasty	Post-Osteoplasty	Post-Op
			Post-Hoc Bonferroni Comparison (* indicates P<.01)			
Pre-Op	31.8	12.4	XXXX	*		
Pre-Osteoplasty	26.9	6.6	*	XXXX	*	*
Post-Osteoplasty	34	5.8		*	XXXX	
Post-Op	31.4	5.3		*		XXXX

Table 1. Mean and standard deviation results for hip internal rotation at various stages during the periacetabular osteotomy surgery. Asterisks denote significant differences in motion patterns at the various time points.

RADIATION KNOWLEDGE AND SAFETY IN ORTHOPAEDIC SURGERY

Umanes MM, Clayton EO, Iglesias B, Whicker EA, Olgun ZD, Donaldson W, Hogan M

Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.

BACKGROUND
Orthopaedic surgeons are among the top three medical professionals who are most exposed to ionizing radiation; hence, they have a responsibility to minimize the risks of ionizing radiation to patients, themselves, and staff. Best-practice principles, including "as low as reasonably achievable" (ALARA), guide clinical practice such that radiation exposure should be clinically justified and performed by a trained professional to minimize radiation exposure. Currently, few studies exist that aim to understand the level of radiation knowledge among academic orthopaedic surgery departments.

PURPOSE
The purposes of the study were to (1) investigate radiation safety best practices, knowledge regarding the ALARA principle, and compliance with protective equipment within an academic department of orthopaedic surgery and (2) identify the availability of and level of satisfaction with protective equipment at the various hospital locations associated with the academic institution.

METHODS
The researchers conducted an anonymous REDCap web-based survey among orthopaedic surgery residents, fellows, physician assistants, faculty, and others within the University of Pittsburgh Department of Orthopaedic Surgery over six months. It collected data on knowledge of radiation safety, basic principles of radiation, and best practices. Knowledge and practice scores were compared among different groups within the department. Descriptive statistics were used to illustrate orthopaedics personnel's surgical practices and radiation safety knowledge. Analysis of variance was used to compare score outcomes between orthopaedics personnel who feel adequately trained in radiation safety knowledge and those who do not feel adequately trained in knowledge of radiation practices. Results with a p value of < 0.05 were considered statistically significant.

RESULTS
Overall, 58 orthopaedic surgery personnel responded to the survey, including 21 (36.21%) residents, nine (15.52%) fellows, five (8.62%) professors, six (10.34%) associate professors, six (10.34%) assistant professors, and 11 (18.97%) physician assistants. The average knowledge and practice scores were 9.72 out of 20 and 19.63 out of 48 points, respectively. No statistically significant differences were found between type of orthopaedic personnel and score outcomes. The availability of some lead protective equipment trended low, but the level of satisfaction with lead aprons overall trended high across hospital locations.

CONCLUSION
There is an opportunity to enhance knowledge of radiation safety and practices among the personnel of the Department of Orthopaedic Surgery at the academic institution. Likewise, there is room for improving personal protective equipment at the hospital locations associated with the academic institution.

UPMC ST. MARGARET

Alex Kline, MD

UPMC St. Margaret and the affiliated UPMC Harmar Surgery Center had another very strong year in 2023–2024.

Resident training remains at the core of UPMC St. Margaret's educational program, as it has for many years. The residents receive a broad experience in the operating room and office setting, where they continue to be exposed to all facets of orthopaedic surgery. They are exposed to managing patients in the operating room, office, and emergency department. The residents continue to enjoy their rotations at UPMC St. Margaret, and it is very exciting to watch them progress.

In addition to the core rotations at UPMC St. Margaret, we have had an increasing number of senior residents who have come back to do elective rotations with us. Their desire to come back for additional training and the eagerness of our faculty to have them speak highly to the quality of training received at UPMC St. Margaret. It is amazing to watch the residents progress during their time with us, and we take great pride in helping to guide them in their career paths. The ongoing relationships that we have amongst our colleagues in the department remain very strong.

In addition to training residents, we have also have the pleasure of helping to train fellows in sports medicine, foot and ankle surgery, and total joints. The training and teaching aspects of the UPMC St. Margaret program have always been and will continue to be a focal point of the UPMC St. Margaret experience.

Next year, we will welcome back Joe Kromka, MD, and Alan Wilson, MD, into the mix at UPMC St. Margaret. We continue to enjoy working closely with the residency program and can't wait for another great year in 2024–2025.

UPMC MERCY

Gele B. Moloney, MD
Division Chief

John R. Fowler, MD
Associate Division Chief

UPMC Mercy continues to thrive as a level 1 trauma center, as well as burn center for the city. Orthopaedic trauma volumes remain robust, and general fracture care is provided by Aaron Taylor, MD, Deniz Olgun, MD, and Gele Moloney, MD. Under the leadership of Associate Division Chief John Fowler, MD, the upper-extremity service at UPMC Mercy continues to thrive with Dr. Fowler and Jennifer D'Auria, MD. The podiatry section remains active under the leadership of Jeff Manway, DPM, and Jarrett Cain, DPM.

In addition to the typical mix of high-energy fractures seen at most level 1 trauma centers, system initiatives continue to direct geriatric fracture volume to UPMC Mercy, providing an opportunity to create a geriatric center of excellence. Significant and ongoing effort has gone into creating geriatric care pathways to improve outcomes. This year has seen the formalization of a Fracture Liaison Service, a combined effort with endocrinology to ensure patients are receiving appropriate pharmacologic treatment for osteoporosis following fragility fracture.

UPMC Mercy has been the recipient of significant infrastructural investment from the system. The UPMC Mercy Pavilion, a 10-story, 410,000-square-foot tower, opened in 2023, with one focus being rehabilitation services, a value to our orthopaedic population. Additionally, 2023 saw the opening of six state-of-the-art operating rooms, with orthopaedic surgery being the first service to move in. Construction is ongoing with additional new operating rooms on the way.

UPMC Mercy also serves as a core site for resident trauma education, with the postgraduate year (PGY)-5 chief residents each spending three months on the trauma service and other residents of varying levels gaining valuable trauma and upper-extremity experience throughout the year. Podiatry residents rotate through both the orthopaedic trauma and podiatry services at UPMC Mercy year-round.

The division could not provide the high-quality care that it does without the dedication of our team of physician assistants who support operations. Matt Tagliaferro, PA-C, was promoted to advanced practice provider (APP) supervisor for his leadership, and Julia Sweeney, PA-C, was promoted to senior APP after three years in orthopaedic surgery.

Dr. Fowler, named last year as associate program director of the residency program, has not slowed in his dedication to excellent clinical care, research, and education. He remains a presence on the national stage.

Dr. Moloney continues to serve as site principal investigator for the Major Extremity Trauma Research Consortium (METRC), as the trauma division is actively involved in some of the largest prospective, multicenter studies in the field of orthopaedic trauma. Drs. Moloney and Taylor are actively enrolling patients in a randomized, controlled trial evaluating the effects of early weight-bearing following ankle fractures, which has the potential to broadly change practice. Dr. Moloney is also active teaching resident courses on a national level through AO North America and the Orthopaedic Trauma Association.

Dr. Taylor continues to provide top-notch orthopaedic trauma care for the most complex of problems. He is valued by the residents as a dedicated educator and continues to expand his involvement within the residency, working most closely with the PGY-4 residents. His annual trauma lectures are widely regarded as some of the best. He also has an elective hip arthroplasty practice, which continues to grow.

Dr. Olgun adds a unique skillset to the group, as she is dual-fellowship-trained in both pediatric orthopaedics and orthopaedic trauma surgery, allowing her to care for complex trauma in patients of all ages. As evidence of her commitment to training residents, she received the Golden Apple Award at last year's resident graduation!

The podiatry section continues to serve as a model for comprehensive diabetic foot and ankle care. The division and the UPMC Mercy Podiatric Surgical Residency have continued their commitment to research and education. The residency and faculty have generated multiple peer-reviewed publications, and the Podiatric Surgery Residency has contributed multiple poster presentations to the American College of Foot and Ankle Surgeons annual meeting.

We look forward to another busy and fulfilling year at UPMC Mercy.

PERIOPERATIVE HYPERGLYCEMIA IS AN INDEPENDENT RISK FACTOR FOR VENOUS THROMBOEMBOLISM EVENTS AFTER OPERATIVE TREATMENT OF GERIATRIC FEMUR FRACTURES

Herman ZJ1, Como CJ[1], Sebastiani R[2], Gilbert R[2], Chang A[2], Moloney GB[1]

[1]Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.
[2]School of Medicine, University of Pittsburgh, Pittsburgh, Pa.

INTRODUCTION

As the population continues to age, the number of geriatric patients with femoral fractures rises.[1] Geriatric femur fractures pose significant challenges in perioperative management, with venous thromboembolism (VTE) and pulmonary embolism (PE), being common. amongst other complications.[2-3] Hyperglycemia, prevalent in the perioperative period, has been implicated in increasing thrombotic risk.[4] However, data remain limited regarding its impact on outcomes following femur fracture fixation in the elderly population.

METHODS

A retrospective cohort analysis was approved by the Institutional Review Board and conducted on patients aged 60 or older who were undergoing operative fixation for femur fractures (AO Foundation/ Orthopaedic Trauma Association classification 31, 32, 33) at a single institution between January 2017 and December 2019. The researchers divided patients, regardless of diabetes mellitus (DM) diagnosis, into two groups based on average postoperative blood glucose (³ 180 mg/dL or < 180 mg/dL) utilizing the first three postoperative blood glucose measurements. Complications were recorded, including PE and VTE within 90 days, superficial or deep surgical site infection (SSI) at 30 and 90 days, other infections, sepsis, reoperation, nonunion, and 30-day mortality. A secondary analysis was performed to evaluate those with and without a DM diagnosis. Multivariate logistic regression analysis controlled for demographic confounding variables.

RESULTS

The study included 626 patients (average age = 78.6 ± 10.0 years, body mass index (BMI) = 27.0 ± 7.7); 30.7% were male, and 25.0% had a DM diagnosis. Patients with mean postoperative glucose values ³ 180 mg/dL were more likely to have a DM diagnosis (87.7% versus 15.6%, $p < 0.001$); were younger ($p = 0.019$); and had higher BMI ($p < 0.001$), hemoglobin A1C levels ($p < 0.001$), and age-adjusted Charlson Comorbidity Index ($p = 0.022$) compared to those with mean postoperative glucose values < 180 mg/dL (Table 1). Sex, fracture type, and American Society of Anesthesiologists score did not differ between groups (all $p > 0.05$) (see Table 1). Of patients with postoperative hyperglycemia, 8.3% developed PE and 3.1% developed DVT compared with 1.8% and 0.7% in the normoglycemic cohort ($p = 0.014$, $p = 0.003$). Logistic regression analysis showed that a mean postoperative glucose value ³ 180 mg/dL independently predicted PE ($p = 0.029$) and VTE ($p = 0.008$). DM diagnosis in the absence of hyperglycemia did not predict PE ($p = 0.221$) or VTE ($p = 0.195$). There was no difference in SSI between groups at 30 days (3.1% versus 4.3%, $p = 1.00$) or 90 days (1.5% versus 2.5%, $p = 1.00$) (see Table 1). There were no differences in superficial infection (0% versus 2.9%, $p = 1.00$), deep infection (4.6% versus 3.7%, $p = 0.73$), or hardware infection (4.6% versus 3.7%, $p = 1.00$) (see Table 1).

CONCLUSION

Acute perioperative hyperglycemia, regardless of DM diagnosis, is an independent risk factor for VTE and PE following geriatric femur fracture fixation. Strict glucose control in the postoperative period may improve outcomes in this patient population. Further research is needed to explore long-term effects and optimize management strategies.

REFERENCES

1. Hemmann P et al. *BMC Musculoskeletal Disorders*. 2021);22:456.
2. Carpintero P et al. *World J Orthop*. 2014;5:402-11.
3. Walter N et al. *Injury*. 2023;54:110822.
4. Akirov A et al. *J Diabetes Complications*. 2017;31:358-63.

Demographic / Outcome Measure	Glucose Cutoff < 180 (n=561)	> 180 (n=65)	P Value
Age (years)	78.9 ± 10.1	75.8 ± 9.1	**0.019**
Sex (male/female)	168M / 393F	24M / 41F	0.26
DM Diagnosis	97 (15.6%)	57 (87.7%)	**<0.001**
BMI (kg/m^2)	26.5 ± 7.6	31.3 ± 7.7	**<0.001**
Fracture Type	Vancouver B1: 1 Intertrochanteric: 240 Subtrochanteric: 30 Femoral Shaft: 203 Supracondylar: 86	Vancouver B1: 1 Intertrochanteric: 32 Subtrochanteric: 3 Femoral Shaft: 17 Supracondylar: 12	0.45
CCI	6.0 ± 2.9	6.9 ± 3.6	**0.037**
Age Adjusted CCI	9.7 ± 2.9	10.6 ± 3.7	**0.022**
ASA Score	3.1 ± 0.6	3.0 ± 0.4	0.42
ASA Score Groups	1: 3 2: 60 3: 356 4: 91	1: 0 2: 4 3: 50 4: 6	0.18
Admission Glucose (mg/dL)	129.4 ± 40.2	210.0 ± 83.2	**<0.001**
Morning of Operation Glucose (mg/dL)	123.9 ± 29.9	195.0 ± 63.1	**<0.001**
Hemoglobin A1C (mg/dL)	6.1 ± 1.7	7.6 ± 1.9	**<0.001**
LOS (days)	7.0 ± 4.2	7.7 ± 4.2	0.27
PE	10 (1.8%)	5 (8.3%)	**0.014**
VTE	14 (2.5%)	7 (10.8%)	**0.003**
SSI 30d	24 (4.3%)	2 (3.1%)	1.00
SSI 90d	14 (2.5%)	1 (1.5%)	1.00
Superficial Infection	16 (2.9%)	0 (0%)	1.00
Deep Infection	21 (3.7%)	3 (4.6%)	0.73
Hardware Infection	3 (0.5%)	0 (0%)	1.00
Additional Infection	97 (17.3%)	11 (16.9%)	1.00
Sepsis	12 (2.1%)	3 (4.6%)	0.20
Reoperation	49 (8.7%)	7 (10.8%)	0.64
Nonunion	14 (2.5%)	2 (3.1%)	0.68
Surgery to Promote Union	10 (1.8%)	0 (0%)	0.61
30 Day Mortality	20 (3.6%)	2 (3.1%)	1.00

Table 1. Cohort demographics and outcome measures separated based on average postoperative glucose values. Continuous variables are displayed as mean ± standard deviation, whereas categorical variables are displayed as number of patients (percentage).

MINIFRAGMENT PLATE FIXATION OF MEDIAL MALLEOLAR FRACTURES IS NOT ASSOCIATED WITH INCREASED RATES OF INFECTION OR REOPERATION WHEN COMPARED WITH SMALL-FRAGMENT SCREW FIXATION

Lau E[1], Li K[2], Moloney G[1]

[1]Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.
[2]School of Medicine, University of Pittsburgh, Pittsburgh, Pa.

INTRODUCTION

Malleolar ankle fractures are common injuries, with annual incidence estimated between 101 and 187 per 100,000 individuals.[1] The medial malleolus is estimated to be involved in 50% of all ankle injuries.[2] Multiple fixation options exist to treat medial malleolar ankle fractures. Minifragment plate and bicortical screw fixation represent two common treatment methods.[3-4] The aim of this study was to compare the outcomes of these two fixation methods regarding rates of infection, reoperation, malunion, nonunion, and other complications.

METHODS

A retrospective cohort study was conducted on all patients surgically treated for bimalleolar or trimalleolar ankle fractures where medial malleolar fixation via minifragment or bicortical screw fixation was utilized. All patients underwent fixation at a single institution between 2016 and 2023 by a single surgeon. Exclusion criteria were those without follow-up and treatment via fixation methods other than minifragment plate or bicortical screws for the medial malleolus. Demographic details and high- versus low-energy mechanism of injury were recorded. Treatment method, infection rates, malunion and nonunion rates, and return to the operating room (RTOR) rates were recorded. Infection was broken down by superficial infections requiring antibiotic treatment and deep infection requiring RTOR. Fractures were classified according to the AO Foundation/Orthopaedic Trauma Association classification. Patients were divided according to fixation method into two groups (minifragment plate, bicortical screws), and data were analyzed with unpaired t-tests.

RESULTS

Of 214 patients identified for possible inclusion, 87 patients who underwent minifragment fixation and 83 who underwent bicortical screw fixation met inclusion criteria. No significant differences were identified between the two groups regarding age, comorbid conditions, energy mechanism, OTA classification, or timeline for advancing to weight-bearing as tolerated. Superficial infection rates were 5.7% and 7.2% and deep infection rates were 3.4% and 1.2% for minifragment and bicortical screw groups, respectively ($p = 0.34$). No significant difference was found between the two groups regarding union, malunion, or loss of reduction rates. RTOR rates did not differ between groups: 9.2% and 9.6% for minifragment and screw fixation, respectively ($p = 0.92$).

DISCUSSION

Comparing medial malleolar fixation methods, no statistical difference was found in rates of infection, reoperation, malunion, nonunion, or other complications. Further studies may include comparison of fixation methods based on fracture pattern, which may better guide treatment and optimize results.

REFERENCES

1. Matson A et al. *JAAOS: Global Research and Reviews*. 2017;1(8):e048.
2. Koval K et al. *Foot Ankle Int*. 2007;28:1249-55.
3. Barbosa P et al. *AO Found*. 2006.
4. Barnes H et al. *Injury*. 2014;45:1365-7.

Figure 1. Representative radiographs of minifragment plate (a) and biocritical screw (b) fixation for medial malleolar fractures included in this study

UPMC EAST

David P. Fowler, MD, FAAOS
Division Chief, Orthopaedic Surgery
UPMC East
Clinical Assistant Professor of Orthopaedic Surgery
University of Pittsburgh School of Medicine

UPMC East opened on July 2, 2012, as a community-based hospital to serve UPMC patients in the eastern suburbs. It was the first paperless hospital in the region. UPMC East grew rapidly and despite that growth has continued to serve the eastern suburbs with very high-level and expert orthopaedic care. UPMC East was one of the first certified centers of excellence for joint replacement in the UPMC system. It continues to provide very high-quality care in the community under the direction of Division Chief David Fowler, Joint Replacement Fellowship Cochair Michael O'Malley, MD, FAAOS, and Johannes Plate, MD, PhD, who has become extremely busy at UPMC East recently. Drs. O'Malley, Plate, and Fowler all perform robotic total joints at UPMC East, and we lead the system in same-day discharges and length of stay while keeping our complication rate quite low.

Steve Rabuck, MD, continues to provide excellent sports medicine coverage and general orthopaedic call coverage. Dr. Rabuck provides orthopaedic coverage for Woodland Hills High School as well as University of Pittsburgh women's basketball.

Over the past few years, Jonathan Hughes, MD, has been performing complex and straightforward sports cases, as well as providing general orthopaedic call coverage. Dr. Hughes serves as the University of Pittsburgh football team physician.

Albert Lin, MD, has continued to expand his extremely busy practice, including complex and straightforward shoulder surgery as well as orthopaedic sports medicine procedures while continuing to cover Duquesne University athletics and Central Catholic High School football. He serves as director of the UPMC Orthopaedic Residency Program. Volker Musahl, MD, has become busier at UPMC East, including taking care of University of Pittsburgh athletes in the eastern suburbs.

Robert Kaufmann, MD, moved over from the UMPC surgery center in Monroeville to UPMC East and continues to expand his University of Pittsburgh Physicians (UPP) hand practice, providing high-level care in a community setting.

Mark Rodosky, MD, has expanded his shoulder practice at UPMC East and is extremely busy, typically operating three days a week. UPMC East remains one of the busiest UPP-covered hospitals in the system. In addition to UPP, we have several active Community Medicine Incorporated (CMI) orthopaedists, including Dr. Hughes, Dean Sotereanos, MD, Stephen Conti, MD, and private practice foot and ankle specialist Victor Prisk, MD.

Jeffrey Manway, DPM, continues to be extremely busy with his podiatric practice, including high-level diabetic foot care.

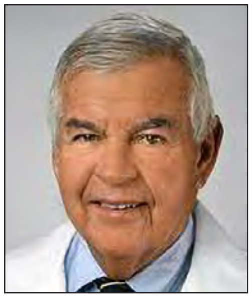
Over the next year, we are hopeful that we can continue to expand our technology and our high-level orthopaedic care in the eastern suburbs. We continue to get busier and busier with our clinical responsibilities in addition to our teaching duties.

Representing the Freddie Fu Cycling Team

Dr. Fowler with his family

Future surgeons in the making!

PITT ORTHO ALUMNI ASSOCIATION



Jack D. Smith, MD
Chair, Pitt Orthopaedic Alumni Association

Pittsburgh Orthopaedics is alive and beyond well as I write this report of the Pitt Ortho Alumni Association. Despite all the turmoil that is surrounding the world today, the Pitt Ortho program has made great strides this year in education, patient care, and research, and these efforts are being recognized locally, nationally, and across the globe, as you will see in this journal.

Once again, we will soon be celebrating this year's graduating class of residents as they move on to high-profile fellowships to continue to build on the strong foundations that they acquired during their time at UPMC. We reward research with awards at the Resident Research Day, and I enjoy presenting those awards on behalf of the association.

In June, the association helps support the graduation dinner and provides gifts to the graduating seniors to help them remember their time at Pitt Ortho. Also, at that time, we welcome another outstanding group of incoming residents to begin their journeys through their training. Congratulations to Chair MaCalus Hogan, MD, MBA, and his team on another successful match.

Many thanks to UPMC for its support and underwriting of a reception at the American Academy of Orthopaedic Surgeons annual meeting in San Francisco, which I was not able to attend because of another conflict with a Pitt Med function in Florida. I heard that the event and venue were great, although the attendance was less than usual due what many believe was the unfortunate situation in San Francisco. I look forward to next year's meeting in San Diego and another chance to connect and catch up.

This has been a great year for the department, most notably thanks to the amazing gift by a grateful patient, Orland Bethel, to establish the Orland Bethel Family Musculoskeletal Research Center under the direction of Joon Lee, MD, in the Ferguson Laboratory. Thank you and congratulations.

SHOULDER AND ELBOW FELLOWSHIP

Christopher C. Schmidt, MD
Program Director

This year marks the fifth year of the American Shoulder and Elbow Surgeons (ASES) approved fellowship at University of Pittsburgh Medical Center in the Department of Orthopaedic Surgery. Nicholas Sotereanos, MD, Albert Lin, MD, and I owe gratitude to the foresight of the late Dr. Freddie Fu. Our goal is to continue to be the most comprehensive shoulder and elbow training program in the country. To that end, we also thank the ASES for awarding our fellowship with a $27,312.49 grant to fulfill our teaching mission.

We are pleased to announce the successful graduation of Omar E. Rodriguez-Alejandro, MD, from our Shoulder and Elbow Fellowship last year. Dr. Rodriguez-Alejandro is extremely well liked and always prepared to solve complex clinical challenges. He was a co-surgeon in more than 500 shoulder and elbow cases. He also found time to complete two research projects, submit them for publication, and present at national conferences.

Dr. Rodriguez-Alejandro completed a mechanical study on the function of the coracohumeral ligament (CHL) and supraspinatus (SS) cord musculotendinous unit. He discovered that the cord and not the CHL, an extension of the rotator cable, is the key structure responsible for transmission of anterior shoulder abduction force. His work has been submitted for publication and was presented at the annual meeting of the Orthopaedic Research Society in February 2024. He also finished a mechanical study on the function of the SS cord and SS strap musculotendinous units, discovering that an intact cord can compensate for a torn SS strap tendon, and vice versa. This helps to explain the efficacy of conservative treatment of small rotator cuff tears. The work, titled “Relative Contributions of the Supraspinatus Cord and Strap Tendons to Shoulder Abduction and Translation,” was published in the January 2024 issue of the *Journal of Shoulder and Elbow Surgery*.

During his time in Pittsburgh, Dr. Omar Rodriguz-Alejandro and his wife, Viviana, and daughter, Marina, celebrated the birth of Mauro Enrique, a heathy Pittsburgh baby boy. Their family enjoyed the company of many friends from an extended Puerto Rico UMPC medical community. They enjoyed the food scene and sporting events that Pittsburgh offers. Dr. Omar Rodriguz-Alejandro is currently completing a second fellowship in sports medicine at the Cleveland Clinic. His goal is to return to Puerto Rico and practice academic medicine. His enthusiasm, work ethic, and energy are missed.

Our current fellow is Justin Badon, MD, from the University of Mississippi Medical Center. His wife, Hannah, is also a medical doctor and is completing her residency in dermatology. They both have enjoyed Pittsburgh, especially the parks, golf courses, and Steelers games. It is a privilege to train Dr. Badon; he is pleasant, studious, and skilled. Dr. Badon is currently working on two rotator cuff anatomical and biomechanical studies with the Shoulder and Elbow Mechanical Research Laboratory and clinical papers with Drs. Lin and Schmidt. His long-term plans are practicing shoulder and elbow surgery at Southern Bone and Joint Specialists in Hattiesburg, Mississippi. He will also be the team physician for the baseball team at the University of Southern Mississippi.

We are pleased to have matched A. Michael Luciani, MD, Geisinger Medical Center, as our 2024–2025 Shoulder and Elbow Fellow and look forward to his arrival.

Our faculty, Drs. Sotereanos and Lin, and I are all high-volume surgeons and come from different training backgrounds. We all work one-on-one in a mentorship environment with the fellow and spend time outside of medicine having fun. The faculty diversity creates a learning environment conducive to open discussions and differences of opinion regarding simple and complex shoulder and elbow pathology and treatment. These respectful disagreements are clearly demonstrated during the weekly Shoulder and Elbow Conference. These conferences are designed to cover the essential core topics in shoulder and elbow surgery. Before each conference, landmark articles are provided to each participant. The conferences rotate equally amongst the faculty members; the fellow runs every fifth conference.

The educational curriculum consists of weekly shoulder and elbow conferences; biweekly cadaveric dissections, including a wet laboratory (scope equipment); biweekly research conferences, monthly journal clubs, visiting professor lectureships, and mortality and morbidity conferences. The educational curriculum is designed by the faculty to provide the fellow the opportunity to develop a solid knowledge base and skill set on which to start his or her career.

The cadaveric laboratory is designed to teach anatomy and solidify hands-on surgical skills, including detailed nerve anatomy, joint replacements, and arthroscopic elbow and shoulder surgery, including arthroscopic-assisted tendon transfers, etc.

Fellowship Personnel
Kathleen Masterson and Bethany Ricci are the fellowship coordinator and laboratory manager/fellowship librarian, respectively. Angie Connelly oversees the fellowship personnel. Together, the team spends countless hours fostering an environment conducive to fellow learning. They deserve great thanks.

Leadership
Christopher C. Schmidt, MD, director
Dean G. Sotereanos, MD, codirector
Albert Lin, MD, faculty

Shoulder and Elbow Fellow, 2023–2024
Justin Badon, MD

Contributing Attending Members
Loukia Papatheodorou, MD

Dr. Rodrigeuz-Alejandro's graduation was well attended!

From left to right: Dean Sotereanos, Omar Rodriguez-Alejandro, and Christopher Schmidt celebrate Dr. Rodrigeuz-Alejandro's graduation from the fellowship.

Dr. Rodrigeuz-Alejandro and Liane Miller discuss important articles at the monthly Journal Club.

From left to right: Omar Rodriguez-Alejandro, Christopher Schmidt, Mark Rodosky, and Neel Patel attend the presentation of Dr. Rodrigeuz-Alejandro's work at the Rotator Cuff Session at the 2023 Annual AAOS Meeting.

From left to right: Brian Foster, Justin Badon, Dean Sotereanos, and Jeff Cully attend a Steelers game.

Clockwise starting at bottom left: Christopher Schmidt, Justin Badon, Jeff Chen, Nicole Shaw, Loukia Papatheodorou, Dean Sotereanos, Bethany Ricci, Abigail Boduch, Joshua Adje, and Albert Lin attend Journal Club.

UPMC INTERNATIONAL: ORTHOPAEDIC CARE AND SPORTS MEDICINE UPDATE

Michael Fetterolf, director,
clinical operations and academic portfolio, UPMC International
John Windle, general manager,
UPMC Sports Medicine, UPMC In Ireland

INTRODUCTION

In Europe, Orthopaedic Care and Sports Medicine is one of UPMC's flagship service lines. The service line is anchored in Ireland, which has exhibited the greatest international growth over the past six years. By the numbers, UPMC performs more than 16,000 orthopaedic procedures in Europe across five hospitals: four in Ireland and one in Italy. This care is delivered by a team of specialists, including:

- 60 UPMC-affiliated orthopaedic surgeons internationally
- 11 primary care sports medicine physicians
- 40 musculoskeletal physiotherapists
- Nine UPMC-trained concussion physicians
- Six outpatient UPMC sports medicine clinics
- UPMC Orthopaedic Care Growth

In 2023, UPMC finalized its acquisition of the renowned Sports Surgery Clinic (SSC), an independent hospital located in Dublin, Ireland. Since 2007, the 101-bed SSC has become a center of excellence for joint replacement and surgery for sports soft-tissue injuries in Ireland. SSC has more than 40 consultants in orthopaedic surgery and allied specialties, supported by a team of more than 400 nurses, physiotherapists, and other healthcare professionals. UPMC SSC joins UPMC's network of orthopaedic, sports medicine, and rehabilitation facilities in Europe, joining:

- UPMC Whitfield Hospital in Waterford, Ireland
- UPMC Kildare Hospital in Kildare, Ireland
- UPMC Aut Even Hospital in Kilkenny, Ireland
- UPMC Salvator Mundi International Hospital, Rome, Italy

Across UPMC's international orthopaedic care and sports medicine network, quality and safety in patient care remain at the core of UPMC's mission. In 2024, UPMC SSC received its sixth Joint Commission International re-accreditation and was recognized for dedication to delivering the highest standards of diagnosis, prehabilitation, treatment, rehabilitation, and full recovery care for its patients.

UPMC SPORTS MEDICINE GROWTH

In 2024, UPMC opened its sixth outpatient sports medicine clinic abroad, in Cork, Ireland, at the Mardyke Arena of University College Cork. The clinic provides injury assessment and diagnosis, rehabilitation, and prevention support. Combined with research and teaching, the UPMC Sports Medicine Clinic at Mardyke Arena will provide world-class care to all levels of athletes.

The clinic in Cork expands UPMC's outpatient sports medicine offering in Ireland, which also includes the following clinics:

- UPMC Sports Medicine at UPMC SSC, Dublin (acquired in 2023)
- UPMC Sports Medicine, Limerick (opened July 2022)
- UPMC Sports Medicine, Tipperary (opened July 2022)
- UPMC Sports Medicine, Mayo (opened October 2022)
- UPMC Sports Medicine, Waterford (opened November 2022)

All of the sports medicine clinics work closely with the orthopaedic surgery services provided at UPMC's hospitals: UPMC Sports Surgery Clinic, Dublin; UPMC Kildare Hospital, Kildare; UPMC Aut Even Hospital, Kilkenny; and UPMC Whitfield Hospital, Waterford. The expansion has resulted in a doubling of year-over-year patient visits across the UPMC Sports Medicine Network.

RESEARCH

The orthopaedic research department in Ireland continues to promote UPMC's footprint of evidence-based medicine at a national and international level. A selection of abstracts from the various research teams are included in this journal and focus on providing excellence in clinical care with a strong emphasis on outcomes-based research, biodynamic research on recovery, and the impact of musculoskeletal exercise on health. Other notable research highlights from 2023 include:

- **University of Limerick's research on concussions in rugby:** In October, the Irish Rugby Injury Surveillance (IRIS) project at the University of Limerick and UPMC have initiated a new strategic research partnership to deepen the understanding of concussion treatments to enhance player health and welfare. Established in 2016 and supported by the Irish Rugby Football Union, IRIS monitors injury trends in Ireland's amateur and school rugby. This new collaboration with UPMC expands IRIS's existing research to explore symptoms, recovery times, and treatment practices for concussion in amateur rugby players. The partnership includes the appointment of Laura Power, PhD, who will conduct research under leading experts at University of Limerick and UPMC, aiming to advance the field of sports medicine and player safety.
- **Fabio Catani appointment:** Fabio Catani, MD, has been appointed an adjunct professor of orthopaedic surgery at the University of Pittsburgh. Dr. Catani clinically led the implementation of the orthopaedic robotic surgery program at UPMC Salvator Mundi International Hospital in Rome, he has presented at various University of Pittsburgh Department of Orthopaedic Surgery educational events (both in person and virtually), and he has visited Pittsburgh on several occasions to establish a framework for a U.S./Italy research program focused on clinical outcomes. Catani completed medical school at the University of Bologna, Italy, and his residency in orthopaedic surgery and physiotherapy at the Istituto Ortopedico Rizzoli of Bologna, Italy. He has been trained in joint biomechanics and motion analysis at Mayo Clinic, MIT, and Nuffield Orthopaedic.
- **MaCalus Hogan keynotes at the British Orthopaedic Foot and Ankle Society meeting:** MaCalus Hogan, MD, MBA, the David Silver Professor and Chair of Orthopaedic Surgery, served as the keynote speaker at the annual British Orthopaedic Foot and Ankle Society meeting held in Belfast, Northern Ireland.

HIGH RATES OF RETURN TO SPORT FOLLOWING IMAGE-BASED ROBO6C-ARM-ASSISTED UNICOMPARTMENTAL KNEE ARTHROPLASTY

Catani F, Zambianchi F, Daffara V, Festa E, Cuoghi Costanni R

Department of Orthopaedics and Traumatology,
Azienda Ospedaliero-Universitaria di Modena, University of Modena and Reggio-Emilia Modena, Italy

BACKGROUND
This study was aimed to assess the return-to-sport (RTS) rate in patients who underwent computed tomography–based robotic-assisted unicompartmental knee arthroplasty (RA-UKA) and to evaluate the clinical performance and the association between patients' sport activity levels and patient-reported outcome measures after surgery.

METHODS
This retrospective study included 218 patients undergoing medial RA-UKA with fixed-bearing implants, performed at a single center between 2014 and 2019. Patients were allocated into two groups based on sport practice and were administered the University of California, Los Angeles (UCLA) activity scale score, the ForgoYen Joint Score-12 (FJS-12), the Knee Injury and Osteoarthritis Outcome Score for Joint Replacement (KOOS-JR), and the Five-Level Likert Scale (5-LLS).

RESULTS
A total of 136 patients (148 RA-UKAs) were included for assessment. The overall RTS rate after surgery was 93.1%. Six subjects who did not practice sport preoperatively were able to start after surgery, and all patients performing sports preoperatively returned to the same activity level. The mean UCLA and FJS-12 scores in the group of patients practicing sports were significantly higher than in the no-sport group ($p < 0.001$ and $p < 0.05$, respectively). Patients who practiced sport were more likely to attain higher FJS-12 and UCLA scores than those who were not performing physical activity.

CONCLUSION
Patients undergoing RA-UKA showed a 93.1% RTS rate after surgery. Differences were detected in terms of postoperative UCLA and FJS-12 scores between patients who performed and who did not practice sport activities after surgery. High levels of postoperative UCLA scores were associated with higher KOOS-JR scores and patient satisfaction.

ROBOTIC-ASSISTED UKA: EXCELLENT SURVIVORSHIP AND CLINICAL PERFORMANCE AT A MINIMUM 10 YEARS OF FOLLOW-UP

Catani F[1], Zambianchi F[1], Stefano S[1], Franceschi G[2]

[1]University of Modena and Reggio-Emilia, Modena, Italy
[2]Policlinico di Abano Terme, Abano Terme (PD), Italy

INTRODUCTION
Although several studies have investigated conventional unicompartmental knee arthroplasty (UKA) performance in the long term, no studies investigating clinical results of image-based robotic-assisted (RA)-UKA with long follow-up have been reported so far. This study was performed to determine the incidence of revision and clinical outcome at a minimum of 10 years of follow-up in patients who had received a medial RA-UKA.

METHODS
The researchers assessed a total of 239 patients (247 knees) undergoing medial RA-UKAs with the MAKO system (Stryker, Fort Lauderdale) at a single center between April 2011 and April 2013. The mean age at surgery was 67.0 years (standard deviation [SD], 8.4). Postoperatively, patients were administered the Forgotten Joint Score-12 (FJS-12) and asked about their satisfaction (from 1 to 5) after surgery. Postoperative complications were recorded. Failure mechanisms, revisions, and reoperations were collected. Kaplan-Meier survival curves were calculated, considering revision as the event of interest.

RESULTS
A total of 188 patients (196 knees) with a 79.4% follow-up rate were assessed at a mean follow-up of 11.1 years (SD, 0.5; minimum of 10 and maximum of 11.9). Seven RA-UKAs underwent revision, resulting in a survivorship rate of 96.4% (confidence interval, 94.6%–99.2%). Causes of revision included aseptic loosening (two cases), infection (one case), post-traumatic reasons (one case), and unexplained pain (three cases). The mean FJS-12 and satisfaction were 82.2 (SD, 23.9) and 4.2 (SD, 1.0), respectively. The majority of patients (92.6%) attained the patient acceptable symptoms state (FJS-12 > 40.63). Male subjects had a higher probability of attaining a "forgotten joint" ($p < 0.001$) and high satisfaction (equal to 5) ($p < 0.05$), when compared with females.

CONCLUSION
RA-UKA patients had lower revision rates for aseptic loosening and osteoarthritis progression compared to conventional treatment at long-term follow-up, as reported in the literature. The good postoperative clinical scores highlight the efficacy of robotic-arm-assisted UKA in restoring knee function and relieving pain.

NO CLINICAL OUTCOME DIFFERENCES BETWEEN ROBOTIC-ASSISTED UNICOMPARTMENTAL AND TOTAL KNEE ARTHROPLASTY FOR THE TREATMENT OF MEDIAL KNEE OSTEOARTHRITIS

Catani F, Zambianchi F, Daffara V

University of Modena and Reggio-Emilia, Modena, Italy

OBJECTIVE
Medial knee osteoarthritis (MKOA) is usually treated with medial unicompartmental knee arthroplasty (UKA) but can also be approached with total knee arthroplasty (TKA). The aim of this retrospective study was to investigate differences in clinical outcomes between patients undergoing robotic-arm-assisted (RA)-UKA and RA-TKA for the treatment of MKOA.

MATERIALS AND METHODS
The study included a total of 173 consecutive subjects with radiographic diagnosis of MKOA treated with either RA-UKA or RA-TKA between 2019 and 2022 at a single center. Patients with fixed flexion contracture > 15°, multicompartmental osteoarthritis, or lateral facet patellofemoral osteoarthritis were excluded. RA-UKA was the preferred surgical indication; RA-TKA was indicated in cases of generalized knee pain, partially insufficient ligamentous laxity, or varus thrust. The study population was assessed postoperatively with the Forgotten Joint Score-12 (FJS-12), Knee Injury and Osteoarthritis Outcome Score for Joint Replacement (KOOS-JR), and Five-Level Likert Scale for Satisfaction (5-LLS).

RESULTS
A total of 136 patients with MKOA (101 RA-UKA and 35 RA-TKA) were included. The mean age of the study population was 71.7 ± 8.8 years, and the mean follow-up was 2.9 ± 1.2 years. Differences were detected between the two groups in terms of severity of preoperative Ahlback score ($p < 0.05$). No statistically significant differences were detected between RA-UKAs and RA-TKAs relative to postoperative patient-reported outcome measures (PROMs) according to multivariate regression models (FJS-12: 88.1 ± 15.8 versus 87.0 ± 17.4, p = 0.72; KOOS-JR: 87.0 ± 13.4 versus 86.3 ± 16.8, p = 0.80; 5-LLS: 4.3 ± 1.0 versus 4.4 ± 1.1, p = 0.75). Considering FJS-12, 99 (98.0%) RA-UKAs and 34 (97.0%) RA-TKAs achieved the patient acceptable symptom state.

DISCUSSION
This is the first study analyzing PROMs in patients undergoing RA-UKAs and RA-TKAs for MKOA. No differences were detected between the two study groups in terms of FJS-12, KOOS-JR, or satisfaction, showing that robotic assistance for UKA and TKA enabled satisfactory results regardless of the chosen treatment.

CLINICAL OUTCOME IS NOT AFFECTED BY FEMORAL COMPONENT ROTATIONAL ALIGNMENT IN WELL-BALANCED, ROBOTIC-ASSISTED TOTAL KNEE ARTHROPLASTY PERFORMED WITH A TIBIA-BASED FUNCTIONAL ALIGNMENT

Catani F, Zambianchi F, Bazzan G, Cuoghi Costantini R

University of Modena and Reggio-Emilia, Modena, Italy

INTRODUCTION
Historically, femoral component rotational malalignment relative to the transepicondylar axis (TEA) in total knee arthroplasty (TKA) has been associated with poor outcomes, due to patellar maltracking, knee flexion instability, or stiffness. This study was designed to evaluate femoral component rotational alignment distribution and its association with clinical outcome in a consecutive series of patients undergoing image-based robotic-arm-assisted (RA)-TKA with a tibia-based functional alignment (tFA) technique.

METHODS
The researchers retrospectively assessed a total of 199 subjects who underwent cruciate-retaining RA-TKA with tFA. Tibial and femoral cuts were performed based on patient-specific soft-tissue guided implant fine-tuning. Intraoperative computed tomography data relative to femoral and tibial implant positioning in three dimensions were collected. At a minimum of two years postoperatively, subjects were assessed with the Forgotten Joint Score-12 (FJS-12), Knee Injury and Osteoarthritis Outcome Score for Joint Replacement (KOOS-JR), and Five-Level Likert Scale (5-LLS) for satisfaction. The association between femoral component rotational alignment relative to TEA and postoperative clinical outcome was assessed by means of linear and multinomial regression models or nonparametric tests, as adequate.

RESULTS
The study included a total of 207 RA-TKAs performed with tFA. Femoral component rotational alignment was found to be different based on postoperative knee alignment, with a mean external rotation in varus knees and mean internal rotation in valgus knees, ranging 6.9° internal to 6.6° external rotation relative to TEA. No association was described between femoral component rotational alignment and postoperative clinical outcome in terms of FJS-12 (p = 0.138), KOOS-JR (p = 0.575), and 5-LLS (p = 0.063).

DISCUSSION
Femoral component transverse alignment in RA-TKA performed with tFA ranged from 6.9° internal to 6.6° external rotation relative to TEA, without impacting postoperative clinical outcomes. This finding supports the use of a patient-specific approach for implant positioning and a soft-tissue guided technique for femoral component rotational alignment in functionally aligned RA-TKA.

THE EARLY IMPACT OF HIP ARTHROSCOPY ON THE RESOLUTION OF SYMPTOM BURDEN IN ATHLETES WITH FEMOROACETABULAR IMPINGEMENT

Filan D, Mullins K, Carton P

UPMC Whitfield, UPMC Sports Medicine, Waterford, Ireland

BACKGROUND
Coexisting symptoms can confound postoperative outcomes following arthroscopic correction of femoroacetabular impingement (FAI). Symptom burden (SB) represents the cumulative load of subjective symptoms reported by the patient.

PURPOSE
The purpose of this study was to quantify the prevalence of symptoms in athletes prior to and following arthroscopic correction of FAI and evaluate the impact of independent and cumulative SB resolution on outcomes.

METHODS
The researchers reviewed prospectively collected data from an institutional hip arthroscopy registry about athletes undergoing primary hip arthroscopy for FAI between 2011 and 2020. A 15-item SB survey assessed the prevalence of symptoms. The cumulative total number of symptoms reported provided the SB score, evaluated preoperatively and one year postoperatively. The researchers calculated a proportional resolution of SB, defined as a minimal clinically important difference (MCID-SB) and substantial clinical benefit (SCB-SB). Patient-reported outcome measures (PROMs) at one and two years postoperatively included the modified Harris Hip Score and 36-Item Short Form Health Survey. PROMs were compared relative to achieving or not achieving MCID-SB and SCB-SB. Multivariable stepwise regression modelling evaluated the association of individual symptom resolution for the ability to achieve MCID and SCB in PROMs.

RESULTS
The study included 386 athletes (509 hips, 89% male, age = 26.3 ± 6.1 years). Preoperatively, SB score was 6.0 ± 2.9, reduced to 2.8 ± 2.7 at one year ($p < 0.001$). A proportional symptom reduction by 48.5% and 70.3% defined the MCID-SB and SCB-SB, of which 63.5% and 43.6% achieved, respectively. Significant improvement in all PROMs from baseline to postoperatively was observed for both groups ($p < 0.001$). Postoperatively, PROMs were superior, and clinically meaningful SB resolution thresholds were achieved ($p < 0.001$). Significantly higher proportion of these cases continued to play their main sport; 79.4% versus 63.1% achieved MCID-SB and 83.8% versus 65.2% achieved SCB-SB ($p < 0.001$). Odds ratios for independent symptoms associated with achieving MCID in PROMs included resolution of groin pain (2.6–5.5), side hip pain (3.4), pain during (3.1) and after (2.6-3.5) activity, hamstring tightness (2.6), and limping after activity (2.6). Symptom resolution associated with achieving SCB included groin pain (3.0–3.1), pain during (3.3) and after (2.7–4.2) activity, and limping after activity (3.0–6.8).

CONCLUSION
Symptom burden and extent of resolution are important measures of outcome. Achieving thresholds of clinically important SB resolution was associated with superior postoperative PROMs and higher rates of return to main sport for this athletic cohort. Resolution of groin pain, pain during and after activity, hamstring tightness, and limping after activity increase odds of achieving clinically important improvement in PROMs.

THE EARLY IMPACT OF HIP ARTHROSCOPY AND IMPACT OF CAPSULAR REPAIR FOR THE RESOLUTION OF GROIN AND LATERAL HIP SYMPTOMS IN ATHLETES WITH FEMOROACETABULAR IMPINGEMENT

Filan D, Mullins K, Carton P

UPMC Whitfield, UPMC Sports Medicine, Waterford, Ireland

INTRODUCTION
Athletes undergoing arthroscopy for femoroacetabular impingement (FAI) can continue to report symptoms as unresolved, postoperatively. Persisting groin and lateral hip pain may be associated with postoperative capsular stiffness or adhesions. It is unclear whether capsular repair could be associated with the development or persistence of these symptoms.

METHODS
The researchers reviewed their prospective arthroscopy registry for athletes younger than 40 years who had primary arthroscopy for FAI and completed preoperative and one-year postoperative symptom questionnaire. Symptom status was categorised as resolved, persisting, or new onset. Patient-reported outcome measures (PROMs) included the modified Harris Hip Score (mHHS), 36-Item Short Form Health Survey (SF-36), UCLA Activity Scale (UCLA), and Western Ontario and McMaster Universities Arthritis Index (WOMAC), which were completed preoperatively and two years postoperatively. Regression analysis assessed the predictive likelihood of capsular repair being associated with postoperative symptom status.

RESULTS
The study included 538 cases. Groin pain and lateral hip pain were self-reported preoperatively in 41% and 32% of cases, respectively, with significantly reduced prevalence by one year postoperatively: 16.5% groin (11.2% persisting, 5.4% new onset) and 15.6% lateral hip (7.8% persisting, 7.6% new onset).

At latest follow-up, PROMs were significantly poorer for those with persisting groin pain (mHHS: $p < 0.001$, UCLA: $p = 0.001$, SF-36: $p = 0.049$, WOMAC: $p = 0.006$) and persisting lateral hip pain (mHHS: $p = 0.008$, SF-36: $p = 0.029$, WOMAC: $p = 0.002$) compared to those whose symptoms were resolved. UCLA was not significantly different irrespective of whether lateral hip pain was persisting or resolved. PROMs were significantly poorer for those with new-onset groin symptoms compared with those whose groin symptoms were resolved ($p < 0.05$ for all). New-onset lateral hip pain was not significantly different compared to resolved lateral hip pain ($p > 0.05$ for all)

Capsular repair did not increase the likelihood of groin or lateral hip pain either persisting ($p = 0.348$ and 0.141 respectively) or new onset ($p = 0.138$ and 0.805, respectively).

CONCLUSION
The development or persistence of postoperative groin pain following arthroscopy for FAI results in poorer outcome at a minimum of two years. Whether the capsule is repaired or not does not seem to influence the development, persistence, or resolution of groin or lateral hip pain postoperatively.

ANTERIOR ACETABULAR RIM RECESSION: DOES EXTENT OF RESECTION MARGIN AFFECT CLINICAL OUTCOME?

Filan D, Mullins K, Carton P

UPMC Whitfield, UPMC Sports Medicine, Waterford, Ireland

PURPOSE

The purpose of this study was to establish whether a measure of anterior acetabular over-coverage and subsequent resection influences patient-reported outcomes, ability to achieve minimal clinically important difference (MCID), or conversion to total hip arthroplasty (THA).

METHODS

Patients undergoing primary THA for FAI from 2014–2018, with available radiographic measures of anterior center-edge angle both pre- and postoperatively were considered (n = 959). Tonnis classification > 1, avascular necrosis, rotated or tilted x-rays, coxa profunda, slipped capital femoral epiphysis, and previous surgery were removed. In all. 83% of cases had a minimum two-year follow-up. A further 109 cases were removed due to unstandardized measurements. Cases were categorized based on the extent of the anterior acetabular over-coverage preoperatively (< 5^{o} over-coverage, 5 ^{o}–10^{o} over-coverage, and > 10^{o} over-coverage), calculated as the difference between the angle created from a vertical line from the center of the femoral head to the most anterior aspect of the acetabular rim and the angle created to the edge of the sourcil on the false profile radiograph. Patient-reported outcome measures (PROMs) included the modified Harris Hip Score (mHHS), 36-Item Short Form Health Survey (SF-36), and UCLA Activity Scale (UCLA). MCID was calculated with a distribution-based technique. Conversion to THA and repeat HA was assessed.

RESULTS

The study included 542 cases. The mean magnitude of anterior acetabular over-coverage was 9.6o ± 5.3^{o} (range = 0^{o}–33^{o}): < 5^{o} (n = 71, 13%), 5^{o}–10^{o} (n = 236, 44%), and > 10^{o} (n = 235, 43%). The amount of acetabular resection was significantly different between groups (p < 0.001). Postoperatively, there was no significant difference in measure of anterior acetabular cover between groups: 33.3^{o}, 32.0^{o}, and 33.0 for < 5, 5–10, and > 10, respectively (p = 0.364). There were no significant differences between groups for any of the PROMs, pre- or postoperatively (p > 0.05). Rates of THR conversion were not significantly different: 2.9%, 3.0%, and 3.4% for < 5, 5–10, and >10, respectively (p = 0.955). There were no significant differences in the rates of achieving MCID for any PROMs between groups: mHHS: p = 0.787, SF-36: p = 0.694, UCLA: p = 0.358 for < 5, 5–10, and > 10, respectively.

CONCLUSION

The extent of anterior rim deformity and resection depth do not have an independent influence on pre- or postoperative PROMs or conversion to THA in this sample.

ROUTINE CAPSULAR REPAIR VERSUS UNREPAIRED CAPSULOTOMY: MINIMUM FIVE-YEAR OUTCOMES FOLLOWING ARTHROSCOPIC CORRECTION OF FEMOROACETABULAR IMPINGEMENT

Filan D, Mullins K, Carton P

UPMC Whitfield, UPMC Sports Medicine, Waterford, Ireland

OBJECTIVE

The objective of this study was to evaluate the impact of routine capsular repair on patient-reported outcomes, survivorship, and achievability of clinically important improvement at a minimum of five years after surgery.

METHODS

The researchers prospectively reviewed their institutional registry for cases undergoing primary hip arthroscopy (HA) for femoroacetabular impingement (FAI) and stratified them into two groups depending on whether the capsule was repaired or not. Routine repair was introduced in late 2013. The no-repair group consisted of patients undergoing HA between January 2010 and June 2013, and the repair group consisted of patients undergoing HA between January 2015 and September 2018. Exclusion criteria consisted of age older than 50 years, Tonnis classification >1, dysplasia (lateral center-edge angle < 25), and concomitant hip pathologies. Patient-reported outcome measures (PROMs) consisted of modified Harris Hip Score (mHHS), 36-Item Short Form Health Survey (SF-36), UCLA Activity Scale (UCLA). Metrics of clinically important improvement were evaluated with minimal clinically important difference (MCID) and substantial clinical benefit (SCB). Rates of repeat HA or total HA (THA) conversion were recorded.

RESULTS

The study included 985 cases (359 no repair, 626 repair); 86% were male, and the average age was 27.4 ± 6.7 years. Significant improvement in all PROMs at a minimum of five years was observed for both groups (p < 0.001 for all; large effect sizes for mHHS and SF-36, medium effect sizes for UCLA). At five years after surgery, there was no significant difference between groups for mHHS (p = 0.078) or UCLA (p = 0.794). SF-36 was significantly poorer for cases undergoing routine repair (p < 0.001); however, effect size was small (0.20). Thresholds of MCID and SCB were calculated as 69% and 86% for mHHS, 64% and 77% for UCLA, 43% and 60% for SF-36. Both groups achieved MCID and SCB at similar rates for mHHS and UCLA. A significantly lower proportion of cases in the repair group achieved MCID for SF-36 (53.6% versus 63.5%, p = 0.034) and SCB for SF-36 (37.3% versus 52.8%, p < 0.001). No significant difference between groups for THA conversion (0.6% no repair versus 0.5% repair) or repeat HA (9.7% no repair versus 8.1% repair).

CONCLUSION

Routinely repairing the capsule following HA for FAI demonstrates no clinical benefit over not repairing the capsule five years after surgery.

THE 'STONE UNDER THE CARPET': ANTERIOR RIM DEFORMITY IN HIP DYSPLASIA: THE MINIMUM FIVE-YEAR OUTCOME FOLLOWING ANTERIOR RIM DEFORMITY CORRECTION AND CHONDROLABRAL STABILIZATION

Filan D, Mullins K, Carton P

UPMC Whitfield, UPMC Sports Medicine, Waterford, Ireland

OBJECTIVE
The objective of this study was to quantify the degree of anterior acetabular bony resection and evaluate the impact on five-year outcomes in a cohort with symptomatic hip dysplasia, managed with arthroscopic surgery.

METHODS
The researchers prospectively reviewed their institutional hip arthroscopy registry for cases undergoing primary hip arthroscopy (HA) for hip dysplasia between 2014 and 2018, defined by lateral center-edge angle < 25º on anteroposterior view. Surgery included correction of the anterior acetabular rim deformity and chondrolabral stabilization, using suture anchor fixation, with no lateral rim recession. Cases were excluded if they had Tonnis classification > 1 or concomitant hip pathology. Anterior center-edge angle (ACEA) was measured relative to two landmarks on false profile radiograph: most anterior aspect of the acetabular rim (anterior rim deformity) and to the edge of the sourcil (true acetabular margin).

Patient-reported outcome measures (PROMs) consisted of modified Harris Hip Score (mHHS), 36-Item Short Form Health Survey (SF-36), and UCLA Activity Scale (UCLA), measured at baseline and a minimum of five years postoperatively. Within-group differences were assessed with Wilcoxon signed-rank and related t-tests depending on normality of data. Rates of conversion to total hip arthroplasty (THA), repeat HA, and achievability of minimal clinically important difference (MCID) were documented.

RESULTS
The study included 71 cases (average age = 33.0 ± 9.6 years, 75% male). ACEA (Pincer) decreased from 36.7 ± 7.1 preoperatively to 29.2 ± 7.6 postoperatively ($p < 0.001$). The ACEA (sourcil) decreased 23.6 ± 5.4 preoperatively to 20.9 ± 6.0 postoperatively ($p < 0.001$). LCEA did not significantly change preoperatively to postoperatively (21.8 ± 2.3 preoperatively to 21.0 ± 4.5 postoperatively, $p = 0.057$). Of the total group, 85% had minimum five-year follow-up. All PROMs significantly improved from baseline: mHHS, 76 (69–93) to 96 (79–100) (p <–0.001); UCLA 6 (4–9) to 7 (6–10) ($p < 0.001$); and SF36 69.9 (48.6–76.4) to 81.6 (67.7–92.8) ($p<0.001$). MCID for mHHS, UCLA, and SF36 (overall) was achieved in 68%, 67.6%, and 69.7% of cases, respectively. Five cases (8.3%) converted to THA at an average 7.6 ± 4.5 months (range = 2.2–14.2). There were two reoperations (3.3%).

CONCLUSION
HA is a safe and effective intervention for hip dysplasia. Correcting the prominent anterior acetabular rim deformity and stabilizing the labrum result in high survivorship (91.7%) and significant clinical improvement at five years postoperatively.

PROMS AND SURVIVORSHIP ARE NOT IMPACTED BY THE SIZE OF CAM DEFORMITY OBSERVED AT TIME OF ARTHROSCOPIC CORRECTION OF FAI: A 10-YEAR FOLLOW-UP STUDY

Filan D, Mullins K, Carton P

UPMC Whitfield, UPMC Sports Medicine, Waterford, Ireland

BACKGROUND
Larger cam deformities are thought to be a poor prognostic factor in femoroacetabular impingement (FAI).

OBJECTIVE
The objective of this study was to investigate the association between the size of cam deformity on measurable hip range of motion (ROM) preoperatively, as well as patient-reported outcome measures (PROMs) and survivorship at 10 years postoperatively.

METHODS
The researchers conducted a retrospective review of data prospectively collected and stored in an institutional hip arthroscopy registry. The study included patients undergoing arthroscopic FAI correction and labral repair as the index procedure between January 2013 and March 2014. Exclusion criteria consisted of Tonnis classification > 1 (n = 41), dysplasia (n = 39), and protrusion (n = 1). Intraoperative assessment of cam deformity size (small, moderate, large) defined the study groups. PROMs were evaluated preoperatively and 10 years postoperatively. They included the modified Harris Hip Score (mHHS), 36-Item Short Form Health Survey (SF-36), UCLA Activity Scale (UCLA), and Western Ontario and McMaster Universities Arthritis Index (WOMAC). ROM was measured with a handheld goniometer. Kaplan-Meier survival analysis evaluated survivorship (avoidance of total hip arthroplasty [THA]) between groups. Analysis of variance and nonparametric analysis compared ROM and PROMs respectively between groups.

RESULTS
In total, 254 cases met the inclusion criteria, of which 180 (71%) (140 patients) had 10-year follow-up and were included in the final analysis. Cam size was defined as small (n = 101, 56%), moderate (n = 54, 30%), large (n = 19, 11%), and not reported (n = 6, 3%). Alpha angles measured on Dunn view were as follows: 54.5 ± 10.5 (small), 64.1 ± 7.7 (moderate), and 70.1 ± 8.1 (large), with subsequent correction reducing alpha angle (AA) by mean 7º, 9º, and 11º respectively ($p = 0.166$). Of measured ROM, internal rotation was the only movement significantly different between groups preoperatively—reduced ROM with increasing cam deformity: (31.8º versus 26.4º versus 21.6º for small, moderate, and large cam, respectively; $p < 0.001$). There were no significant differences in any PROMs between groups preoperatively or postoperatively ($p > 0.05$ following Bonferroni correction for multiple tests). In all, 34 (18.9%) cases underwent a repeat hip arthroscopy; 6 (3.3%) underwent THA conversion at 10 years. No significant difference was found in the rates of THA conversion between groups: 95%, 100%, and 100% survivorship for small, moderate, and large groups, respectively ($\chi^2 = 3.7$, $p = 0.155$).

CONCLUSION
The magnitude of cam deformity at time of surgery was not associated with PROMs or survivorship at 10 years postoperatively. Baseline internal rotation is reduced with increasing cam size, a useful examination and potential red flag in the diagnostic workup of FAI.

THE PRESENCE OF LOWER BACK PAIN IN ATHLETES DOES NOT NEGATIVELY IMPACT POSTOPERATIVE OUTCOMES FOLLOWING ARTHROSCOPIC CORRECTION OF FAI: A MATCHED COHORT STUDY

Filan D, Mullins K, Carton P

UPMC Whitfield, UPMC Sports Medicine, Waterford, Ireland

BACKGROUND

Pre-existing low back pain (LBP) can negatively influence composite postoperative patient-reported outcomes in patients undergoing hip arthroscopy (HA) for femoroacetabular impingement (FAI). Improvement in functional-based outcomes has also been demonstrated in such patients.

PURPOSE

The purpose of this study was to evaluate the impact of LBP on both physical (PCS) and mental (MCS) components of health independently.

METHODS

The authors reviewed prospectively collected data from competitive field-based athletes undergoing arthroscopic correction of FAI between 2014 and 2021. Inclusion criteria were age younger than 45 years and available baseline and two-year postoperative 36-Item Short Form Health Survey (SF-36) scores. Exclusion criteria were Tonnis classification >1, lateral center-edge angle < 25^{o}, and concomitant pathology. Athletes were stratified based on their self-reporting LBP prior to arthroscopy, and they were matched 1:1 (gender and age within two years) with athletes not reporting LBP (hip only [HO]). Clinical improvement was evaluated through minimal clinically important difference (MCID) calculated by an anchor-based percentage of possible improvement technique. Continuation of primary sports (CTP) was also evaluated.

RESULTS

The study included 108 matched cases (mean age = 24.8 ± 5.7 years, 94% male). Preoperatively, median (interquartile range) PCS was significantly lower in the LBP group (51.9 [43.1–73.8] versus 60.6 [48.1–80.6], p = 0.016). No differences were found in MCS (p = 0.206). Postoperatively, there was no difference between groups for PCS (89.7 [74.7–96.3] versus 86.3 [71.3–93.8], p = 0.100) or MCS (88.8 [77.1–93.0] versus 87.5 [78.2–92.0], p = 0.486) for HO and LBP, respectively. Both groups demonstrated significant improvements from baseline to follow-up (p < 0.001). MCID rates of achievement for PCS and MCS were similar: PCS, 57.4% versus 54.2% (p = 0.636); MCS, 31.5% versus 34.6% (p = 0.629) for LBP and HO, respectively. CTP was achieved at similar rates: 65% versus 71% for LBP and HO, respectively (p = 0.363).

LPB group: PCS MCID was achieved in a higher proportion of cases where CTP was achieved (64.6% versus 42.9%, p = 0.036). MCS MCID was achieved at similar rates irrespective of whether CTP was achieved: (33.8% versus 25.7%, p = 0.402).

HO group: PCS MCID (55.7% versus 51.7%, p = 0.717) and MCS MCID (35.7% versus 37.9%, p = 0.835) were achieved at similar rates irrespective of whether CTP was achieved.

CONCLUSION

Functional outcomes were initially poorer for athletes with concomitant LBP. However, MCS was not impacted. The presence of LBP did not negatively influence postoperative functional or emotional outcomes for this patient population.

Rates of MCID and CTP are similar in the presence or absence of concomitant LBP. The rates of MCID achievement in MCS are lower than that of PCS overall, which is consistent with the existing literature reporting limited improvement in this component of overall health following arthroscopic intervention for a mechanical hip pathology.

DISCRIMINATORY ABILITY OF BASELINE WOMAC SCORE IN PREDICTING CONVERSION TO THA IN A NON-ARTHRITIC COHORT AT A MINIMUM OF FIVE YEARS AFTER HIP ARTHROSCOPY FOR FAI

Filan D, Mullins K, Carton P

UPMC Whitfield, UPMC Sports Medicine, Waterford, Ireland

BACKGROUND

The Western Ontario and McMaster Universities Arthritis Index (WOMAC) is a validated patient-reported outcome measure (PROM) for use in an osteoarthritic population and has formed the basis of validated PROMs used for the assessment of non-arthritic hip conditions such as femoroacetabular impingement (FAI). However, the usefulness of the WOMAC in predicting conversion to total hip arthroplasty (THA) following hip arthroscopy (HA) in this non-arthritic population is not documented.

OBJECTIVE

The objective of this study was to determine the ability of preoperative subsets of the WOMAC to predict the incidence of THA conversion.

METHODS

The researchers retrospectively reviewed a prospective institutional HA registry for cases undergoing primary HA for FAI between 2014 and 2018, with completed preoperative and minimum five-year postoperative WOMAC questionnaire data. Exclusion criteria consisted of Tonnis classification >1 at time of index surgery. Pain (P), stiffness (S), and physical function (PF) subsets were evaluated independently and combined (W) for their predictive ability of classifying conversion to THA using receiver operating characteristic curve analysis. Thresholds predictive of conversion to THA were estimated with Youden's Index and area under the curve (AUC). An AUC > 0.7 was considered acceptable and > 0.8 considered excellent.

RESULTS

In total, 1,532 cases were initially considered, of which 1,104 (72%) had minimum five-year follow-up. After excluding those cases with preoperative Tonnis classification > 1, 994 cases were included in the analysis (81% males, mean age = 31.2 ± 10.5 years). Preoperative scores (median, interquartile range) were as follows: P, 5 (2–9); S, 3 (2–4); PF, 12 (5–22); and W, 21 (9–34). In addition, 4.2% (n = 42) of cases converted to THA at a mean 31.1 ± 35.5 months following HA. Baseline thresholds characterizing conversion to THA for each of the subsets was as follows: P, 7.5 (AUC 0.66; 95% confidence interval [CI], 0.57–0.75); S, 3.5 (AUC 0.63; 95% CI, 0.54–0.71); PF, 25.5 (AUC 0.70; 95% CI, 0.61–0.78); and W, 33.5 (AUC 0.69; 95% CI, 0.61–0.70).

CONCLUSION

For cases undergoing arthroscopic correction of FAI, the physical function component of the WOMAC may be useful in determining future conversion to THA. Baseline score > 25.5 is an acceptably predictive threshold resulting in THA conversion.

A HIGH PROPORTION OF ATHLETIC CASES WITH REDUCED MENTAL HEALTH STATUS IMPROVE THIS COMPONENT OF HEALTH FOLLOWING HIP ARTHROSCOPY FOR FAI

Filan D, Mullins K, Carton P

UPMC Whitfield, UPMC Sports Medicine, Waterford, Ireland

OBJECTIVES

The objectives of the study were to: (1) identify the prevalence of reduced mental health (rMH) status in athletes undergoing hip arthroscopy for femoroacetabular impingement (FAI); and (2) compare patient-reported outcome measures, continue to play (CTP), and minimal clinically important difference (MCID) achievability between rMH versus normal mental health status.

METHODS

The researchers reviewed competitive athletes undergoing hip arthroscopy (HA) for FAI between 2014 and 2021 with available two-year outcomes from a prospective registry. The population norm for the mental component score (MCS) of the 36-Item Short Form Health Survey is 50. Athletes with a baseline MCS < 50 were defined as the rMH group and were matched in a 1:1 ratio to those with baseline MCS > 50 (control). Four subscales of physical health (PCS) were assessed: physical functioning (PF), role-physical (RP), bodily pain (BP), and general health (GH). MCID was calculated with 0.5 standard deviation (SD) distribution technique, independently for PCS and MCS. CTP status was evaluated through a dichotomous question: "Have you returned to your main sport following surgery?"

RESULTS

The study identified 341 athletic cases, of which 37 (11%) had rMH status. All 37 cases were matched with 37 controls. At two years postoperatively, 81% of rMH transitioned to MCS > 50. All cases in the control group remained MCS > 50. In both groups, 63% CTP in their main sport at two years ($p > 0.999$). Calculated MCID was 11 points for both PCS and MCS. In addition, 84% rMH and 67% controls achieved MCID in PCS ($p = 0.095$). Also, 87% rMH and 50% controls achieved MCID in MCS ($p = 0.002$). Preoperatively, all subscales of the PCS were significantly poorer for those with rMH ($p < 0.001$ for all). At two years postoperatively, there was no significant difference between groups across PF ($p = 0.462$), RP ($p > 0.999$), BP ($p = 0.101$), or overall PCS ($p = 0.138$). GH remained significantly poorer for those with rMH: 70 (58–85) versus 90 (78–95) ($p < 0.001$). Secondary analysis based on mental health status at two years (rMH, n = 7 versus control, n = 67) revealed PF ($p = 0.025$), BP ($p < 0.001$), GH ($p = 0.001$), and overall PCS ($p = 0.006$) were poorer for cases with sustained rMH. RP was not statistically significantly different between these subgroups ($p = 0.057$).

CONCLUSION

One in 10 athletic cases with FAI have reduced mental health status. Following HA, a high proportion improve this component of health, achieving a clinically important improvement in MCS at a higher rate compared to controls. Clinically important improvement in PCS is achieved at a similar rate irrespective of baseline MH status.

MULTIPLE PROMS MEASURING THE SAME END RESULT: IMPROVEMENT FOLLOWING ARTHROSCOPIC CORRECTION OF FAI: A PRELIMINARY SYSTEMATIC REVIEW AND META ANALYSIS

Filan D, Mullins K, Carton P

UPMC Whitfield, UPMC Sports Medicine, Waterford, Ireland

BACKGROUND

Multiple patient-reported outcome measures (PROMs) within the same cohort are routinely used to measure the impact of hip arthroscopy (HA) for the treatment of femoroacetabular impingement (FAI).

OBJECTIVES

The objectives of this study were to: (1) evaluate the percentage of acquired change across different outcome measures; and (2) investigate whether the modified Harris Hip Score (mHHS), as the most commonly reported PROM, can be used to generate a reliable score in alternative PROMs.

METHODS

The researchers conducted a systematic review in PubMed of outcome-based studies investigating the arthroscopic correction of FAI. Studies reporting more than one PROM within the same cohort of patients were considered. Exclusion criteria included no preoperative and postoperative raw scores reported, only one PROM reported, surgical intervention other than HA, and concomitant pathologies. Pre- and postoperative PROM means and standard deviations were extracted. Percentage score change was calculated with the following equation: percentage of possible improvement = (change in outcome score/max possible score − preoperative score) x 100. Paired samples t-tests were performed to evaluate whether the proportional change in mHHS was significantly different to alternative PROMs. Linear regression modelling was performed to test whether mHHS as a dependant variable could significantly predict alternative PROMs. The R^2 value determined the robustness of the predictive ability of the model.

RESULTS

The researchers considered 226 of the most recently published papers by publication date (May 2022–March 2024); 84 papers were included. The top four PROMs most frequently reported were included in subsequent analysis: mHHS (93%), Hip Outcome Score Sport Scale (HOS-SS) (60%), Hip Outcome Score Activities of Daily Living (HOS-ADL) (54%), and International Hip Outcome Tool (iHOT-12) (39%). The percentage change achieved was not significantly different for alternative PROMs when compared to the mHHS: HOS-SS versus mHHS (54.7% versus 56.5%, $p = 0.191$), HOS-ADL (59% versus 56.3%, $p = 0.066$), or iHOT-12 (53.5% versus 56.9%, $p = 0.109$). The overall regressions were statistically significant: HOS-ADL preoperatively ($R^2 = 0.195$, $F[1.81] = 19.7$, $p < 0.001$), HOS-ADL postoperatively ($R^2 = 0.341$, $F[1.80] = 41.3$, $p < 0.001$), iHOT12 preoperatively ($R^2 = 0.486$, $F(1.59) = 55.7$, $p < 0.001$), and iHOT12 postoperatively ($R^2 = 0.117$, $F[1.59] = 7.8$, $p = 0.007$). mHHS significantly predicted HOS-ADL ($\beta = 0.442$ and $\beta = 0.497$) and iHOT12 ($\beta = 0.790$ and $\beta = 0.394$) pre- and postoperatively, respectively.

CONCLUSION

The percentage of possible improvement achieved is not significantly different between the most commonly used PROMs. mHHS may be used to predict preoperative iHOT12 score given the moderate R^2 value (0.486).

SUBJECTIVE REPORTING OF POSTOPERATIVE HIP FLEXIBILITY FOLLOWING ARTHROSCOPIC CORRECTION OF FAI IS NOT OBJECTIVELY MEASURABLE

Filan D, Mullins K, Carton P

UPMC Whitfield, UPMC Sports Medicine, Waterford, Ireland

OBJECTIVE

The objective of this study was to determine whether a change in patients' subjective feeling of hip flexibility, following arthroscopic correction of FAI, correlates with an objectively measured change in hip range of motion (ROM) and reported patient-reported outcome measures (PROMs).

METHODS

The researchers reviewed the institutional registry for patients undergoing hip arthroscopy (HA) for FAI between 2018 and 2021. Inclusion criteria consisted of primary HA for FAI. Exclusion criteria consisted of age older than 50 years at time of surgery, Tonnis classification > 1, dysplasia, labral excision/no repair, significant articular cartilage damage observed intraoperatively, and revision surgery. Follow-up was a minimum of two years. Standard follow-up assessment included an evaluation of PROMs (hip-specific modified Harris Hip Score [mHHS] and generalized health and well-being 36-Item Short Form Health Survey [SF-36]) either via online/postal assessment questionnaires or in clinic when they opted for an in-person postoperative follow-up as recommended. For those attending for clinical review, objective ROM was measured and included in the final analysis. Patients were categorized as "less flexible," "no change," or "more flexible" based on their subjective rating on the focused question "Would you currently describe yourself as more flexible or less flexible than before your surgery?" ROM was assessed with a dual-operator technique with a handheld goniometer.

RESULTS

Overall, 370 cases met the inclusion criteria, of which 71% (n = 264) had available follow-up at a minimum of two years postoperatively. Of those, 65% (n = 171) had ROM available, and those cases were included in the final analysis. Mean age was 28.1 ± 8.6 years (95% confidence interval [CI], 26.8, 29.4), and mean follow-up duration was 37.7 months (95% CI, 36.2, 39.2). The study found that 49.7% (n = 84) described themselves as more flexible, 24.3% (n = 41) no change, and 24.3% (n = 41) less flexible. There was no significant difference between groups for any of the PROMs measured either preoperatively or postoperatively or the change between two time points ($p > 0.076$). There was no difference in pre-operative mHHS or SF-36 between groups describing themselves as either more/less/same flexibility. Post-operative PROMs were poorer for those describing themselves as "less flexible," which was statistically significant when compared to more flexible (mHHS, $p < 0.001$; SF36, $p < 0.001$) and no change (mHHS, $p < 0.014$; SF-36, $p < 0.001$).

CONCLUSION

Patients describing themselves as having less flexibility following HA for FAI report poorer PROMs compared to those describing more flexibility or no change. However, measured ROM was similar for all cases irrespective of subjective interpretation of postoperative flexibility.

HIGH SURVIVORSHIP AND EXCELLENT FIVE-YEAR OUTCOMES IN PATIENTS OLDER THAN 40 YEARS UNDERGOING ARTHROSCOPY FOR FEMOROACETABULAR IMPINGEMENT

Mullins K, Filan D, Carton P

UPMC Whitfield, UPMC Sports Medicine, Waterford, Ireland

OBJECTIVES

The objective of this study was to assess five-year clinical outcomes in adults older than 40 years following hip arthroscopy for femoroacetabular impingement (FAI) compared to a younger matched control group.

METHODS

All primary arthroscopies for FAI between 2009 and 2016 were considered (n = 1,762). Hips presenting with Tonnis classification > 1, lateral center edge angle < 25, or prior hip surgery were excluded. Younger (< 40 years) and older hips (> 40 years) were matched for gender, Tonnis grade, capsular repair, and radiological parameters. Survival (avoidance of total hip replacement [THR]) was compared between the groups. Patient-reported outcome measures (PROMs) were also completed at baseline and five years to assess changes in functional capacity. Additionally, hip range of motion (ROM) was assessed at baseline and review. The minimal clinically important difference (MCID) was determined and compared between groups.

RESULTS

Ninety-seven older hips were matched to 97 younger controls (78% male in both groups). The average age of the older group at the time of surgery was 48.0 ± 5.7 years, compared to 26.7 ± 6.0. Six (6.2%) of the older hips and 1 (1%) of the younger hips converted to THR ($p = 0.043$, effect size = 0.74, large). There were statistically significant improvements in all PROMs. At follow-up, there were no differences in PROMs between groups. Significant improvements in hip ROM were also observed, with no difference in ROM between groups at either time point. Similar achievement of MCID was observed in both groups.

CONCLUSION

Older patients experience a high survivorship rate at five years, although this may be lower than younger patients. Where THR is avoided, large clinically significant improvements in pain and function are observed.

TEN-YEAR CLINICAL OUTCOME FOLLOWING ARTHROSCOPY FOR FAI WITH CONCOMITANT LATERAL RIM DYSPLASIA: A CASE-CONTROL MATCHED STUDY

Mullins K, Filan D, Carton P

UPMC Whitfield, UPMC Sports Medicine, Waterford, Ireland

BACKGROUND

Controversy surrounds the role of hip arthroscopy (HA) in patients with femoroacetabular impingement (FAI) and concomitant dysplasia. Long-term outcome data are also lacking.

OBJECTIVE

The objective of this study was to determine the long-term (minimum 10-year) clinical outcomes following HA for FAI in the presence of concomitant lateral rim dysplasia compared to a matched control group.

METHODS

The researchers prospectively collected and reviewed data from patients undergoing HA between January 2009 and October 2013. Patients with lateral rim dysplasia, defined as a lateral center-edge angle (LCEA) of < 25^o, were matched in a 1:2 ratio to patients with an LCEA >30^o, based on sex, Tonnis angle, and age. Outcomes included were survival (avoidance of total hip replacement [THR]), rates of repeat HA, and patient-reported outcomes (PROs: modified Harris Hip Score [mHHS], 36-Item Short Form Health Survey [SF-36], UCLA Activity Scale [UCLA], and Western Ontario and McMaster Universities Arthritis Index [WOMAC]). Survivorship was assessed between groups with a Kaplan-Meier curve and log rank test, whereas revision rates between groups were assessed with a chi-squared analysis. Between- and within-group analyses for PROs were conducted with Mann Whitney U and Wilcoxon signed-rank test, respectively. The patient acceptable symptom state (PASS) was determined with an anchor question. The proportion of cases achieving PASS was compared between groups via chi-squared analysis, and receiver operating characteristic curves with Youden's index were used to determine cutoffs for each PRO that would equate to PASS. Finally, a sub-analysis between those with severe (LCEA < 20^o) and borderline (LCEA 20^o–25^o) dysplasia was conducted.

RESULTS

Fifty-five cases with dysplasia were included, of which 46 (84%) had 10-year outcomes. They were matched to 110 control cases, of which 90 (82%) had 10-year outcomes. There were no statistical differences between any baseline demographic or preoperative PROs between those with outcomes at 10 years and those without.

The average age at the time of surgery was 33 ± 9 years for the dysplasia group and 32 ± 10 for the control group ($p > 0.05$). There was no statistical difference between groups for baseline metrics apart from the LCEA (22 ± 2^o versus 36 ± 4^o, $p < 0.001$, effect size = 0.814, large), sharp angle (41 ± 3^o versus 36 ± 3^o, $p < 0.001$, effect size = 0.625, large) and Tonnis angle (12 ± 3^o versus 4 ± 4^o, $p < 0.001$, effect size = 0.719, large).

At 10 years, 91% of dysplasia cases and 96% of control cases had retained their natural hips and avoided THR. There was no statistical difference between the dysplasia group and control group for survival or revision rates (15% versus 11%, $p > 0.05$). Tonnis angle was identified as a predictor variable of THR conversion in regression analysis. The model indicated that for every unit increase in Tonnis angle, the odds of THR increased by 1.162 ($p = 0.031$; 95% confidence interval, 1.011–1.135). Both groups reported improvements in PROs, and there was no difference between PRO scores at either time point ($p > 0.05$ for all). Eighty-five and 83% of dysplasia and control cases, respectively, achieved PASS. The thresholds for PASS for mHHS, UCLA, SF-36, and WOMAC were 80, 7.5, 83, and 15, respectively. Sub-analysis indicated no statistical differences in THR, revision, outcomes, or PASS between those with severe and borderline dysplasia.

CONCLUSION

HA for symptomatic FAI is a successful treatment in cases where dysplasia (LCEA < 25^o) is present. Low complication rates, comparable outcomes to those without lateral rim dysplasia, and a high survivorship rate of 91% at minimum 10-year follow-up make HA an excellent treatment option for FAI in the presence of dysplasia and a safe and effective alternative to peri-acetabular osteotomy.

REVISION SURGERY FOR RESIDUAL BONY DEFORMITY IN FAI CASES RESULTS IN HIGH SURVIVORSHIP AND GOOD CLINICAL OUTCOME AT FIVE YEARS: COMPARISON WITH MATCHED PRIMARY CASES

Mullins K, Filan D, Carton P

UPMC Whitfield, UPMC Sports Medicine, Waterford, Ireland

BACKGROUND
The exponential rise in arthroscopy for femoroacetabular impingement (FAI) has led to increased revision surgery rates, although this is often an exclusion criterion from arthroscopy literature.

OBJECTIVE
The purpose of this study was to examine midterm (minimum five-year follow-up) outcomes after revision arthroscopic correction of FAI compared with a matched control group of primary surgical cases.

METHODS
The researchers retrospectively reviewed prospective outcome data, collected in a consecutive series of patients undergoing revision arthroscopic FAI correction. Revision procedures were compared to a matched group of primary surgical cases. Survivorship was defined as the avoidance of total hip replacement (THR) and assessed with a Kaplan-Meier curve with the log-rank test. Regression analysis was conducted to identify predictors of THR conversion. Patient-reported outcomes (PROs) compared between groups included the modified Harris Hip Score (mHHS), UCLA Activity Scale (UCLA), 36-Item Short Form Health Survey (SF-36), and Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) preoperatively and at five years postoperatively). The proportion of patients across groups achieving the minimal clinically important difference (MCID) was compared for each PRO. Finally, a sub-group analysis was performed to compare the outcomes of those who had their index surgery at the authors' clinic and those who had an index procedure elsewhere.

RESULTS
The study included 124 revision cases and 268 primary cases. The main indication for revision surgery was residual bony deformity. Both groups had high survivorship rates at five years (> 90%), although revision cases did have a statistically higher conversion to THR than primary cases (6.5% versus 1.5%, $p = 0.008$). Increasing age and revision surgery were identified in regression analysis as predictors for THR conversion. Where THR was avoided, improvements in PROs were observed in both groups ($p < 0.001$ for all). Prior to surgery, revision cases reported lower scores for all PROs. At five years, the only statistical difference between the groups was in the distribution of mHHS scores. There were no differences in the rate of MCID achievement between groups.

CONCLUSION
Residual bony deformity is the main indication for revision arthroscopy. Revision procedures may have lower survival than primary cases, although overall survivorship at midterm follow-up is high. When THR is avoided, improvements in pain and function can be expected, similar to primary surgical cases.

CLINICAL PRESENTATION OF FAI IN FEMALE ATHLETES

Mullins K, Filan D, Carton P

UPMC Whitfield, UPMC Sports Medicine, Waterford, Ireland

BACKGROUND
Femoroacetabular impingement (FAI) is a common pathology in young athletes. With greater female involvement in sport, it is important to identify sex-specific characteristics of injury patterns, to improve diagnostic accuracy and treatment effectiveness. The aim of this study was to compare clinical, radiological, and associated symptoms between male and female athletes diagnosed with FAI.

METHODS
The researchers reviewed prospectively collected data from an institutional hip arthroscopy registry for athletes undergoing primary hip arthroscopy for FAI between 2011 and 2020. Inclusion criteria consisted of diagnosed FAI, no prior surgery, involved in competitive/recreational athletic activities, and age younger than 40 years. Exclusion criteria consisted of Tonnis classification > 1 and dysplasia (lateral center-edge angle < 25^{o}).

Patients completed patient-reported outcomes at presentation, which consisted of the modified Harris Hip Score (mHHS), 36-Item Short Form Health Survey (SF-36), and Western Ontario and McMaster Universities Arthritis Index (WOMAC). The patients also completed a specific 15-item questionnaire which assessed the prevalence of both primary and secondary symptoms. Primary symptoms included anterior groin pain exacerbated by activity, in addition to the subjective feeling of stiffness. Secondary symptoms included pain in the lower back, thigh, referred pain extending toward the knee, and functional symptoms (e.g., clicking). Range of motion (flexion, adduction, abduction, and external and internal rotation) was quantified with a dual-operator goniometric protocol. Chi-squared analysis and non-parametric Mann-Whitney U tests were used to determine differences between males and females for categorical and numerical variables, respectively.

RESULTS
The study included 511 athletic cases, of which 54 were female (10.6%). There was no difference in the training frequency between the groups. Female athletes were older than their male counterparts at the time of presentation (30 ± 7 versus 26 ± 6, $p < 0.001$). Females had lower alpha angles on both anterior-posterior (49 ± 19^{o} versus 67 ± 18^{o}, $p < 0.001$) and Dunn view (51 ± 15^{o} versus 60 ± 13^{o}, $p < 0.001$) radiographs. Females had higher levels of external (42 ± 9^{o} versus 38 ± 8^{o}) and internal rotation (34 ± 14^{o} versus 26 ± 10^{o}, $p < 0.001$). Females reported lower scores on mHHS (72 ± 12 versus 82 ± 12, $p < 0.001$) and SF36 (66 ± 16 versus 72 ± 16, $p < 0.001$) and higher scores for WOMAC (27 ± 16 versus 19 ± 16, $p < 0.001$) compared to males at presentation, indicating greater levels of dysfunction.

Differences in primary and secondary symptoms were reported between sexes. Greater proportions of females reported anterior groin pain (50% versus 32%, $p = 0.010$) and hip pain during activity (82% versus 68%, $p = 0.043$). In addition, a greater proportion of females presented with pain at the side of the hip (50% versus 29%, $p = 0.002$) and pain extending down the thigh (17% versus 7%, $p = 0.010$). In contrast, a smaller proportion of females reported stiffness after activity compared to males (52% versus 78%, $p < 0.001$).

CONCLUSION
Despite smaller numbers of female athletes, differences in FAI presentation between the sexes were observed. Females were older, had greater levels of pain and dysfunction during activities of daily living, and had a higher proportion of primary and secondary symptoms compared to males.

PREDICTORS OF CONTINUING TO PLAY AFTER SURGICAL CORRECTION OF FAI IN ATHLETES

Mullins K, Filan D, Carton P

UPMC Whitfield, UPMC Sports Medicine, Waterford, Ireland

BACKGROUND

Femoroacetabular impingement (FAI) is a common pathology in young athletic cohorts. Continuing to play following intervention is central to patient satisfaction, and it is important to outline realistic expectations in this group prior to treatment. The aim of this study was to identify baseline demographics that would predict the likelihood of continuing to play sport following surgery.

METHODS

The researchers conducted a retrospective analysis of prospectively collected data from an institutional hip registry. Competitive athletes undergoing primary arthroscopy for femoroacetabular impingement between January 2009 and December 2021 were identified for inclusion (n = 1,405). Those without return-to-play data at two-year follow-up were excluded. Binary logistic regression models were used to identify baseline demographics likely to influence the probability of whether an athlete will continue with sporting involvement. Important baseline demographics were included in a bivariate regression analysis, and any statistically significant variables were then included in a multivariate forward stepwise regression analysis. The variables included in the analysis were age at surgery, symptom duration, sex, lateral center edge angle, alpha angle, and Tonnis classification. Preoperative patient-reported outcome scores (modified Harris Hip Score, 36-Item Short Form Health Survey, UCLA Activity Scale, and Western Ontario and McMaster Universities Arthritis Index) were also included in the model.

RESULTS

The analysis included 629 cases. The main sports were hurling and Gaelic football. The average age at time of surgery was 27 ± 7 years; 95% of the cohort was male, and the preoperative alpha angles and lateral center-edge angles were 67 ± 18 and 34 ±7, respectively. Twenty-four percent of the group had a symptom duration of less than six months, 25% between six and 12 months, 20% between one and two years, 23% between two and five years, and 8% more than five years. In addition, 73% of cases had Tonnis classification of 0, 17% Tonnis 1, 8% Tonnis 2, and 2% Tonnis 3. Also, 74% were continuing to play at two years following intervention. Binary logistic regression indicated that increasing age, higher Tonnis classification (≥ Tonnis 2), and prolonged symptom duration (> two years) decreased the odds of continuing to play two years after surgery (see Table 1).

CONCLUSION

Those with longer symptom durations who are older at the time of intervention and have more advanced osteoarthritic changes in the joint may be less likely to continue with sports two years after surgery. Athletes should be appropriately counselled preoperatively as to the likelihood of continuing with sport based on clinical presentation prior to intervention to ensure realistic expectations of the procedure.

Variable	Significance Value	Exp (B)	Confidence Interval for Exp (B)
Age at surgery	0.014	0.967	0.941–0.993
Tonnis classification 2	0.007	0.419	0.222–0.791
Tonnis classification 3	0.001	0.110	0.029–0.422
Symptom duration > two years	0.002	0.313	0.151–0.649

Table 1. Demographic variables likely to decrease the odds of continuing to play following arthroscopy for femoroacetabular impingement

EARLY MCID ACHIEVEMENT IS ASSOCIATED WITH BETTER LONG-TERM OUTCOMES FOLLOWING ARTHROSCOPY FOR FAI

Mullins K, Filan D, Carton P

UPMC Whitfield, UPMC Sports Medicine, Waterford, Ireland

BACKGROUND
Postoperative factors, identified in early review, that could detect patients at risk of deterioration would be clinically beneficial.

OBJECTIVE
The objective of this study was to determine whether early improvement is associated with long-term survival and outcome following arthroscopy for femoroacetabular impingement (FAI).

METHODS
Those undergoing primary arthroscopy between January 2009 and March 2014 (n = 1,017) were considered for inclusion. Exclusion criteria consisted of Tonnis classification > 1 (n = 192) and lateral center-edge angle < 25^{o} (n = 68). Those without outcomes at one year <u>and</u> 10 years were also excluded (n = 271). Finally, those who had either a total hip replacement or revision procedure within one year of the index surgery were removed from the analysis (n= 50). The researchers calculated the minimal clinically important difference (MCID) on the modified Harris Hip Score at one year using the potential-of-possible-improvement method. Patients were categorized as early improvement (EI) or delayed improvement (DI) based on MCID achievement at one year. Survival, revision rate, and patient acceptable symptom state (PASS) were compared between the groups with a Kaplan-Meier curve and chi-squared analysis.

RESULTS
The study included 436 cases. The average age at the time of surgery was 32 ± 10 years, and 82% of cases were male. Seventy-five percent had a Tonnis classification of 0. Seventy-nine percent achieved MCID at one year and were categorised as EI, whereas 21% did not and were categorised as DI. There was no significant difference between the groups for any baseline demographic features (age, lateral center-edge angle, alpha angle, Tonnis classification, gender; $p > 0.05$ for all).
By the 10-year review, there were six THR conversions in the EI group compared to 16 in the DI group, leading to a significantly lower survival rate in the DI group (98% compared to 82%, $p < 0.001$). Revision rates were lower in the EI group (6% versus 12%), and the EI group had higher levels of PASS achievement at 10-year review (86% in the EI group compared to 68% in the DI group, $p < 0.001$).

CONCLUSION
Early clinical improvement, measured as the proportion of patients meeting one-year MCID following hip arthroscopy for FAI, is associated with better long-term survival, avoidance of revision, and higher levels of satisfaction.

A COMPARISON OF AEROBIC- AND RESISTANCE-EMPHASIZED EXERCISE ON CARDIOMETABOLIC HEALTH AND QUALITY OF LIFE IN MEN RECEIVING ANDROGEN DEPRIVATION THERAPY FOR PROSTATE CANCER: PROTOCOL FOR A FEASIBILITY TRIAL

Murphy K[1,2], Kehoe B[1], Denieffe S[3], Hacking D[2], Fairman CM[4], Harrison M[1]

[1]Department of Sport and Exercise Science, South East Technological University, Waterford, Ireland
[2]UPMC Hillman Cancer Center, Whitfield Hospital, Waterford, Ireland
[3]School of Humanities, South East Technological University, Waterford, Ireland
[4]Department of Exercise Science, Arnold School of Public Health, University of South Carolina, Columbia, S.C.

BACKGROUND
Those with intermediate- and high-risk prostate cancer typically receive androgen deprivation therapy (ADT) as part of their treatment. ADT often results in extensive side effects, including increased risk of cardiometabolic disease. Many ADT side effects can be influenced by exercise, both resistance and aerobic training. Exercise regimens typically combine aerobic and resistance exercise, but the appropriate emphasis for achieving the broadest range of therapeutic benefits has yet to be determined. The authors aim to determine the feasibility of undertaking a larger trial comparing resistance- versus aerobic-emphasized exercise interventions in men with prostate cancer undergoing ADT. The trial will also investigate preliminary evidence of differences between arms for cardiometabolic health and quality-of-life outcomes.

METHODS
This is a six-month, randomized, two-armed feasibility trial. Prostate cancer patients undergoing ADT and radiotherapy will be recruited (n = 24) and randomized to either a resistance- or aerobic-emphasized group. Participants will attend twice-weekly supervised individual or small-group sessions, with 75% of exercise time in the primary exercise modality. The primary outcome will be feasibility, determined via assessment of recruitment, retention, adherence, safety, and acceptability. Secondary outcomes will include quality of life, body composition, vascular indices, aerobic and muscular fitness, and cardiometabolic health blood biomarkers.

CONCLUSION
It is envisaged that the trial will provide valuable information and preliminary difference data that will aid in the design of an efficacious larger trial that will adopt a major and minor emphasis approach to the scheduling of resistance and aerobic exercise.

ORTHOPAEDIC RESEARCH UPDATE

James H-C. Wang, PhD
Vice Chair of Orthopaedic Research
Nam Vo, PhD
Deputy Vice Chair of Orthopaedic Research

The Department of Orthopaedic Surgery had another successful and fruitful year of research across its 11 distinct laboratories, spread across five different locations and covering a wide spectrum of musculoskeletal research activities.

Under the molecular and cellular musculoskeletal research umbrella, Hang Lin, PhD, leads the Joint Tissue Biology, Pathology, and Engineering Laboratory in conducting interdisciplinary research, emphasizing the creation of tools and techniques to explore the development, function, pathology, and regeneration of cartilage and other musculoskeletal tissues. Peter Alexander, PhD, at the Ferguson Laboratory continues his research on osteoarthritis and ligamentum flavum hypertrophy. Under the leadership of James Wang, PhD, the MechanoBiology Laboratory (MBL) continues to pursue extensive and innovative research in the areas of tendon stem cell mechanobiology, molecular mechanisms of mechanical overloading–induced and aging-related tendinopathy, soft-tissue wound healing and tendon-to-bone interface regeneration, and functional tissue engineering of injured tendons and ligaments. The research mission of the Ferguson Laboratory for Orthopaedic and Spine Research, codirected by Nam Vo, PhD, Gwendolyn Sowa, MD, PhD, and Joon Lee, MD, is to investigate the biology of intervertebral disc aging and intervertebral disc degeneration (IDD) and perform deep phenotyping of chronic low back pain (LBP) in patients. The Ferguson Laboratory also actively develops biologic and therapeutic treatments to prevent and/or minimize IDD and LBP and provides exciting educational and research training opportunities for trainees.

Within the imaging and robotic musculoskeletal research domain, the mission of the Biodynamics Laboratory, directed by William Anderst, PhD, is to investigate the relationships among dynamic joint function and joint disease, injury, and treatment; to develop methods for assessing the dynamic function of joints and musculoskeletal tissues; and to provide unique training opportunities to fellows and students alike. Using state-of-the-art robotic technology, the Orthopaedic Robotics Laboratory, codirected by Volker Musahl, MD, and Richard Debski, PhD, is dedicated to the prevention of degenerative joint disease by improving diagnostic, repair, and rehabilitation procedures for musculoskeletal injuries. The Orthopaedic Engineering Laboratory, directed by Patrick Smolinski, PhD, and managed by Monica Linde, MSIE, RN, in collaboration with the Department of Mechanical and Materials Science in the Swanson School of Engineering, houses the Double-Bundle Anterior Cruciate Ligament Reconstruction Study Group. Bradley Nindl, PhD, is the director of the Neuromuscular Research Laboratory, which offers a comprehensive profile of an individual’s function by evaluating the sensory and motor characteristics specific to musculoskeletal injury and pathology.

Several laboratories continue to establish and improve the standard of care for musculoskeletal conditions. The Arthroplasty Design and Outcomes Laboratory, directed by Kenneth Urish, MD, PhD, focuses its efforts on improving functional outcomes in the non-operative and operative treatment of knee and hip arthritis, optimizing implant performance, and preserving joint function. The Sports Medicine Concussion Research Program, with Michael Collins, PhD, as director and Dr. Anthony Kontos, PhD, as research codirector, sets the standard of care for sports injuries by employing a targeted, evidence-based approach for assessment, management, and treatment of patients with concussion using advanced equipment. The Foot and Ankle Research Laboratory, under the direction of Dr. MaCalus Hogan, MD, MBA, focuses its research on regenerative bioengineering using stem cells and biomaterials, biomechanical assessment of foot and ankle injuries and fixation techniques, as well as clinical outcomes research. Finally, the Musculoskeletal Oncology Laboratory (MOL), directed by Kurt Weiss, MD, investigates osteosarcoma metastatic disease and the metastatic potential in other sarcomas, with a focus on establishing a vigorous, comprehensive sarcoma research program at the University of Pittsburgh for patients with metastatic sarcoma.

Throughout the year, academic excellence has resulted in many awards and recognition for the research faculty and trainees in the department. A few examples are highlighted below.

Dr. Lin successfully acquired a new National Institutes of Health (NIH) R21 grant, in addition to publishing eight papers in leading journals with an impact factor (IF) higher than 10 last year. He was named co-chair of the biomaterials group in the Orthopaedic Research Society (ORS) and chair of the Communication Committee of the International Chinese Musculoskeletal Research Society. Dr. Urish finished enrollment on two separate U.S. Food and Drug Administration (FDA) clinical studies. Dr. Urish became a member of the Knee Society, an invite-only group, and he is the first physician from Pittsburgh elected to this group.

Drs. Collins and Kontos of the Concussion Research Laboratory enrolled more than 500 subjects across 15 externally funded, prospective clinical research studies. Among the funded projects in 2023 were four clinical trials funded by the Centers for Disease Control and Prevention and Department of Defense (DOD). Drs. Kontos and Collins were the first- and fourth-ranked researchers in the field of sport-related concussion (*World Neurosurgery*, 2022). Their laboratory's publications appeared in high-impact journals in 2023, including *Sports Medicine* (IF 11.93), *American Journal of Sports Medicine* (IF 6.1), and *Journal of Neurotrauma* (IF 4.2).

Dr. Wang and Dr. Jianying Zhang, PhD, had a successful pre-IND (investigational new drug application) meeting with the FDA and DOD, with the aim to test the safety and efficacy of a lotion formulation of metformin as a topical application for the prevention and treatment of tendinopathy.

Drs. Vo, Sowa, and Lee from the Ferguson Laboratory acquired two NIH R01 grants to study lactate metabolism and cellular senescence of intervertebral disc, as well as one large NIH U19 consortium grant to phenotype chronic LBP and verify efficacies of different treatments.

Reaffirming the department's tradition of superior representation at annual scientific meetings, the department had another successful year at the annual ORS meeting. At the ORS 2024 meeting, faculty and researchers gave several podium and poster presentations. Dr. Anderst's lab had four podium and 15 poster presentations. Dr. Lin's lab gave four poster presentations, and the Ferguson Lab gave six poster presentations, including one from Dr. Alexander's lab. Dr. Wang's lab also had one podium and five poster presentations. Dr. Debski earned special recognition as an ORS Fellow. Dr. Weiss served as faculty for the ORS grant-writing workshop, and Dr. Vo served as a moderator for the intervertebral disc section.

Notably, 2023 marked the inaugural year of the Orland Bethel Family Musculoskeletal Research Center (BMRC), a groundbreaking center that supports and promotes leading-edge musculoskeletal medicine as a major focus at the University of Pittsburgh Schools of the Health Sciences. Funding opportunities for early-career scientists to promote generation of critical preliminary data for breakthrough treatments will be awarded in fall of 2024. A joint grant partnership with ORS was announced at ORS' 70th annual meeting in February 2024 and will amplify the impact of the fellowship grants. Two support staff were hired to assist the BMRC's mission, including an operations manager and a communications specialist. Additionally, hiring of core lab staff for muscle and bone research is in progress. Renovation of BMRC core lab spaces has begun and will continue through 2026.

Research-related services of the department continue to offer monthly seminars spearheaded by Drs. Vo and Wang. A highlight was that Yan Ma, PhD, chair and professor of the Department of Biostatistics at the University of Pittsburgh School of Public Health, presented a lecture on his group's statistical research interests in missing data imputation, machine learning, and meta-analysis, as well as the formation of collaborative research between his department and the Department of Orthopaedic Surgery.

Drs. Collins and Kontos delivered multiple lectures highlighting their clinical profiles model and research as part of the 14th World Congress on Brain Injury in Dublin, Ireland. Dr. Kontos was an invited presenter on the effects of soccer heading at the 2023 U.S. Soccer/Major League Soccer/National Women's Soccer League's Head Injury Summit II in Chicago.

MOL, codirected by Kurt R. Weiss, MD and Ines Lohse, PhD, published seven papers in the past year, with manuscripts currently in preparation. Their work was presented at the Musculoskeletal Tumor Society in Banff, Canada; the Connective Tissue Oncology Society in Dublin, Ireland; and the Orthopaedic Research Society in Long Beach, California. Dr. Weiss has been a visiting professor at the University of Toronto, before the FDA, and at the ORS grant-writing course, which he will codirect at next year's meeting. Dr. Lohse has been named codirector of the UPMC Hillman Cancer Center Summer Academy Cancer Biology Site and was recently admitted to the University of Pittsburgh Mothers Leading Science program. Her proposal for the 2024 LifeX Accelerator Program was accepted, and she has already begun this exciting opportunity. The future is bright for the MOL as they continue basic, translational, and clinical research in musculoskeletal oncology.

In closing, the commitment and diligence of our faculty and staff, as showcased in this research overview and the subsequent laboratory abstracts in this journal, serve as a testament to their outstanding contributions to both our department and the broader community.

OVERVIEW

The Ferguson Laboratory for Orthopaedic and Spine Research continues to expand the boundaries of basic and clinical spine research under the direction of Joon Lee, MD, Gwendolyn Sowa, MD, PhD, and Nam Vo, PhD. The primary focus of the laboratory is to understand the biology of spine and other orthopaedic degeneration and to develop biological, biomechanical, and cell-based therapies for these pathological conditions. The laboratory is composed of exceptionally skilled clinician-scientists, basic science researchers, and biomedical engineers who provide a multidisciplinary approach to address these complex disease processes.

Biology of Disc Degeneration

The overall goal of Dr. Vo's research is to understand the mechanisms of intervertebral disc degeneration (IDD) matrix loss and explore therapeutic strategies to minimize this loss, with a particular focus on the roles of autophagy and cellular senescence in modulating age-associated IDD. Drs. Vo, Lee, and Sowa were awarded a National Institutes of Health (NIH) R01 grant from the National Institute on Aging to study cellular senescence as a driver of disc aging. Postdoctoral fellow Prashanta Silwal, PhD, and Physician Scientist Training Program (PSTP) student James Kim continued the work on the mechanisms of disc cellular senescence and autophagy in age-associated IDD.

Bioenergetics and Metabolism

Historically, lactate has been viewed as a harmful waste product of glycolysis. However, given the unique environment of disc cells, it is hypothesized that lactate may serve important energetic and regulatory functions within the disc. Dr. Vo and Dong Wang, MD, PhD, have previously accrued evidence that lactate generated within the anaerobic environment of the nucleus pulposus is utilized by the neighboring annulus fibrosus as an energy source. Furthermore, recent studies indicate that lactate is used for epigenetic regulation within the nucleus pulposus. As a result of this work, Drs. Vo, Lee, and Sowa were awarded an NIH R01 grant from the National Institute of Arthritis and Musculoskeletal and Skin Disease (NIAMS) to study lactate as an epigenetic regulator and a biofuel in age-dependent IDD. Dr. Wang has spearheaded this work and has presented several posters on disc lactate at both the Orthopaedic Research Society (ORS) and Philadelphia Spine Research Society (PSRS) annual meetings. PSTP student Trudy Zou continued this work, studying the role of lactate in epigenetic gene regulation of IDD and identifying the enzymes involved in histone lactylation using human disc cells, presenting her findings at multiple annual meetings.

Joint Degeneration

Peter G. Alexander, PhD, continues to adapt his knowledge and skills in tissue engineering, animal-model development, and osteoarthritis of the hip and knee to problems of the spine. His first project involves ligamentum flavum hypertrophy (LFH), a prevalent cause of lumbar spine stenosis (LSS) that affects millions of Americans annually. The molecular cause of LFH is unknown, and there is no remedy short of laminectomy. To address this, Dr. Alexander is working on a multi-tissue 3D model of the ligamentum flavum that reports changes in elastin expression with inflammation. To complement the *in vitro* model, he is collaborating with Dr. Lee and orthopaedic surgery residents in their research year to develop an LFH-inducing instability model in rats for *in vivo* pathogenic studies and molecular therapy testing. Aspects of these projects were presented at meetings of PSRS, ORS, and department. In a second project, Dr. Alexander is developing methods to identify the secretome produced by cells of the synovial joint and intervertebral disc. Changes in tissue crosstalk are now recognized as major drivers of various diseases, including osteoarthritis and intervertebral disc disease. The specific conditions Dr. Alexander is analyzing are articular cartilage overload and intervertebral disc herniation. He will identify and map changes in the secretome using recently reported proximity labeling strategies developed at the University of Pittsburgh Aging Institute. These strategies are being deployed both in a unique *in vitro*, dual-flow, tissue-engineered model of the synovial joint and IVD and *in vivo* genetic models that promise to revolutionize the understanding of osteoarthritis and IDD.

Ligamentum flavum hypertrophy

Current surgical intervention to treat IDD addresses the resultant biomechanics of degeneration but neglects the underlying pathophysiology of disease. Gene- and cell-based therapies have the potential to address the imbalance between catabolism and anabolism that occurs within the disc tissue. Building upon the work of former lab resident Richard Wawrose, MD, Anthony Oyekan, MD, demonstrated successful reduction in markers of LFH in cell culture using overexpression of microRNA-29a. This work was once again presented by current lab resident Christopher Como, MD, and has sparked interest in further experiments on human ligamentum flavum. Additionally, Dr. Alexander, Prashanta Sawil, and Karen Clark have developed protocols for 3D tissue-engineered ligament tissue fabrication, gene delivery, and analysis of tissue health and disease to advance this work. Currently, a team led by Drs. Como and Alexander is developing a rat spine instability model to better understand LFH disease pathogenesis. The ultimate goal will be to test novel therapeutic treatments for lumbar spinal stenosis utilizing the novel rat spine instability model.

Biomarker Discovery

In work funded by the NIH, Dr. Sowa investigates the correlation of biochemical and imaging biomarkers to IDD severity and pain. Recently, proteomic analysis of clinical samples has yielded promising results. In collaboration with Michael Schneider, DC, PhD, differential mass spectroscopy was used to identify factor 5 protein as a potential biomarker for clinical severity in patients with lumbar spine stenosis and chronic low-back pain. This work was selected for the International Society for the Study of the Lumbar Spine's 2022 Best Paper Award.

Other avenues of research include utilizing serum-based biomarkers in conjunction with imaging biomarkers to predict individual responses to treatments and studying the gut microbiome and its relationship with chronic low-back pain, with preliminary results indicating a correlation of certain microbiome populations with low-back pain severity, well received at the 2024 HEAL (Helping to End Addiction Long-Term) annual meeting.

The Ferguson Lab continues to carry out experiments in "LB3P: Low Back Pain Research Study," a mechanistic research center funded through a U19 award from the NIH HEAL Initiative. The LB3P Center is an innovative, multidisciplinary collaboration of investigators at UPMC and the University of Pittsburgh. The center will collect data from three key contributing domains of chronic low-back pain: biological, biomechanical, and behavioral. Researchers will analyze the data and perform in-depth phenotyping of patients with chronic low-back pain with the goal of characterizing patients and directing targeted treatments. Drs. Sowa and Vo are co–principal investigators of this large U19 consortium project grant, which began in 2019 (U19AR076725-01) and totaled nearly $22 million in funding. This U19 grant has also resulted in multiple supplemental fundings, including NIAMS funding for a multisite proposal titled "Expanding BACPAC Capacity: Phenotyping Non-LBP Controls for BACPAC Consortium Research," a collaborative clinical trial Biomarkers for Evaluating Spine Treatments (BEST), and several consortium-wide harmonization efforts and site-specific protocol papers recently published in a BACPAC supplement of *Pain Medicine* journal.

New Beginnings
The Ferguson Laboratory is extremely excited to be the future site of the Orland Bethel Family Musculoskeletal Research Center (BMRC). Orland Bethel and his family donated an astonishing $25 million, and the University of Pittsburgh matched this gift, totaling $50 million to build a comprehensive musculoskeletal research center for the entire university and UPMC. BMRC will promote transformative research to further study musculoskeletal disorders and will feature the core laboratories of the Ferguson Laboratory; the Joint Tissue Biology, Pathology, and Engineering Laboratory; the Musculoskeletal Regenerative Rehabilitation Laboratory; the Musculoskeletal Oncology Laboratory; the Pittsburgh Orthopaedic Spine Research Group; the Surgery of the Upper Extremity Research Group; the Foot and Ankle Injury Research Group, the Biodynamics Laboratory, and the MechanoBiology Laboratory.

PERSONNEL
Faculty
Gwendolyn A. Sowa, MD, PhD, codirector
Nam Vo, PhD, codirector
Joon Y. Lee, MD, clinical director
Peter G. Alexander, PhD
Allison C. Bean, MD, PhD
Jeremy D. Shaw, MD
William Donaldson III, MD

Research scientists
Dong Wang, MD, PhD
Harsha Nagar, PhD

Postdoctoral fellows
Prashanta Silwal, PhD

Residents
Christopher John Como, MD

Research specialists
Dwight Best
Paulo Coelho, lab manager
Karen L. Clark
Qing Dong
Wan Huang
Harsha Nagar
Camilla Piechocki
Minying Yang

Students
Anna Bailes
Joseph Chen
Julia Giroski
James Kim
Valerio Tonelli Enrico
Kareem Zein
Trudy Zou

Administrative support
Michelle Darabant
Lori Freund

The Ferguson Lab at the annual Orthopaedic Research Society meeting

Nam Vo, PhD, and Joon Lee, MD, with their research team at the Orthopaedic Research Society meeting

The Ferguson Lab enjoying dinner during the Orthopaedic Research Society meeting this year

ASSESSING THE EFFECT OF PROTAC 753B ON INTERVERTEBRAL DISC AGING

Alexander PG[1], Clark KL[1], Wang D[1], Dong Q[1], Lee JY[1], Sowa GA[1], Vo NV[1]

[1] Department of Orthopaedic Surgery, University of Pittsburgh, Pa.
[2]Department of Physical Medicine and Rehabilitation, University of Pittsburgh, Pa.

INTRODUCTION
Low-back pain (LBP) is one of the most common musculoskeletal conditions requiring medical care and contributing to patient impairment and disability. Age is the leading risk factor for intervertebral disc (IVD) degeneration, and cellular senescence is a major driver of aging. Senescent cells are known to be resistant to apoptotic cell death, upregulating "senescent cell anti-apoptotic pathways" (SCAPs) such as the BCL/BAX pathways. PROTAC 753b is an engineered peptide designed to knock down the expression of Bcl-x_L/Bcl2. The objective of this study was to assess whether systemic 753b can reduce age-related IVD degenerative changes in a mouse model.

METHODS
Twenty mice of equal mixed sexes and 16 months of age were treated with 753b. Males and females were divided into one of three groups: aged untreated, aged vehicle control, and 753b-treated groups. A cohort of 10 untreated young male and female mice were used as comparatives. After six months of treatment (22 months of age), the spines were harvested and tissues processed for histology (paraffin embedding), protein or RNA isolation. Safranin O/Fast green–stained sections were scored with the MERCY score by three independent investigators. Western blots were carried out for aggrecan degradation, and gene expression of the following genes was analyzed by reverse transcription polymerase chain reaction (RT-PCR) for the following genes: p16 and p21 (senescence regulators), Aggrecan (AGG; NP matrix), MMP13 (a SASP mediator of AGG degradation), and TIMP1&3 (regulators of MMP activity).

RESULTS
In this pilot study (n = 5 per group), histopathological analysis revealed that both male and female aged mice have significantly degenerated IVDs than young mice (see Figure 1A). Aged male mice showed a four-point decrease in score ($p < 0.05$) with 753b treatment, whereas female mice merely trended lower. Immunohistochemistry revealed a partial recovery of Aggrecan deposition in the nucleus pulposus NP of aged male mice treated with 753b but no significant change in the aged females (see Figure 1B). Similarly, Western blot demonstrated a decrease of MMP-mediated AGG degradation in aged male mice treated with 753b but no significant change in aggrecanase-mediated degradation (see Figure 1C). In addition, 753b treatment of aged females resulted in no significant changes in the presence of either AGG neo-epitope (see Figure 1C). RT-PCR showed that AGG gene expression and other genes were unchanged by 753b treatment in both male and female aged mice, except for p21 in aged female mice (data not shown).

DISCUSSION
Protein analyses indicate that 753b can partially ameliorate age-related IVD degeneration in aged male mice, in part by preserving Aggecan in the IVD (nucleus pulposus). 753b treatment did not significantly improve IVD health in aged female mice, which may be explained by a delayed effect of 753b evident in transcriptional changes observed in females in the absence of histomorphological improvement. The inability of 753b to completely block IVD degeneration in both sexes indicates that other SCAPs may still be active in IVD senescent cells and/or that senescence accounts for only part of the degeneration observed with aging. Nonetheless, the results of this pilot study show a sex-dependent response to 753b treatment that should be studied more extensively.

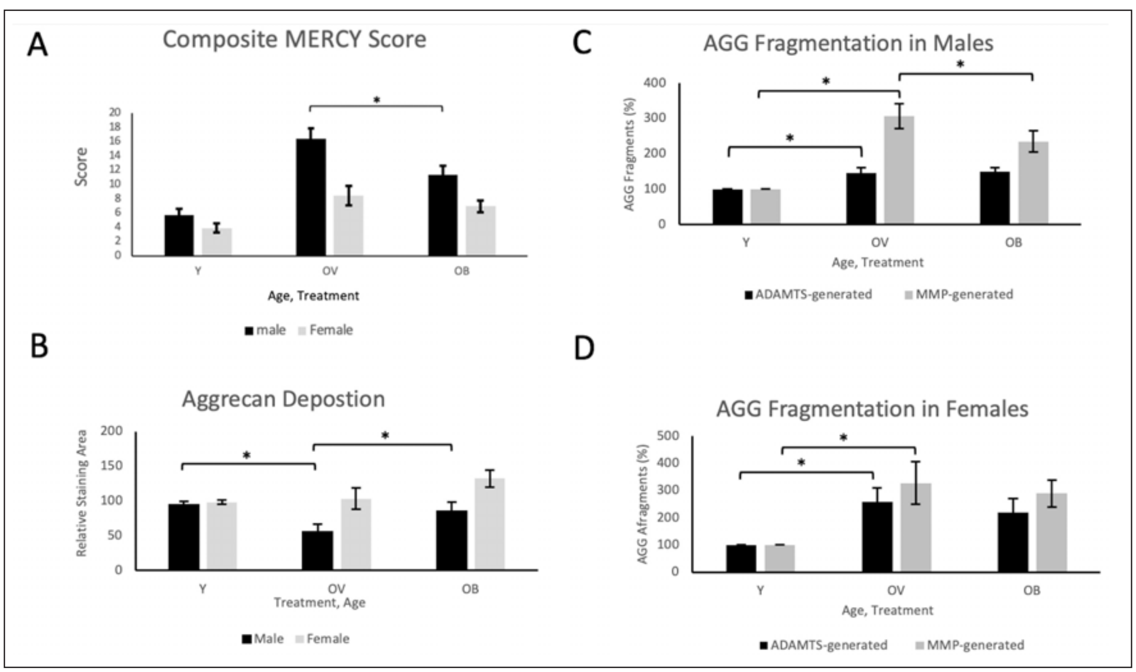


Figure 1. Effect of PROTAC 753b on intervertebral disc aging. (A & B) Histopathological scores in (A) male and (B) female mice, (C & D) Immunohistochemical staining for Aggrecan in (C) male and (D) female mice. There were five animals per group. * = p < 0.05

GAIT: AN INDICATOR OF PAIN AND FUNCTION IN CHRONIC LOW-BACK PAIN

Bailes AH[1,2], Johnson ME[3], Redfern M[2], Perera S[4], Greco C[1,5], Sowa GA[2,6], Cham R[1,2], Bell KM[2]

[1]Department of Physical Therapy, University of Pittsburgh, Pittsburgh, Pa.
[2]Department of Bioengineering, University of Pittsburgh, Pittsburgh, Pa.
[3]Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.
[4]Department of Medicine, University of Pittsburgh, Pittsburgh, Pa.
[5]Department of Psychiatry, University of Pittsburgh, Pittsburgh, Pa.
[6]Department of Physical Medicine and Rehabilitation, University of Pittsburgh, Pittsburgh, Pa.

INTRODUCTION

Chronic low-back pain (cLBP) is associated with gait impairments.[1] Gait may serve as an important biomarker for improvement following therapy interventions.[2] However, gait has not been sufficiently studied in relationship to pain and function in cLBP.

METHODS

Adults with cLBP completed a two-minute walk test around a 37.5 m oval track while wearing an inertial measurement unit (IMU, Lifeware LLC, Pittsburgh, Pennsylvania) over the L5 spinous process. Step time average, step time variability, step length, and symmetry were calculated based on linear trunk accelerations,[3] and gait speed was calculated based on distance walked. Participants completed the PEG tool (Pain, Enjoyment, General activity; scores closer to 10 indicate worse pain) to quantify pain intensity/interference and the PROMIS Physical Function SF-6b tool (mean t-scores = 50 ± 10; higher scores indicate better function) to quantify physical function. Pearson correlation coefficient (r) was used to determine strength of associations between gait and pain/physical function.

RESULTS

Eleven adults (eight female, age = 40 ± 17 years, pain duration ≥ 3 months) with cLPB participated in the study after completing an informed consent process approved by the University of Pittsburgh Institutional Review Board. Participants with a history of cancer, spinal cord compression, discitis, or activity restrictions prohibiting them from protocol completion were excluded. The mean PEG scores and PROMIS Physical Function t-scores were 2.8 ± 1.8 and 47.8 ± 8.2, respectively. There was a moderate to strong correlation between step-time average and PEG ($r = 0.67$, $p = 0.02$) and a moderate to strong correlation between gait speed and PROMIS Physical Function ($r = 0.62$, $p = 0.04$). There were no other significant associations.

DISCUSSION

Gait speed and step time may be important movement biomarkers to consider when evaluating patients with cLBP. Generalizability of results are limited by the small study cohort and this cohort's relatively low pain burden and high level of physical function.

REFERENCES

1. Smith JA et al. *J Sport Health Sci*. 2022;11(4):450-65.
2. Barzilay Y et al. *Eur Spine J*. 2016;25(9):2761-6.
3. Zijlstra W & Hof AL. *Gait Posture*. 2003;18(2):1-10.

DISENTANGLING THE ROLES OF PAIN AND PAIN-RELATED PSYCHOLOGICAL FACTORS IN GAIT FOR CHRONIC LOW-BACK PAIN: A PRELIMINARY STUDY

Bailes AH[1,2], McKernan GP[3], Greco C[4], Redfern M[1], Sowa G[3], Bell KM[1], Piva S[2], Brach JS[2], Cham R[1], LB3P Investigators

[1]Department of Bioengineering, University of Pittsburgh, Pittsburgh, Pa.
[2]Department of Physical Therapy, University of Pittsburgh, Pittsburgh, Pa.
[3]Department of Physical Medicine and Rehabilitation, University of Pittsburgh, Pittsburgh, Pa.
[4]Department of Psychiatry, University of Pittsburgh, Pittsburgh, Pa.

INTRODUCTION

Individuals with chronic low-back pain (cLBP) move differently than their peers,[1] but the relative contributions of pain itself and pain-related psychological factors remain unclear. Much of the research has focused on small samples performing simple tasks (e.g., forward flexion), while failing to consider larger samples performing functional tasks.[2] This study moves beyond simple movements through use of a wearable sensor to examine gait in a large sample of individuals with cLBP. The researchers hypothesized that individuals with high pain intensity, fear avoidance (FA), and/or pain catastrophizing (PC) would demonstrate worse gait quality.

METHODS

Three hundred and fifty-eight participants (57.8 ± 16.1 years of age; 38% male, 61% female, < 1% non-binary) with cLBP completed a two-minute walk test around a 37.5-meter indoor track. Participants were fitted with an inertial measurement unit (Lifeware Labs, LLC, Pittsburgh, Pennsylvania) placed over the L5 spinous process. Gait speed was calculated based on distance walked, and stride time variability and gait symmetry were derived from linear trunk accelerations in the sagittal plane. Participants completed the Pain Enjoyment and General Activity scale (PEG, scale of 0–10) to quantify pain, the Fear Avoidance Beliefs Questionnaire–Physical Activity sub-scale (FABQ-PA, scale of 0–24) to quantify FA, and the six-item Pain Catastrophizing Scale (PCS, scale of 0–24) to quantify PC. Participants were divided into mild (0–3, n = 140), moderate (4–6, n = 126), and high (7–10, n = 92) pain groups based on the PEG; low (0–13, n = 145) and high (14–24, n = 213) FA groups based on the FABQ-PA;[3] and low (0–15, n = 303) and high (16–24, n = 55) PC groups based on the PCS. One-way analyses of variance and independent t-tests were used to compare gait metrics between groups.

RESULTS

Participants scored 4.8 ± 2.3 on the PEG, 9.0 ± 5.6 on the FABQ-PA, and 13.9 ± 5.5 on the PCS. Individuals who reported moderate to severe pain, high FA, or high PC exhibited slower gait speeds ($p < 0.0001$, $p = 0.01$, $p = 0.001$, respectively). There were no differences in variability or symmetry.

DISCUSSION

The results from the current study suggest that both pain itself and pain-related psychological factors impact gait speed in cLBP. Future analysis should statistically account for factors known to impact gait quality (e.g., age) and examine the functional implications of differences in gait quality in these cLBP subgroups.

SIGNIFICANCE

This study provides a novel contribution to the literature because: 1) it is a first step toward disentangling the movement-related contributions of pain and pain-related psychological factors; 2) it investigates gait, an important yet understudied movement in cLBP; and 3) it incorporates innovative technological solutions to examine functional movement strategies.

ACKNOWLEDGMENTS

The Back Pain Consortium Research Program is administered by the National Institute of Arthritis and Musculoskeletal and Skin Diseases. This research was supported by the National Institutes of Health through the NIH HEAL (Helping to End Addiction Long-Term) Initiative under award number U19AR076725-01. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health or its NIH HEAL Initiative.

REFERENCES

1. Smith JA et al. *J Sport Health Sci*. 2022;11(4):450-65.
2. Ippersiel P et al. *Phys Ther*. 2022;102(2).
3. George SZ et al. *J Orthop Sports Phys Ther*. 2008;38(2):50-8.

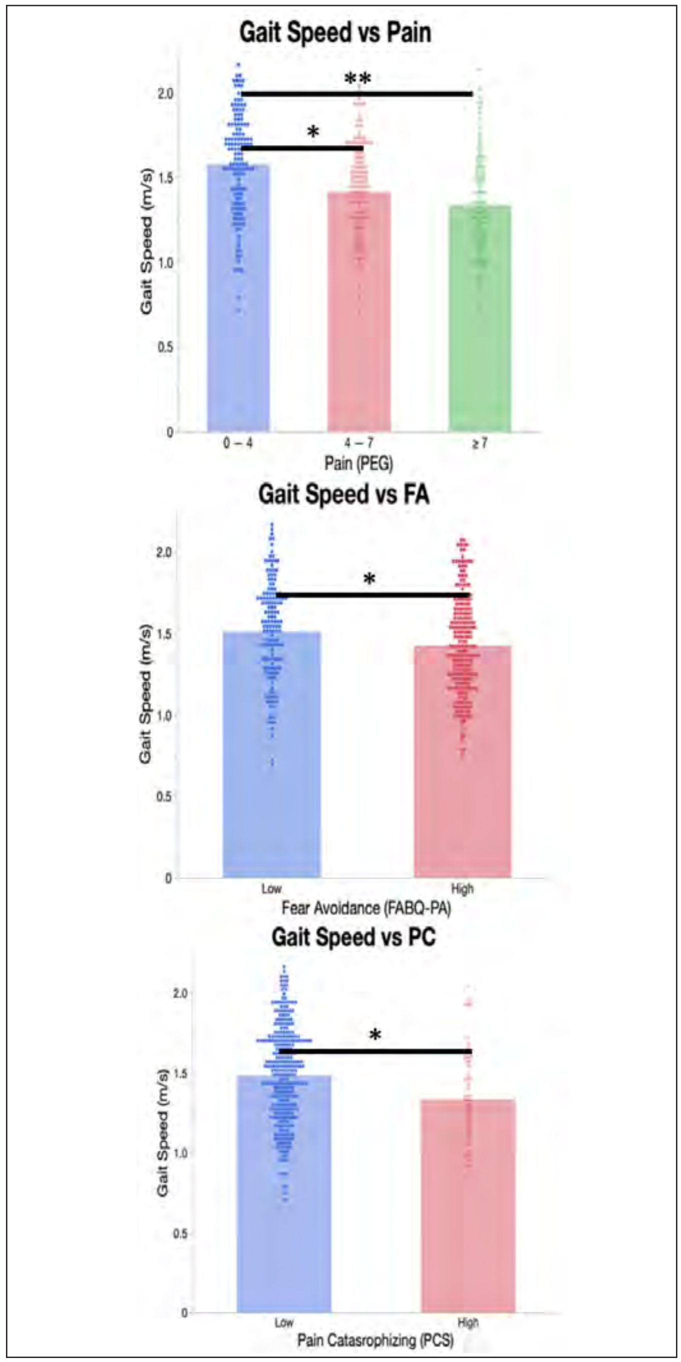


Figure 1. Gait speed versus a) pain, b) fear avoidance, and c) pain catastrophizing

A 3D CULTURE SYSTEM TO MODEL THE LIGAMENTUM FLAVUM IN HEALTH AND DISEASE

Clark KL, Tang MY, Sahil P, Vo NV, Lee JY, Alexander PG

Ferguson Laboratory, Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.

INTRODUCTION

Lumbar spinal stenosis (LSS) is a prevalent and disabling cause of low-back pain (LBP), affecting an estimated 30 million persons in the United States. Laminectomies are among the most common procedures for LSS, indicating the prevalence of ligamentum flavum hypertrophy (LFH). LFH may be described as a form of fibrosis caused by increased expression of collagen I (COL1) and collagen III (COL3), concurrent with a decrease in elastin expression. Decades of work in tissue engineering has demonstrated the benefits of 3D systems for recapitulating physiologic cell responses over 2D culture. The goal in this study was to validate a 3D system for the modeling of LF tissue and hypertrophy.

METHODS

Human LF cells were enzymatically harvested from surgical waste tissue following laminectomy according to a protocol approved by the Institutional Review Board. Cells were expanded to the second passage before they were encapsulated within a 5% (w:v) collagen I hydrogel (BioMatrix) at 1 x 10^6 cells/ml and deposited into vacuum-actuated molds within Tissue-Train™ (FlexCell) plates to form static tensile 3D constructs. Samples were matured in basal medium (BM) for seven days before exposure to TGFb1 (10 ng/ml; hypertrophic cytokine) or IL1b (10 ng/ml; inflammatory cytokine) for 24 hours. Expression of COL1, Col3, and elastin was analyzed by reverse transcription polymerase chain reaction (RT-PCR).

HYPOTHESIS

The authors hypothesized that (1) 3D cultures would produce more matrix than 2D cultures, and (2) that inflammatory conditions (IL1b) would decrease the COL1/COL3 expression ratio and reduce elastic expression, a hallmark of LF hypertrophy, as compared to controls.

RESULTS

Constructs comprised of 1 x 10^6 human LF cells in collagen 1 hydrogels formed ligament-like structures over the eight-day duration of the experiment. RT-PCR demonstrated that 3D cultures produced higher levels of COL1, COL3, and elastin. TGFb1, a known factor in tendon and ligament development, increased elastin expression, and the elastin/COL1 expression ratio increased as compared to constructs in basal medium. In contrast, IL1b, a known inflammatory cytokine, reduced the elastin/COL1 expression ratio and increased the COL3/COL1 expression ratio (disproportionally higher COL3 expression).

DISCUSSION

The use of 3D models of tissues is known to report more physiologically relevant outcomes than 2D cultures for the study of tissue development, homeostasis, disease modeling, and therapeutic testing. Demonstrating the culture of LF cells in 3D and their response to hypertrophic and inflammatory cytokines represents a first step toward use of this model in testing the ability of novel therapeutic such as miR29a to prevent or treat LF hypertrophy.

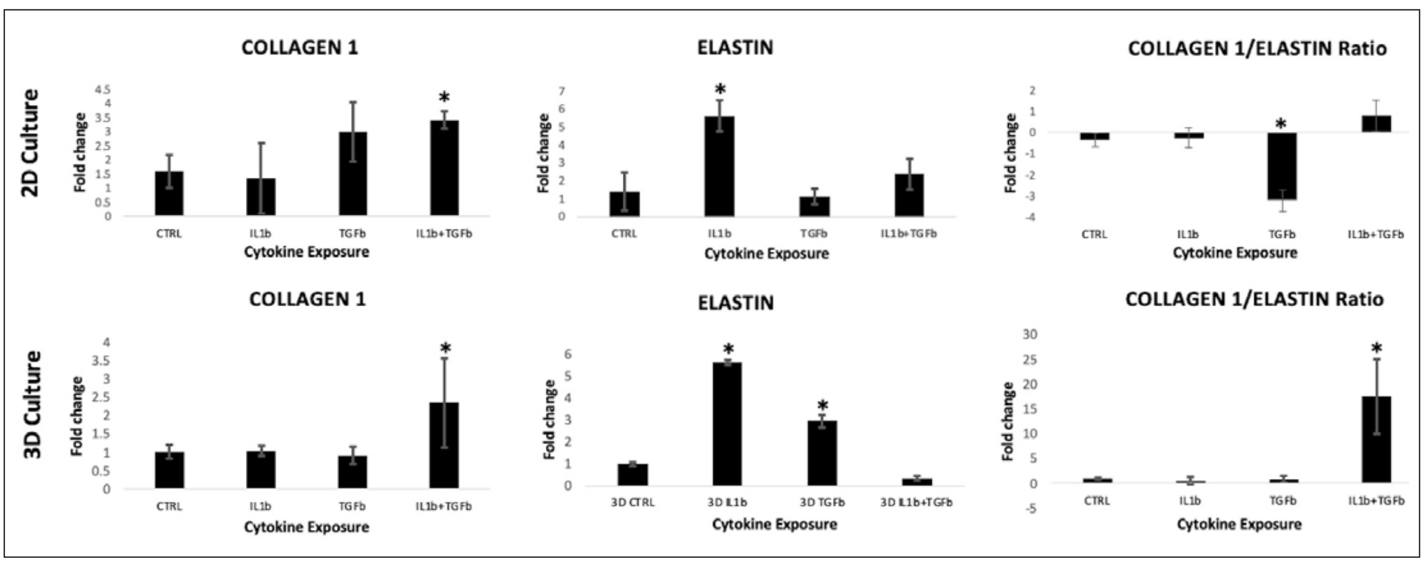


Figure 1. Gene expression analysis of ligament tissue markers in 2D and 3D cultures
*** = $p < 0.05$**

A RAT INSTABILITY MODEL TO STUDY LIGAMENTUM FLAVUM HYPERTROPHY

Como CJ, Clark KL, Sahil P, Tang Y, Vo NV, Lee JY, Alexander PG

Ferguson Laboratory, Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.

INTRODUCTION
A primary cause of lumbar spinal stenosis (LSS), a prevalent and disabling cause of low-back pain (LBP), is hypertrophy of the ligamentum flavum (LF). The (LF) is a short, thick ligament that connects the laminae of adjacent vertebrae along the length of the spine, playing an important role in spine stability. LF hypertrophy (LFH) is characterized by increased TGFb1 and IL6, an increase in the collagen-1 (COL1)/elastin expression ratio, immune cell invasion, and the emergence of the myofibroblast. Unfortunately, the pathogenic mechanisms from injury to disease are unknown. Animal models have historically been important in determining disease mechanisms and testing therapeutics. The goal of this study is to develop a rapid, affordable, and relevant model of LFH induced by mechanical instability to gain insight into the cellular and molecular mechanisms that lead to LFH.

METHODS
Fisher 343 rats will be put into deep sleep. After the region of the lumbar spine is shorn and made sterile, spinal instability with LF preservation will be created by removing the facet joints and pars articularis with bone-cutting clippers and transection of the interspinous ligament while preserving the LF and intersegmental musculature (see Figure 1). After closure and recovery, the animals will be maintained for eight weeks with free access to food and water in a standard cage or via a food access tube that induces hyperflexion. At eight weeks, the lumbar spine will be imaged by magnetic resonance imaging and computed tomography, the LF in the destabilized and adjacent segments collected, and one of three analytical tools (histology/immunohistochemistry for LFH markers, molecular analysis by reverse transcription polymerase chain reaction, and single-cell RNA sequencing and mechanical testing) to verify segment instability.

HYPOTHESIS
The authors hypothesize that spine instability can be achieved with preservation of the LF such that LFH is a consequence. The resulting LFH will have hallmarks of clinical LFH, including increased TGFb1 and IL6, an increase in the collagen-1 (COL1)/elastin expression ratio, immune cell invasion, and the emergence of the myofibroblast.

DISCUSSION/FUTURE DIRECTIONS
The development of the rat model described here will complement existing rat intervertebral disc degeneration models used by the Ferguson Laboratory to examine spine degeneration, aging, and pain behavior. Most importantly, the model will provide the opportunity to assess pathogenesis of LFH over time using high-content techniques such as single-cell RNA sequencing to greatly contribute to the understanding of LFH pathogenesis in terms of changing cell populations, changing phenotypes, and altered signaling pathways that hopefully lead to new, effective treatments for LFH.

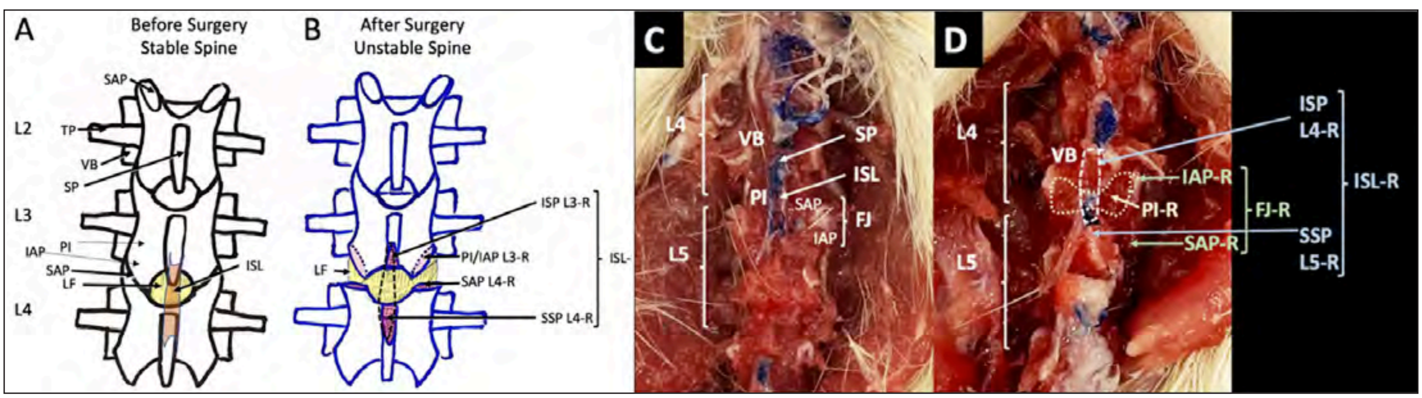


Figure 1. Schematic representation of proposed rat spine instability model. Schematic of L2-L4 rat spine (A) before surgery, (B) after destabilization and cadaveric demonstration of instability model, (C) before surgery, and (D) after destabilization.

Labels: SAP = superior articular process, TP = transverse process, VB = vertebral body, SP = spinous process, PI = pars interarticularis, IAP = inferior particular process, SAP = superior articular process, LF = ligamentum flavum, ISL = interspinous ligament, ISP L3-R = inferior spinous process of L3 resected, SSP L4-R = superior spinous process of L4 resected, ISL-R = interspinous ligament resected, PI/IAP L3-R = pars interarticularis/inferior articular process of L3 resected, SAP L4-R = superior articular process of L4 resected

ESTABLISHING AN *IN VIVO* RAT SPINE INSTABILITY MODEL OF LIGAMENTUM FLAVUM HYPERTROPHY

Como CJ[1,3,4], Tang MY[1,3,4], Vo N[1,3,4], Sowa GA[2,3,4], Lee JY[1,3,4], Alexander PG[1,3,4]

[1]Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.
[2]Department of Physical Medicine and Rehabilitation, University of Pittsburgh, Pittsburgh, Pa.
[3]Pittsburgh Orthopaedic Spine Research Group, Pittsburgh, Pa.
[4]Orland Bethel Family Musculoskeletal Research Center (BMRC), Pittsburgh, Pa.

INTRODUCTION

Low-back pain (LBP) remains the leading cause of years lost to disability, costing the United States $87.6 billion annually.[1-3] Lumbar spinal stenosis (LSS) significantly contributes to LBP, representing the most prevalent reason for lumbar spine surgery in adults. Ligamentum flavum (LF) hypertrophy (LFH) is a key contributor to LSS, but there is limited research investigating the pathogenesis of LFH in LSS due to the lack of a reliable and reproducible animal model of LFH.[4-6] Because LFH is thought to be induced secondary to instability, a validated *in vivo* model of spine instability is required to study the development of LFH. This study aims to develop an *in vivo* rat instability model for LFH with the eventual goal of testing novel therapeutic targets to treat LSS.

METHODS

Adult 6-month-old Fischer 344 rats will be put into deep sleep. After sterile preparation of the lumbar spine, flexion and extension x-rays will be obtained. A trained orthopaedic surgery resident will perform the surgery. Spinal instability will be induced by removing the L4-L5 interspinous ligament, the L4 spinous process, and bilateral L4 inferior articular processes (see Figure 1). The soft tissue and skin will be closed with suture. Flexion and extension x-rays will be obtained prior to the cessation of anesthesia. All animals will be monitored for eight weeks after surgery. Postoperative monitoring will include behavioral analysis evaluating activity level, gait/posture, fur appearance, appetite changes, licking/biting/chewing, and aggression. All animals will be sacrificed eight weeks after surgery. After sacrifice, LF samples will be collected from each rat for histologic and polymerase chain reaction (PCR) analyses. LF specimens at the operative level and immediately above will be divided longitudinally, with each half designated for either histological or PCR analysis.

HYPOTHESIS

The authors hypothesize that the proposed rat spine instability model will create lumbar spinal stenosis characterized by increased LF thickness, increased collagen I and III expression, and decreased elastin expression.

DISCUSSION / FUTURE DIRECTIONS

The development of the rat model described above will complement existing rat intervertebral disc degeneration models utilized by the Ferguson Laboratory to examine spine degeneration, aging, and pain behavior. Most importantly, the model will provide the opportunity to assess pathogenesis of LFH over time, with the ultimate goal of developing new and effective treatments for LFH.

REFERENCES

1. Wu A et al. *Ann Transl Med*. 2017;8:299.
2. Deyo RA et al. *Annual Review of Public Health*. 1991;12:141-56.
3. Murray CJL et al. *JAMA*. 2013;310:591-608.
4. Sun C et al. *FASEB J*. 2020;34:9854-68.
5. Sakai Y et al. *J Orthop Sci*. 2017;22:27-33.
6. Munns JJ et al. *PLoS One*. 2015;10:e0128321.

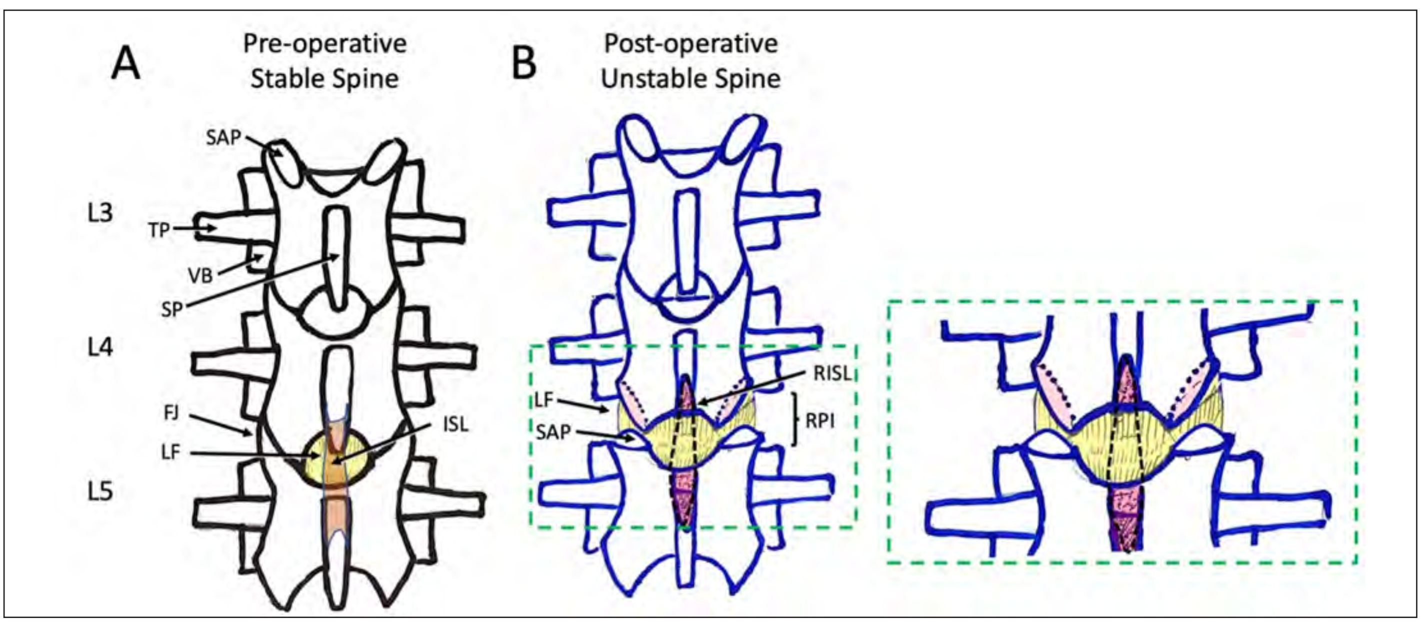


Figure 1. Schematic representation of proposed rat spine instability model: (A) Rat spine from L3-L5, (B) Destabilized rat spine at L4-L5

Labels*:* SAP = superior articular process, TP = transverse process, VB = vertebral body, SP = spinous process, FJ = facet joint, LF = ligamentum flavum, ISL = interspinous ligament, RISL = resected interspinous ligament, RPI = resected pars interarticularis

ROLE OF G0/G1 SWITCH GENE2 IN TRANSFORMING GROWTH FACTOR β1-INDUCED HYPERTROPHY OF LIGAMENTUM FLAVUM

Silwal P[1], Lee JY[1], Sowa GA[1,2], Vo NV[1]

[1]Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.
[2]Department of Physical Medicine and Rehabilitation, University of Pittsburgh, Pittsburgh, Pa.

INTRODUCTION

Lumbar spinal stenosis (LSS) is a major spinal disorder in elderly patients contributing to back pain.[1] Hypertrophy of ligamentum flavum (HLF) is the main etiology of LSS. Studies have shown several histological changes in thickened ligamentum flavum (LF), including a loss of elastic fibers and increased collagen fibers and proteoglycans, led by upregulation of collagenases; cell differentiation to myofibroblasts; and several growth factors, such as transforming growth factor-beta (TGF-β), inflammatory cytokines, angiogenesis factors, etc., contributing to pathological changes in HLF.[2-3] G0/G1 switch gene 2 (G0S2), first identified in activated lymphocytes to regulate lipid metabolism to control cell proliferation, is implicated in the regulation of diverse biological and pathological processes such as cell proliferation, apoptosis, inflammation, metabolism, and carcinogenesis (Matsunaga, 2016).[4] Recent studies have shown that G0S2 mediates the renal inflammation and fibrosis leading to chronic kidney disease; [5] however, its role in HLF is not known. Here, the authors identified that G0S2 expression is increased upon TGF-β1 stimulation of LF cells and regulates the expression of genes involved in fibrogenesis.

METHODS

LF specimen collected during surgery were used to isolate the LF cells from HLF and adjacent non-HLF (control) tissue. LF cells were stimulated with TGF-β1 (5 or 10 ng/ml) for 24 hours or transfected with control siRNA (siCN) and G0S2-specific siRNA (siG0S2) for 48 hours followed by stimulation with TGF-β1 (5 ng/ml) for 24 hours. Real-time polymerase chain reaction was performed to assess relative gene expression. Unpaired t-test was performed to calculate significance.

RESULTS

Stimulation of control or HLF cells with TGF-β1 induced the expression of *G0S2* (see Figure 1A). Next, the researchers confirmed siRNA efficiency using the different doses of siG0S2 and decided to use 100 pmol of siRNA for further experiments (see Figure 1B). TGF-β1 increased the expression of *TGFB1*, collagen-1 (*COL1*), versican (*VCAN*), and alpha smooth muscle actin (α-SMA/*ACTA2*) in both normal and HLF cells, revealing the induction of extracellular matrix fibrosis and myofibroblast differentiation by TGF-β1 (see Figure 1C). Knockdown of G0S2 by siRNA significantly inhibited the TGF-β1-mediated expression of *TGFB*, *VCAN*, and *ACTA2* (see Figure 1C), revealing the potential role of G0S2 in LF fibrosis and hypertrophy.

DISCUSSION

The results show that G0S2 is implicated in fibrotic signaling in LF cells, as it can be induced by TGF-β1. G0S2 knockdown decreased the TGF-β-induced expression of *TGFB*, *VCAN*, and *ACTA2* in LF cell culture. Specifically, *VCAN* and *ACTA2*, which refer to proteoglycans and myofibroblast differentiation, respectively, are the pathological markers for thickened LF and are inhibited by G0S2 knockdown. Future studies are necessary to establish the molecular mechanisms behind G0S2 regulation of fibrogenesis and its regulation of HLF.

SIGNIFICANCE

This study identified G0S2 as a potential regulator of pathologic development of HLF, which can be a potential therapeutic target.

REFERENCES

1. Weinstein et al. *Spine (Phila Pa 1976)*. 2010.
2. Hur et al. *Eur Spine J*. 2017.
3. Yabe et al. *J Orthop Res*. 2016.
4. Matsunaga et al. *EBioMedicine*. 2016.
5. Xu et al. *Mediators Inflamm*. 2020.

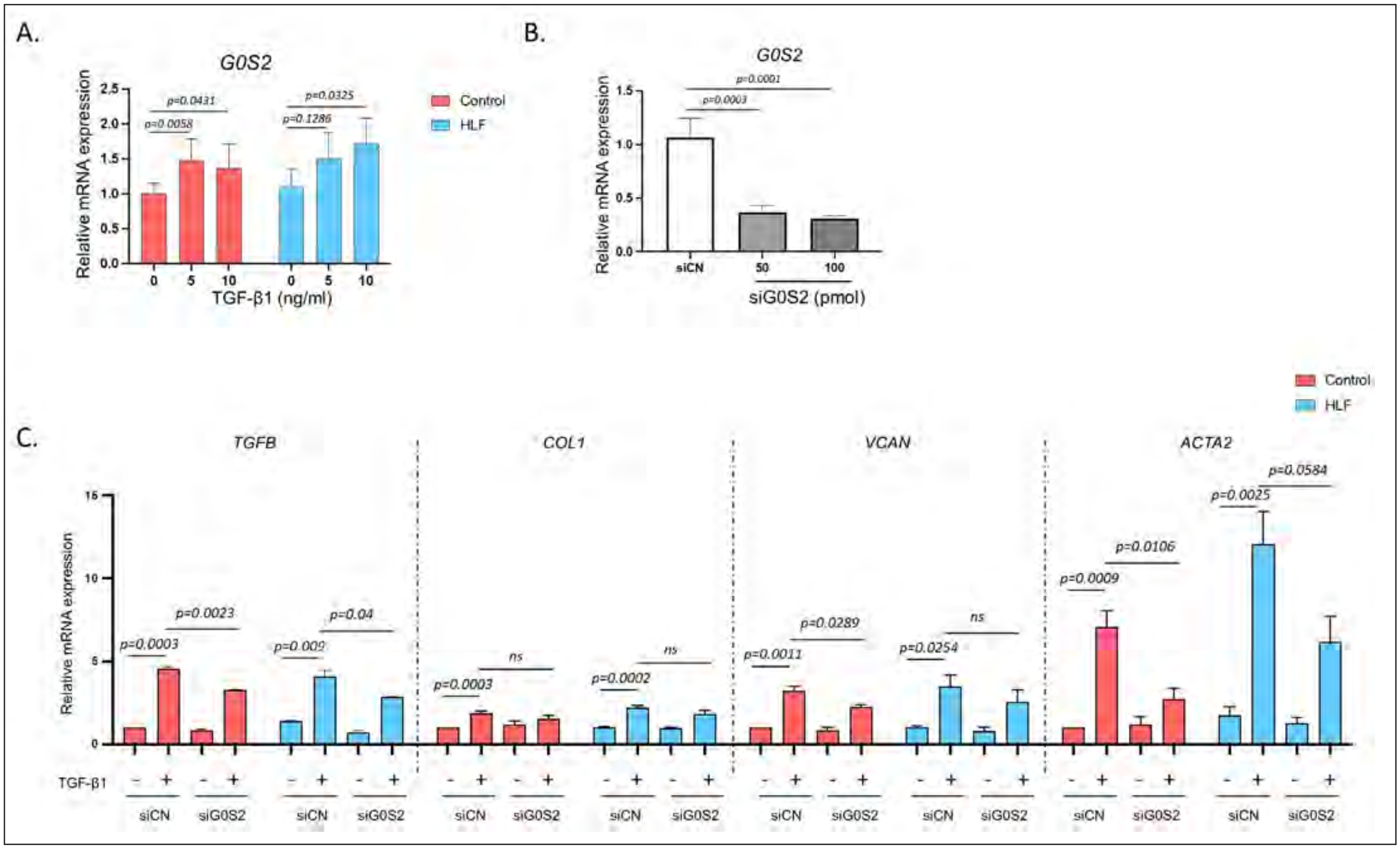


Figure 1. Role of G0S2 in TGF-β1-induced fibrogenic signaling in LF cells. A. Dose-dependent effects of TGF-β1 stimulation in *G0S2* gene expression. B. *G0S2* gene expression in HLF cells transfected with different doses of G0S2 siRNA. C. Effects of G0S2 knockdown in TGF-β1 stimulated expression of *TGFB*, *COL1*, *VCAN*, and *ACTA2* (α-SMA) gene expression in control and HLF cells.

PLASMA PROTEOMICS ANALYSIS IN CHRONIC LOW-BACK PAIN SUBJECTS: A PRELIMINARY ANALYSIS

Tonelli Enrico V[1,2,3], Piva S[3], Patterson C[3], McKernan G[2], Greco C[3,4], Vo N[1], Sowa GA[1,2]

[1]Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.
[2]Department of Physical Medicine and Rehabilitation, University of Pittsburgh, Pittsburgh, Pa.
[3]Department of Physical Therapy, University of Pittsburgh, Pittsburgh, Pa.
[4]Department of Psychiatry, University of Pittsburgh, Pittsburgh, Pa.

INTRODUCTION
Chronic low-back pain (cLBP) is a multifactorial condition often resulting in significant pain, decreased function, and poor treatment outcomes. Systemic inflammation has been increasingly investigated as a contributor to cLBP. The authors explored a range of inflammation-related blood biomarkers (both pro- and anti-inflammatory) linked to painful conditions. They hypothesized that higher pro-inflammatory and lower anti-inflammatory marker concentrations would be correlated with higher pain and disability.

METHODS
A convenience sample of 413 subjects with cLBP was included in the analysis. Plasma samples were analyzed for anti-inflammatory markers interleukin-1 receptor antagonist (IL-1ra) and IL-10 and for pro-inflammatory markers IL-6, IL-15, interferon-alpha (IFNa), interferon-gamma (IFNg), tumor necrosis factor-alpha (TNFa), and sialic-acid-binding immunoglobulin-like lectin-9 (Siglec-9). Cytokine quantification was performed with ELLA kits (SPCKC-PS-000323 and ST01E-PS-003426; ProteinSimple, San Jose, California) on samples processed according to the manufacturer's specifications. Cytokine concentrations were normalized through log transformation.

Low-back pain levels and disability were collected at the time of blood draw using the Numeric Pain Rating Scale and the Oswestry Disability Index (ODI). Individual regressions were run between each cytokine, pain, and ODI. All regressions were additionally run stratified by sex (males and females) and age (< 55 years old and > 55 years old).

RESULTS
Across the entire cohort, pain demonstrated a negative correlation with IL-1ra ($p = 0.047$, $R^2 = 0.008$), and ODI showed a negative correlation with IL-1ra ($p = 0.015$, $R^2 = 0.014$) and a positive correlation with IL-6 ($p = 0.001$, $R^2 = 0.055$).

When analyzing the population subdivided by sex, individual positive correlations with pain were found in females only for IL-6 ($p = 0.042$, $R^2 = 0.014$), not for males. For ODI, individual positive correlations were found in both males and females for IL-6 (males: $p = 0.005$. $R^2 = 0.047$; females: $p = 0.001$, $R^2 = 0.061$). In addition, a negative correlation between ODI and IL-1ra ($p = 0.019$, $R^2 = 0.033$) was also observed in males, whereas in females, a positive correlation between ODI and TNFa ($p = 0.048$, $R^2 = 0.015$) was observed.

In the population subdivided by age, individual positive correlations were found in those > 55 years of age between IL-6 and pain ($p = 0.039$, $R^2 = 0.013$) and ODI ($p= 0.001$, $R^2 = 0.071$). In addition, in those > 55 years of age, negative correlations were noted with IL-1ra and pain ($p = 0.025$, $R^2 = 0.018$) and ODI ($p = 0.019$, $R^2 = 0.020$). No correlations were found in those < 55years of age for pain and ODI.

DISCUSSION
These results indicate a correlation of pain and ODI with IL-6 (pro-inflammatory) and IL-1ra (anti-inflammatory) in cLBP subjects. The differences observed during analyses by sex and age point to potentially different mechanisms of action and phenotypes that will require further evaluation. For example, decreased anti-inflammatory cytokines in the population older than 55 years indicate a potential role played by the decreased anti-inflammatory capacity typical of this age group.

The results confirm the hypothesis tested for cytokines IL-1ra, IL-6, and, to a lesser extent, TNFa. Due to the exploratory nature of this study, correction for multiple comparisons was not performed, which limits the interpretation of these findings. In addition, the clinical relevance of these modest correlations will need to be explored and may suggest the need for examining combinations of biomarkers (e.g., interaction between pro- and anti-inflammatory cytokines) and a larger pool of cytokines.

ASSESSING HEART RATE VARIABILITY METRICS IN CHRONIC LOW-BACK PAIN AND SUBJECTS WITHOUT LOW-BACK PAIN

Tonelli Enrico V[1,2,3], Johnson M[1,3,4], Cook H[1,4], Bell K[1,4], Vo N[1], Quinby E[3], Sedor Schiffhauer Z[1,2], Sowa GA[1,2]

[1]Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.
[2]Department of Physical Medicine and Rehabilitation, University of Pittsburgh, Pittsburgh, Pa.
[3]Department of Physical Therapy, University of Pittsburgh, Pittsburgh, Pa.
[4]Department of Bioengineering, University of Pittsburgh, Pittsburgh, Pa.

INTRODUCTION
The purpose of this study was to explore differences in heart rate variability (HRV) metrics between subjects with chronic low-back pain (cLBP) and those without low-back pain (non-LBP). The authors hypothesized that, compared to non-LBP, cLBP subjects would have decreased HRV, a measure of autonomic nervous system (ANS) dysfunction, which has been associated with systemic inflammation and altered modulation of pain.

METHODS
Ten cLBP subjects and 11 non-LBP controls were age-matched (within 10 years) and recruited for two visits (V1 and V2). One week apart, test visits were conducted at an academic physical therapy research clinic. Subjects performed the two-minute walk test, then rested for a minimum of two minutes afterward. For each visit, the two minutes of resting time were used for processing raw heart rate data with the HRVTool Matlab toolbox to calculate heart rate (HR) and different HRV metrics, including standard deviation of RR waves (SDNN), root mean squares of successive differences (RMSSD), percentage of RR intervals with at least 50 ms deviation from the preceding RR interval (pNN50), and difference of consecutive RR intervals weighted by their mean (rrHRV). Traditional statistics (t-test and logistic regression) and a machine learning approach (neural network, NN) were used. For the NN, subjects from each visit were stratified to distribute cLBP/non-LBP evenly, then divided randomly into a training subset (TS, n = 11 for V1 and V2) and a validation subset (VS, n = 11 for V1 and n = 7 for V2). The NN was implemented for each visit to predict cLBP versus non-LBP based on a model including all processed metrics (HR, SDNN, RMSSD, pNN50, and rrHRV).

RESULTS
cLBP and non-LBP ($p > 0.05$). Logistic regressions for the association of each metric with the presence/absence of LBP also found no significant associations ($p > 0.05$). For V1, the NN correctly predicted cLBP versus non-LBP with 93.3% accuracy in the TS ($R^2 = 0.34$) and 80% accuracy in the VS ($R^2 = 0.28$). For V2, the NN correctly predicted CLBP versus non-LBP with 83.3% accuracy in the TS ($R^2 = 0.35$) and 91.7 accuracy in the VS ($R^2 = 0.28$).

DISCUSSION
HRV metrics considered individually did not show significant differences or associations between the two groups. Nonetheless, the NN approach showed excellent predictability across all models (TS and VS for both visits). These findings indicate the need for a larger, adequately powered sample size that this project could not achieve. It also highlights the benefit of using a more complex statistical approach to combine different HRV metrics (each with a different physiological implication) into one model.

SIGNIFICANCE
This study shows promising results on the possible use of a combination of HRV metrics as clinical biomarkers for cLBP. These preliminary findings point to possible alterations of ANS function in cLBP. If replicated in a larger sample size, this discovery could potentially be used in clinical practice as a risk-predicting tool for cLBP. Furthermore, it indicates the potential clinical relevance of including interventions directed at improving ANS function in the treatment of cLBP.

ASSOCIATION BETWEEN LEPTIN PLASMA CONCENTRATION, PAIN, AND FUNCTION IN CHRONIC LOW-BACK PAIN

Tonelli Enrico V, McKernan G, Vo N, Sowa GA

University of Pittsburgh, Pittsburgh, Pa.

INTRODUCTION
Chronic low-back pain (cLBP) is a multifactorial, highly prevalent condition with a significant impact on function, productivity, and overall quality of life. Growing evidence points to dysregulation of the gut-brain axis as a potential contributing factor to cLBP. Leptin, a hormone predominantly made by adipose cells and enterocytes in the small intestine, has been associated with gut-brain axis signaling and modulation. Moreover, leptin participates in the pathogenesis of neuropathic pain and plays a role in immuno-metabolic inflammation, characteristic of many chronic pain conditions. The authors hypothesized that plasma leptin levels would be associated with the severity of pain and functional levels in a cLBP population.

METHODS
The researchers recruited 392 subjects with cLBP as part of a large observational cohort on cLBP. For this project, cLBP was defined as "pain lasting at least three months, for at least half of the days in the past six months." Pain was assessed with the Numerical Pain Rating Scale (NPRS, scale of 0–10), and functional levels were assessed with the Oswestry Disability Index (ODI, scale of 0–100). Both NPRS and ODI were completed at the same time point of blood collection. Leptin quantification was performed with enzyme-linked immunosorbent assay kits on plasma samples that were processed according to the manufacturer's specifications. Leptin concentrations were assessed for their linear associations with NPRS and ODI. The same analyses were run and also adjusted for age and sex.

RESULTS
Leptin was significantly associated in the unadjusted models with NPRS ($R^2 = 0.01$, $p = 0.025$) and ODI ($R^2 = 0.012$, $p = 0.031$) scores. When adjusted for age and sex, the associations were not significant ($p > 0.05$).

DISCUSSION
These results highlight leptin's small but nonetheless significant role in explaining the variability of pain and function in a CLBP population. The loss of significance in the adjusted models underlines that leptin may be an insufficient standalone marker for pain or functional levels in cLBP subjects.

SIGNIFICANCE
The systemic implications of an observable trend among leptin, pain, and function warrant further research into systemic changes that may characterize the complex cLBP population. Potential mechanisms involving the gut-brain axis and immune-metabolic changes in chronic pain conditions likely involve other relevant biomarkers in addition to leptin.

UNIQUE GUT MICROBIOME SIGNATURE ASSOCIATED WITH PAIN AND DISABILITY IN A CHRONIC LOW-BACK PAIN POPULATION: AN EXPLORATORY ANALYSIS

Tonelli Enrico V[1,2,3], Methé B[4], Li K[4], Fitch A[4], Patel A[4], Vo N[1], Morris A[4], Sowa GA[1,2]

[1]Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.
[2]Department of Physical Medicine and Rehabilitation, University of Pittsburgh, Pittsburgh, Pa.
[3]Department of Physical Therapy, University of Pittsburgh, Pittsburgh, Pa.
[4]Department of Pulmonary, Allergy and Critical Care Medicine, University of Pittsburgh, Pittsburgh, Pa.

INTRODUCTION

Chronic low-back pain (cLBP) is a multifactorial condition with various potential mechanisms and causes leading to its common debilitating outcome. Systemic inflammation is a potential mechanism for cLBP subjects. The gut microbiome (GM) has been increasingly studied as a potential contributor to systemic inflammation through neuro-immune, endocrine, and metabolic mechanisms. Alpha diversity, the measure of microbiome diversity within a subject, has been associated with health status, with lower diversity generally linked to worse health outcomes. The present study explored associations among GM, pain, and function, hypothesizing that the GM of cLBP subjects with higher pain severity and disability would be associated with decreased relative abundance of specific species linked to positive health outcomes and decreased diversity measures.

METHODS

The researchers recruited 419 participants from a larger study of cLBP. The clinical variables of pain and disability were collected with the Numeric Pain Rating Scale (NPRS) and the Oswestry Disability Index (ODI). The GM from stool was classified with 16S rRNA gene sequences and investigated through abundance-based and distribution-based methods built on individuals' taxonomic profiles. The relative species abundances (abundance-based method) utilized the additive-log ratio (alr) in linear association models against NPRS and ODI. Separate statistical models were constructed with alr while controlling for appropriate covariates (sex, age, body mass index, education, income, race) and compared to models with covariates only. The distribution-based methods utilized two alpha diversity indexes: the Shannon index and tail statistic. Linear association models were run among alpha diversity indices, NPRS, and ODI.

RESULTS

Significant associations between the relative taxa abundance and ODI were highlighted in the case of *Lachnospira* ($p = 0.007$) and *Anaerostipes* ($p = 0.010$) (negative associations), as well as *Subdoligranulum* ($p = 0.005$), *Ruminococcaceae* ($p = 0.022$), and *Christensenellacea* ($p = 0.010$) (positive associations). *Blautia* was the only taxon found to have a significant positive association ($p = 0.002$) with pain. Comparisons of reduced models (covariates only, $R^2 = 0.29$) against full models (covariates + alr, $R^2 = 0.25$) determined that inclusion of the microbiota significantly improved the prediction of ODI ($p = 0.0198$) but not for pain. Both diversity measurements were significantly associated with ODI (positive association, tail coefficient = 4.12, $p < 0.0001$; Shannon coefficient = 1.74, $p < 0.001$), but not with pain.

DISCUSSION

These results begin to define GM characteristics for a cLBP population. Although each altered taxa has been associated with one or more chronic conditions, this pattern has not been reported previously. For example, decreased *Lachnospira* has been observed in various diseases, though its role remains unclear. An increase of one or more of *Ruminococcaceae*, *Alistipes*, and *Blautia* has been observed in different inflammation-based conditions, including arthritis, obesity, diabetes, Parkinson disease, Alzheimer disease, polyneuropathy, depression, and irritable bowel syndrome. The significant R^2 improvement in the model, including alr compared to the model excluding it, suggests that GM significantly contributes to explaining the variability of ODI. Interestingly, the authors observed a positive association between all the diversity measures and ODI. This finding contradicts most of the literature on GM, citing higher diversity as a contributor to health, and requires further analysis.

PERTURBATION OF HISTONE LACTYLATION ON GENE EXPRESSION IN RAT NUCLEUS PULPOSUS CELLS

Wang D[1], Zou T[1], Lee JY[1], Sowa GA[1, 2], Vo N[1]

[1]Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.
[2]Department of Physical Medicine and Rehabilitation, University of Pittsburgh, Pittsburgh, Pa.

INTRODUCTION

The hypoxic nucleus pulposus (NP) of the intervertebral disc produces lactate from anaerobic respiration. Histone lactylation is a novel epigenetic post-translation modification.[1] The authors' lab detected high levels of histone lactylation in the lactate-rich regions of the disc NP but not in vertebral bone and paraspinal muscle. The histone deacetylases (HDAC) family includes HDAC1-11, some reported to have cognate histone delactylase activities.[1-2] Pracinostat is a potent chemical inhibitor of HDAC1-11 with IC50 of 40-140nM. This study aims to modulate NP histone lactylation by inhibiting HDACs with Pracinostat to study epigenetic regulation of key genes involved in extracellular matrix homeostasis and lactate metabolism.

METHODS

Primary rat NP cells were isolated from the spines of 3-month-old male F344 rats as approved by the University of Pittsburgh's Institutional Animal Care and Use Committee. Cells were cultured in DMEM/F12 and reconditioned in DMEM with 1 mM glucose, 1% FBS at 2% O2 for 24 hours. For histone delactylases inhibition in which histone lactylation is expected to increase, 10x of the IC50 of Pracinostat (1.5 uM) were used to treat NP cells in DMEM media with 1 mM glucose, 1% FBS, 10 mM lactate at 2% O2 for 24 hours. Western blot for histone lactylation/acetylation and reverse transcription polymerase chain reaction for matrix homeostasis genes aggrecan/MMP13/Cox2 and lactate metabolism genes LDHA/MCT4 were tested. Significance was determined with a student's t-test ($n = 9$).

RESULTS

Rat NP cells treated with Pracinostat for 24 hours exhibited no cytotoxicity effects. Pracinostat treatment of NP cells resulted in an increase of both histone lactylation and acetylation but more significantly in histone acetylation (see Figure 1). With histone delactylase inhibition, ACAN expression was significantly decreased while MMP13 and Cox2 expression was significantly increased. LDHA and MCT4 expression was also greatly increased (see Figure 2).

DISCUSSION

Inhibition of HDAC1-11 increased histone lactylation in NP cells, suggesting that some HDACs within this group have histone delactylase activities. The identities of which HDACs are histone delactylases in NP cells are being investigated. Inhibition of HDAC1-11 greatly decreased aggrecan but increased expression of the catabolic genes MMP13 and Cox2, indicating epigenetic regulation of disc matrix homeostasis through histone modification by both lactylation and acetylation. Inhibition of HDAC1-11 increased expression of LDHA and MCT4, suggesting that genes involved in NP lactate metabolism are epigenetically controlled in part by histone lactylation and acetylation.

SIGNIFICANCE

This study reveals the role of histone lactylation in epigenetic control of matrix homeostasis and lactate metabolism, providing a new epigenetic mechanism of regulation of NP cell function, which can be therapeutically targeted to prevent disease progression in intervertebral disc degeneration.

REFERENCES

1. Zhang D et al. *Nature*. 2019;574:575-80.
2. De Ruijter AJ et al. *Biochem J*. 2003;370(3):737-49.

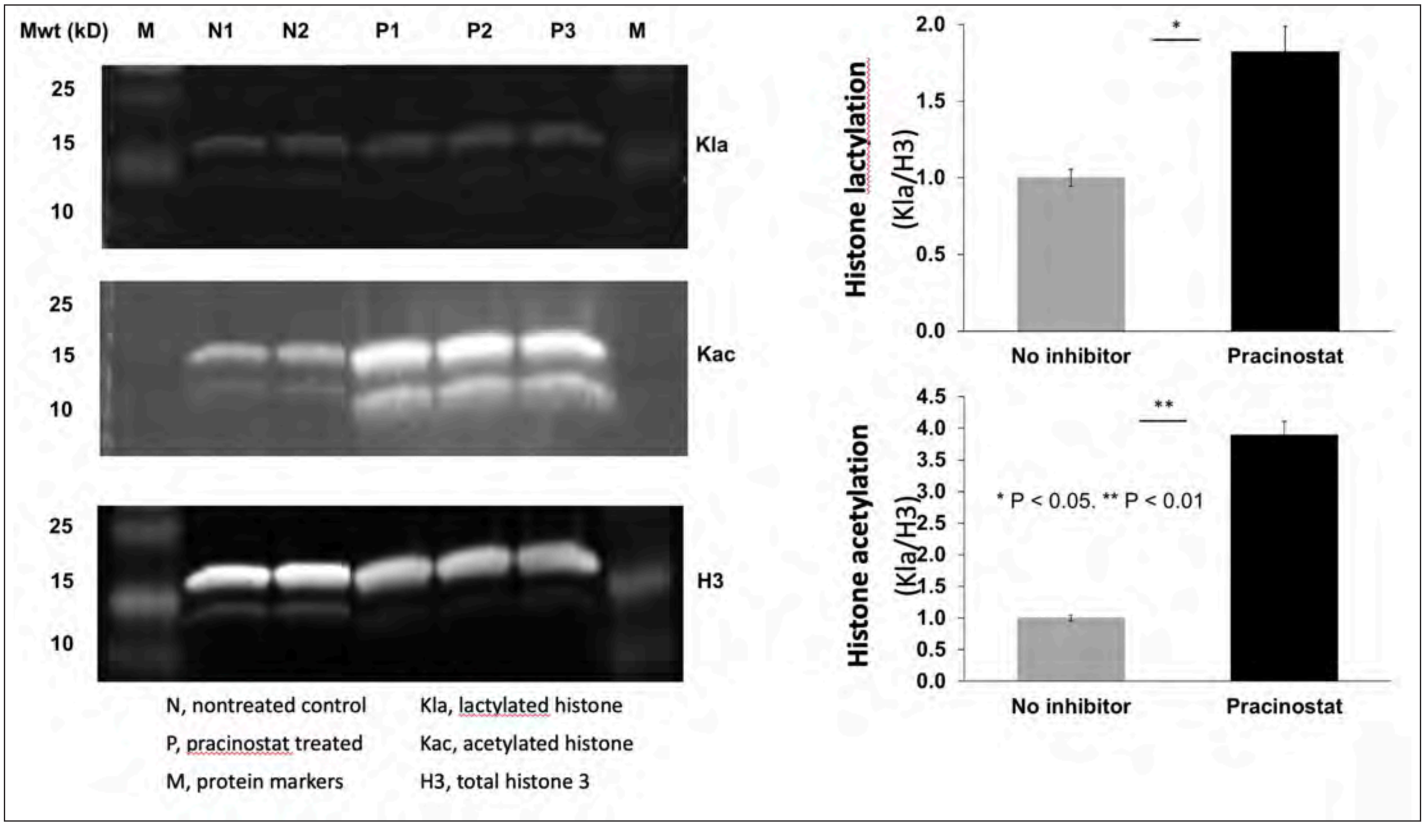


Figure 1. Western blot of histone lactylation and acetylation

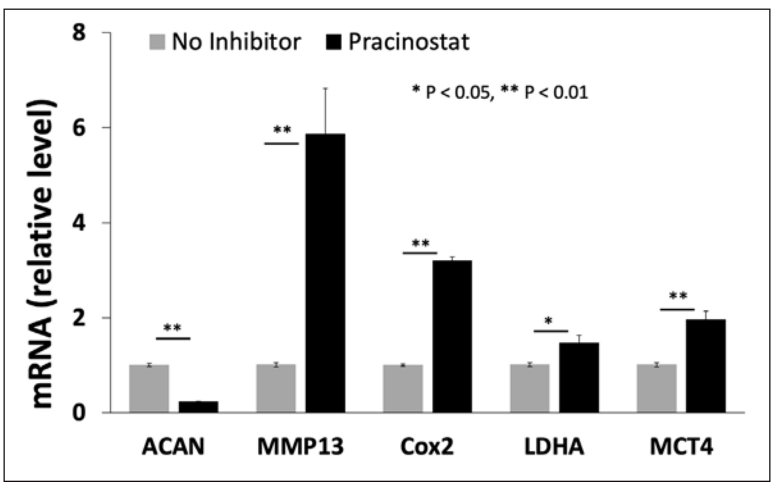


Figure 2. Effect of Pracinostat on gene expression

MICRORNA-29A: A NOVEL THERAPEUTIC TARGET TO TREAT LUMBAR SPINAL STENOSIS

Wawrose R[1,2,3], Oyekan A[1,2,3], Como CJ[1,2,3], Chen SR[1,2,3], Couch B[1,2,3], Chen J[1,2,3], Shaw JD[1,2,3], Donaldson WF[1,2,3], Sowa G[1,2,3], Vo N[1,2,3], Lee JY[1,2,3]

[1]Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.
[2]Pittsburgh Orthopaedic Spine Research Group, Pittsburgh, Pa.
[3]Orland Bethel Family Musculoskeletal Research Center, Pittsburgh, Pa.

INTRODUCTION

Lumbar spinal stenosis (LSS) remains the most common indication for spinal surgery among individuals older than 65 years.[1] Despite its common association with LSS, the intricacies of ligamentum flavum hypertrophy (LFH) remain inadequately understood.[2] LFH occurs secondary to fibrosis, yet the molecular mechanism remains elusive.[3] Although studies have explored causative factors of LFH, investigations into protective factors are lacking. MicroRNA-29a has recently emerged as a "master fibromiRNA" regulator, with reduced levels linked to fibrosis in various organs.[4] Additionally, microRNA-29a represses TAB1-mediated TIMP-1 production, associated with LFH.[5-7] This study tests the hypothesis that patients with symptomatic LSS would exhibit decreased microRNA-29a expression in LFH tissue. Furthermore, the study investigates whether transfection of LFH cell culture with microRNA-29a inhibitor increases expression of fibrotic proteins implicated in LFH.

METHODS

Six patients (three males, three females; age = 68 ± 10.8 years) underwent L3-L5 laminectomy for symptomatic spinal stenosis. LF thickness was measured on preoperative axial T1 magnetic resonance imaging to identify hypertrophic and non-hypertrophic levels.[8] LF tissue was collected from L4/L5 and non-hypertrophic LF was removed from L2/L3. Three groups were established: control, microRNA-29a inhibitor (with low [100 nM] and high [300 nM] concentrations), and microRNA-29a over-expressor groups. Reverse transcription polymerase chain reaction and the comparative ΔΔCt method assessed relative microRNA-29a levels and gene expression profiles of fibrosis-related genes (collagen I, collagen III). Statistical analyses identified differences between groups.

RESULTS

LF thickness in the stenotic levels was significantly higher compared to non-stenotic levels. Collagen I mRNA levels were significantly higher and microRNA-29a levels were significantly lower in hypertrophic LF compared to controls (see Figure 1A). Collagen III mRNA levels were higher in hypertrophic LF, though not statistically significant. MicroRNA-29a levels correlated negatively with type I and type III collagen levels. Over-expression of microRNA-29a resulted in a 0.58-fold decrease in relative gene expression of collagen I, with no substantial alteration in collagen III expression (see Figure 1C). Inhibition of microRNA-29a at 100 nM resulted in a 9.4-fold increase in collagen I expression relative to control. The 300 nM dose resulted in a 14.1-fold increase in the relative gene expression of collagen I (see Figure 1B). For collagen III, inhibition at 100 nM dosing resulted in a 2.0-fold increase and 300 nM dose resulted in a 2.5-fold increase (see Figure 1D).

DISCUSSION

These findings suggest that microRNA-29a may play a protective role against LFH, serving as a potential therapeutic target in LSS management. Stimulation of microRNA-29a production attenuated expression of key genes promoting LFH. This pilot study sets the stage for further investigations using LF cell cultures to test therapeutic agents that upregulate microRNA-29a to mitigate LFH. Moreover, it aims to elucidate the molecular mechanisms through which microRNA-29a controls fibroblast collagen production.

SIGNIFICANCE

This study underscores the potential use of microRNA-29a in treating LFH, laying the groundwork for developing therapeutic products for LSS management.

REFERENCES

1. Bae et al. *Spine*. 2013.
2. Szpalski et al. *Eur Spine*. 2003.
3. Sairyo et al. *Spine*. 2007.
4. O'Reilly et al. *Arth Res and Therapy*. 2016.
5. Ciechomska et al. *PLoS One*. 2014.
6. Park et al. *JBJS*. 2005.
7. Wawrose et al. *Eur Spine*. 2022.
8. Sakamaki et al. *Arch of Ortho & Trauma Surg*. 2009.

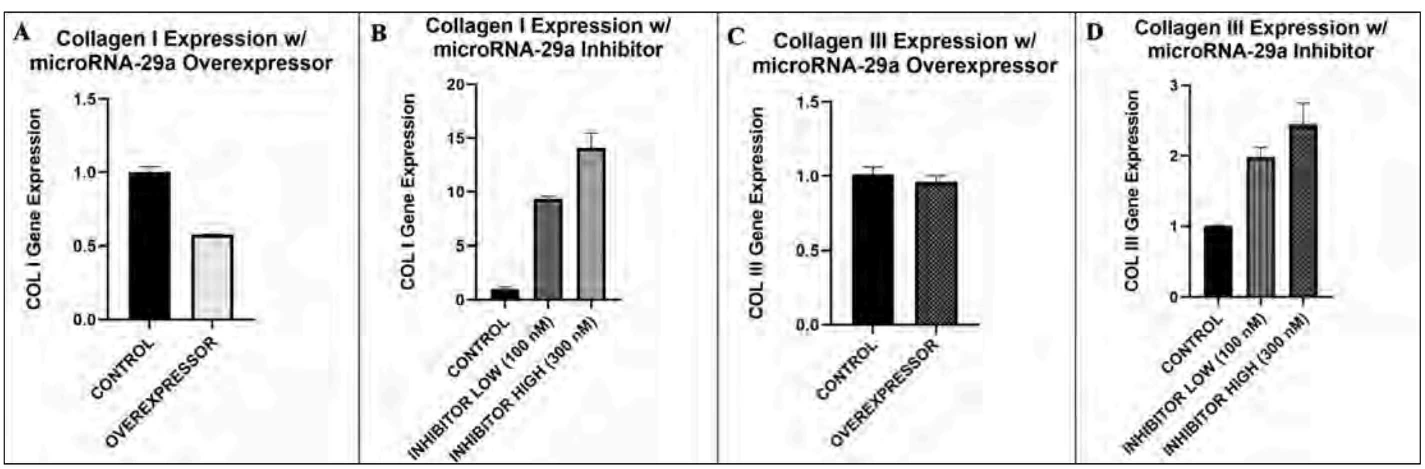


Figure 1. Regulation of gene expression of (A, B) Collagen I and (C, D) Collagen III in LF cell culture treated with (A, C) microRNA-29a over-expressor and (B, D) microRNA-29a inhibitor.

ASSAYING EXTRACELLULAR MATRIX GENE EXPRESSION BY VERTEBRAL ENDPLATE CHONDROCYTES IN 3D HYDROGEL CULTURE

Wood PB[1,2], Clark KL[1], Alexander PG[1]

[1]Ferguson Laboratory, Department of Orthopaedic Surgery, Pittsburgh, Pa.
[2]Department of Bioengineering, University of Pittsburgh, Pittsburgh, Pa.

INTRODUCTION

Intervertebral disc degeneration (IDD) affects more than 50 million Americans annually. Though powerful tools, animal models and 2D transwell systems have been unable to help in the identification of new therapeutic interventions for the treatment of IDD. Human cell–based 3D microphysiological systems are hypothesized to provide a stronger test bed for therapeutic testing. The study of vertebral endplate cartilage (VEC) in IDD is often neglected despite the high correlation of VEC calcification and subchondral MODIC changes with IDD and low-back pain. The goal of this study is to establish a 3D model of the VEC using human patient–derived vertebral endplate chondrocytes in chemically defined scaffolds and media. Here, the authors test: (1) the addition hyaluronic acid (HA) to a photocrosslinkable gelatin scaffold (mGel), (2) the enhancement of TGFβ3 signaling by BMP6, and (3) hypoxic culture environments on VEC matrix gene expression.

METHODS

Primary human vertebral endplate chondrocytes (VEC) were harvested from surgical waste following disc fusion surgery. Hydrogel scaffolds were prepared with cells at passage 3 encapsulated at 7×10^6 cells/ml in methacrylated gelatin only (mGel) or 9% gelatin + 1% hyaluronic acid (mGel-HA). The 7 uL constructs (2 mmÆ x 1 mm[h]) were maintained in basal chondrogenic medium for 14 days in normoxic or hypoxic (5% O2) conditions in presence of one of four growth factor conditions: 10 ng/mL of transforming growth factor-β3 (TGFβ3), 20 ng/ml bone morphogenetic protein-6 (BMP6), TGFβ3 and BMP6, or no additional growth factor. Cultures were harvested at 14 days and gene expressed by reverse transcription polymerase chain reaction for the anabolic cartilage markers COL2 and ACAN described in previous publications.

RESULTS

The researchers observed three important results. First, VEC expresses highest levels of COL2 and ACAN in 5% oxygen conditions as compared to normoxic conditions (see Figure 1). Second, COL2 and ACAN expression by VEC trended higher in hydrogels of mGel alone, as compared to mGel-HA (see Figure 2). Third, BMP6 and TGFB3 stimulation of VEC 3D cultures enhanced COL2 and ACAN expression (see Figure 2).

DISCUSSION

The addition of HA to the VEC scaffold unexpectedly reduced ECM production by VEC at 14 days. It is possible that at 14 days, the growth factor sequestration function of HA is not yet evident in cultures normally maintained for 28 days. Second, the beneficial effect BMP6 supplementation on MSC, chondrocyte, and iPSC matrix elaboration was not observed in the VEC constructs, possibly reflecting the irreversibly altered phenotype of the VEC used in this study. Third, the researchers found that the incubation conditions of hypoxia and low glucose increased VEC matrix gene expression, which mimics the *in vivo* physiological state of these cells.

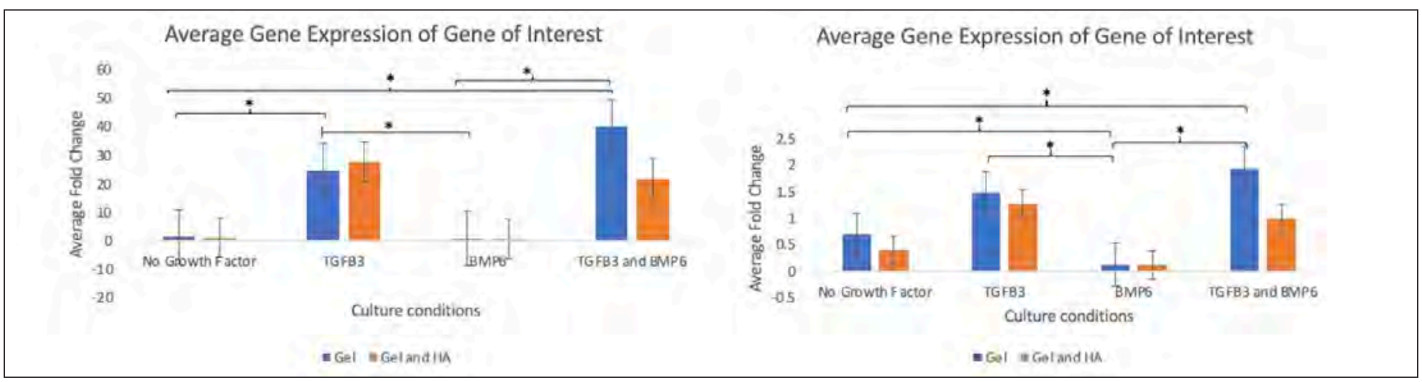


Figure 1. Chondrogenic gene expression in VEC hydrogels cultured in normoxic and hypoxic conditions
*** $p < 0.05$**

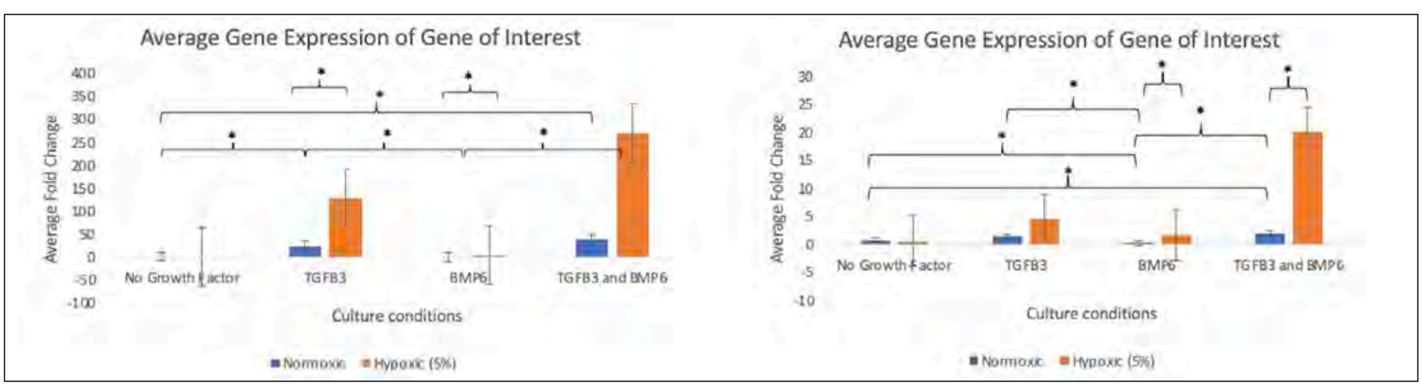


Figure 2. Chondrogenic gene expression in VEC hydrogels cultured in gelatin versus gelatin-HA hydrogels cultured in normoxic conditions
*** $p < 0.05$**

VALIDATION OF A HIGH-THROUGHPUT BIOREACTOR COMPRESSION CHAMBER FOR SMALL-ANIMAL SPINE MECHANOBIOLOGY

Zein K[2], Pashaj X[2,3], Bell K[3], Lee JY[2], Sowa GA[1], Vo N[2]

[1]Department of Physical Medicine and Rehabilitation, University of Pittsburgh, Pittsburgh, Pa.
[2]Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.
[3]Department of Biomedical Engineering, University of Pittsburgh, Pittsburgh, Pa.

INTRODUCTION

Intervertebral disc degeneration (IDD) is one of the most common reasons for low-back pain (LBP).[1-2] IDDs are attributed in part to differences in mechanical loading experienced by the spine. *Ex vivo* models, such as rodent functional spinal units (FSUs), are used to simulate intervertebral discs under different mechanical constraints to observe the biological outcomes. The authors' prior work has demonstrated that rodent FSUs under increased mechanical compression have been correlated to increased anticatabolic gene expression.[3] This study aimed to demonstrate that a high-throughput compression chamber can mechanically emulate prior work and sustain physiological conditions for rodent FSUs.

METHODS

The bioreactor must maintain physiological conditions of 37°C and 5% CO_2/O_2. Components of the bioreactor must withstand physiological conditions and be able to comfortably fit within a Heracell 150i incubator. Components in contact with animal tissue must tolerate sterilization techniques. The dimensions of the rodent FSUs guided the dimensions of the actuator mechanism. The controller of the bioreactor was written in MATLAB 2017 and was designed to place a load on four different FSUs through four different actuators at different loading profiles (cyclical, rest, ramp and hold).

The FSUs were isolated from Sprague Dawley rats and consisted of lumbar intervertebral discs and the superior and inferior vertebral bodies. Four FSUs were supported by 3D-printed thermoplastic polyurethane washers and cultured in 1–3 ml F12 media, in 12-well plates. The surface area of the superior vertebral body was calculated assuming an elliptical shape. The force magnitude was adjusted for 1 MPa and 3 Mpa, and the target force was calculated to be 8 N and 23.4 N, respectively.

RESULTS

The final bioreactor design met design requirements. The load cell (Sentran PC3-50-000) and motor (PI M-229.26s) controlled the height of the actuator to maintain the load parameters.

DISCUSSION

The design of the bioreactor satisfied all the design constraints. The controller and actuator place loads on the specimen within the required parameters. In the future, the researchers will do biological tests such as MTT assays, media analysis, TUNEL assays, etc., to better understand gene expression of nucleus pulposus and annulus fibrosus cells of the intervertebral disc.

REFERENCES

1. Frymoyer JW et al. *Orthop Clin North Am*. 1991;22(2):263-71.
2. Luoma K et al. *Spine (Phila Pa 1976)*. 2000;25(4):487-92.
3. Hartman RA et al. *J Biomech*. 2012;45(2):382-5.

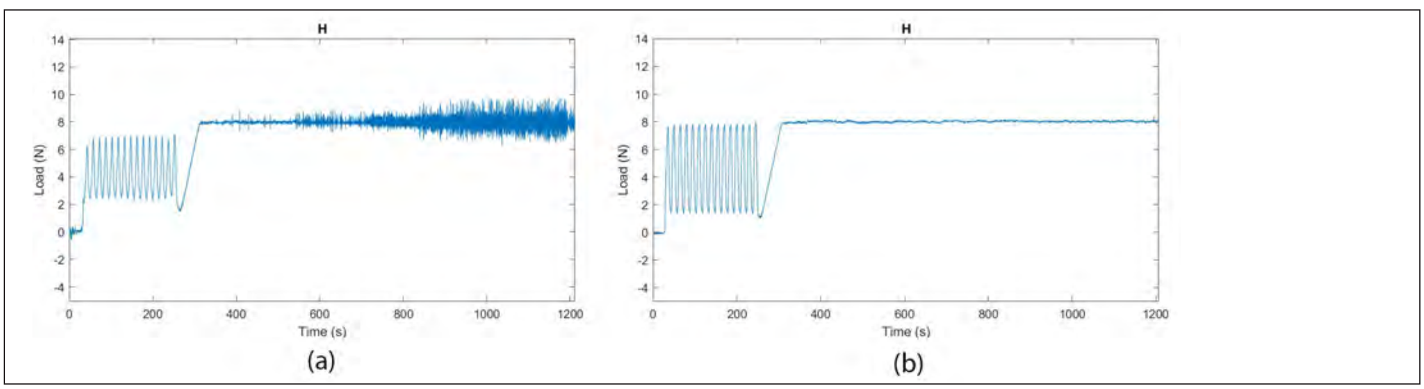


Figure 1. Example load profile for the actuators: (a) before and (b) after optimization, consisting of cyclical loading, a rest, and a ramp and hold. The average target load of all actuators during hold were found to be 8.00 ± 0.65 before optimization and 8.00 ± 0.11 after.

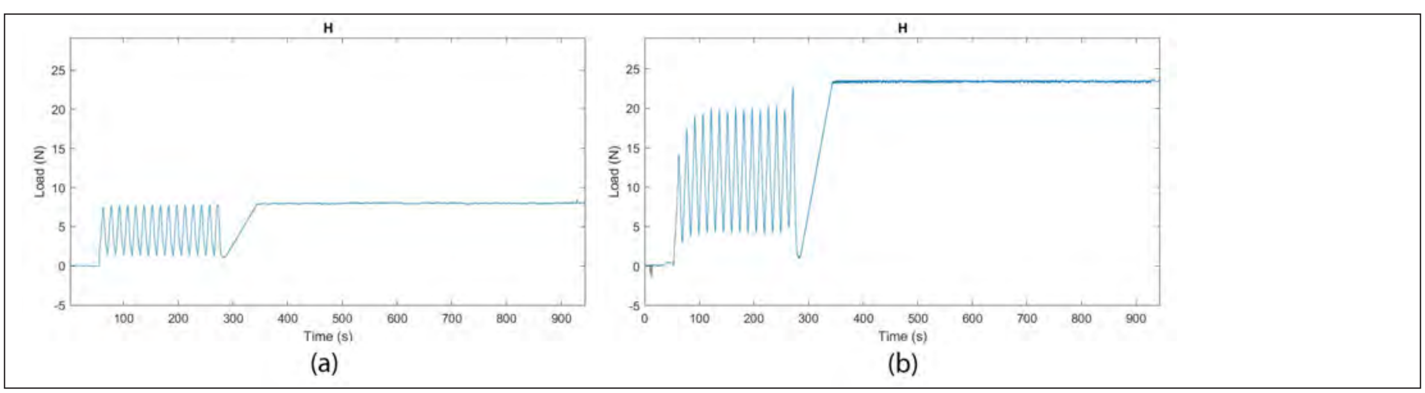


Figure 2. Load profile of the four actuators after optimization, shown running consistently for 15 minutes at (a) 1 MPa and (b) 3 MPa

COMBINED TREATMENT WITH DASATINIB AND QUERCETIN INCREASES RESPONSE OF ENGINEERED CARTILAGE CONSTRUCTS DERIVED FROM LATE-PASSAGE HBM-MSCS

Zhou H[1-3], He C[1,2], Clark KL[1], Lin H[2], Alexander PG[1,2]

[1] Ferguson Laboratory, Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.
[2]Joint Tissue Biology, Pathology, and Engineering Laboratory, Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.
[3] Clinical Medicine Eight-Year Program, Xiangya Medical School, Central South University, Changsha, Hunan, China

INTRODUCTION

Aging is the greatest risk factor for the development of osteoarthritis (OA). A key feature of aging tissue is the emergence of senescent cells. Senescent cells are non-proliferative, expressing pro-survival factors while propagating inflammation and the senescence phenotype. In articular cartilage, these are associated with altered matrix composition, reduced matrix hydration, and cellularity that results in cartilage erosion. Removal of senescent chondrocytes using senolytics is hypothesized to slow or prevent OA. The combination of dasatinib and quercitin was the first senolytic medication to be described. Preliminary data from the authors' labs indicates that cell senescence contributes to the inability of high-passage stromal stem cell–derived chondrocytes to tolerate otherwise physiological loading conditions. The authors hypothesized that the senolytic combination of D+G can reduce the catabolic responses of high-passage (old) mesenchymal stromal cell–derived cartilage constructs to chronic overloading.

METHODS

Tissue-engineered cartilage (TEC) was made with late-passage (p10) human bone marrow–derived mesenchymal stromal cells (hBM-MSCs) to model aging. These cells were encapsulated within 15% methacrylated gelatin at 20 x 10^6 cells/ml and differentiated in serum-free chondrogenic medium containing 10 ng/ml TGFβ3. After 25 days of differentiation, TEC were exposed to 5 nM dasatinib + 50 nM quercetin (D+Q), a combination of senolytics in Food and Drug Administration trial, or 0.1% DMSO (vehicle). A mechano-active tissue engineering system was used to load constructs with 0%, 5%, 15%, or 25% strain for three hours per day for the last seven days of culture to model physiologic and sub-acute traumatic loads.

RESULTS

In determining the optimal dose for treatment, the researchers observed that D+Q killed senescent cells in constructs without compromising cell viability (see Figure 1A). In comparison to vehicle controls, gene expression of D+Q-treated p10 cells assumed a pattern similar to that seen in TEC with p4 (young cells; data not shown). Specifically, COL2 and ACAN increased at strains up to 15% (anabolic) but increased at subacute strains of 25% (see Figure 2). Among catabolic genes analyzed, D+Q treatment caused MMP13 decrease with 25% strain, whereas ADAM TS5 increased with 25% strain (see Figure 2).

DISCUSSION

D+Q restored the response of p10 TEC to pattern more similarly to p4 TEC. The recovery is not complete, paralleling outcomes reported *in vivo* (e.g., partial phenotypic recovery with D+Q treatment in muscle, skeletal, and spinal tissues). These results indicate that there is a complex relationship between aging and the induction of catabolic processes after mechanical overload and may help explain the differing susceptibility of young and old cartilage to mechanical forces. The data also indicate that inhibiting cell senescence through D+Q treatment may benefit older patients but that D+Q may not reduce the effects of chronic overload in the etiology or pathogenesis of OA.

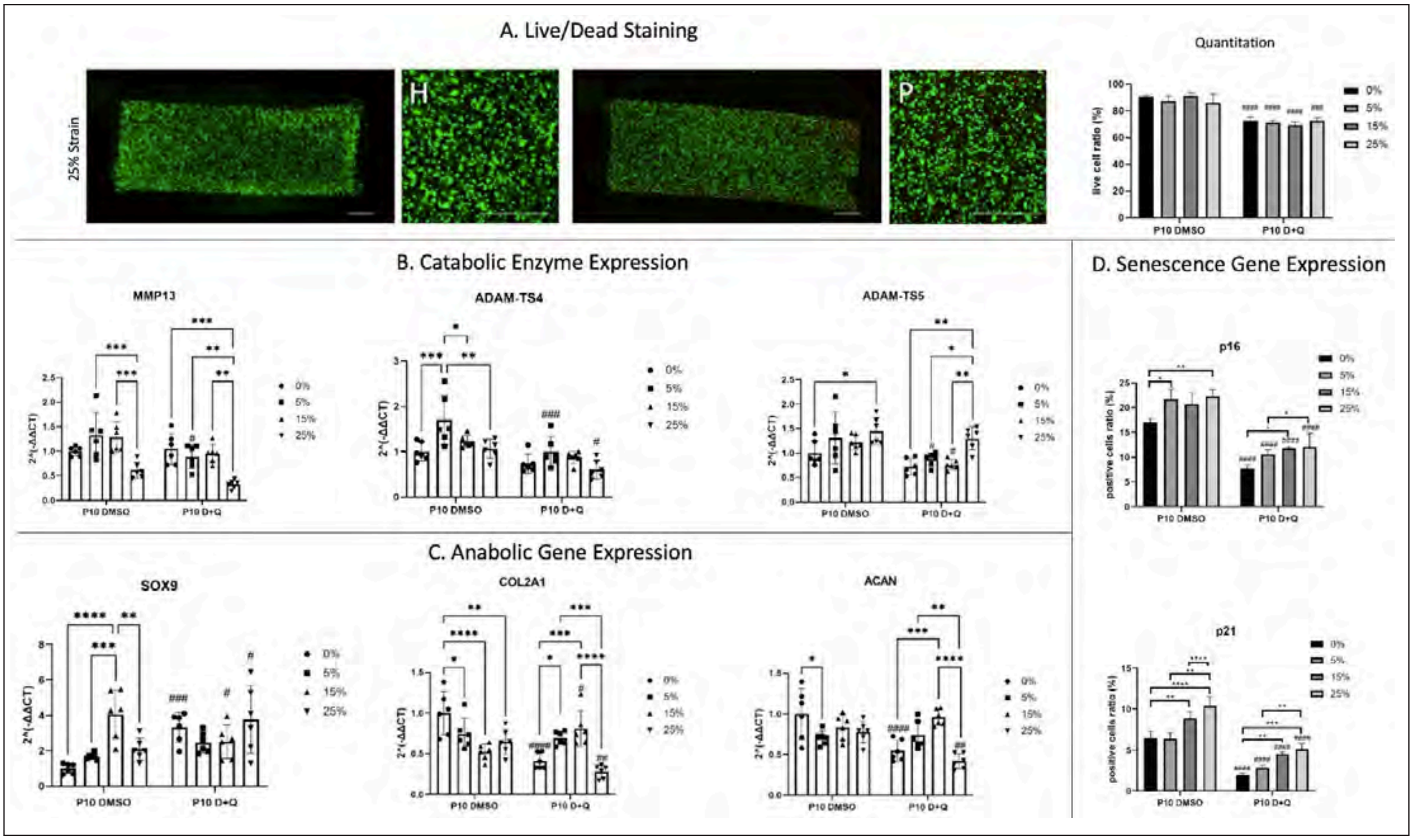


Figure 1. (A) Live (green) and dead (red) staining for the constructs, (B) Reverse transcription polymerase chain reaction **for cartilage anabolic and catabolic genes in p10 constructs treated with DMSO or D+Q subject to different strains. D+Q treatment changed COL2 and ACAN expression patterns to strain. Two experiments, n = 3 each; **** p < 0.0001; *** p < 0.001; ** p < 0.01; * p < 0.05, compared to 0% strain; #### p < 0.0001, ### p < 0.001, ## p < 0.01, # p < 0.05, compared to same strain in DMSO groups**

ROLE OF MOF IN EPIGENETIC REGULATION VIA HISTONE LACTYLATION OF ANNULUS FIBROSIS CELLS

Zou T[1,2], Wang D[1], Lee JY[1], Sowa G[1,2], Vo N[1]

[1]Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.
[2]Department of Physical Medicine and Rehabilitation, University of Pittsburgh, Pittsburgh, Pa.

INTRODUCTION

Intervertebral disc degeneration (IDD), a leading cause of low-back pain, is present in more than 90% of spines by age 60. The intervertebral disc is composed of the outer annulus fibrosis (AF) cells and the inner, more hypoxic nucleus pulposus cells. IDD is characterized by inflammation and high lactic acid in the disc. Recently, lactate has been identified as a novel histone lysine post-translational modification. The authors' lab has found that there are high levels of histone lactylation in lactate-rich regions of the disc that are not present in vertebral bone or paraspinal muscle. They hypothesize a novel role for lactate in the epigenetic regulation of disc health via histone lactylation. They explored the role of a histone lysine acetyltransferase, MOF, as a cognate histone lysine lactyltransferase (lactate "writer"). To do this, they first silenced MOF in rat AF cells treated with IL-1β to mimic the inflammatory condition found in IDD. They then quantified the levels of lactylated histones and expression of key matrix homeostasis genes that control IDD.

METHODS

Primary rat AF cells were isolated from the spines of three 3-month-old male F344 rats as approved by the University of Pittsburgh's Institutional Animal Care and Use Committee. Cells were expanded. Lipofectamine and Kat8 (MOF) siRNA were used to transfect cells. Cells were treated with low-nutrient media for 24 hours to mimic physiological conditions. Cells were then treated with 10 mM lactate. AF cells were also treated with -/+ IL-1β (5ng/ml) to model the inflammatory IDD condition. Gene expression was measured with reverse transcription polymerase chain reaction. Protein expression of histone lactylation and histone acetylation (PTM Biolabs) was measured with Western blot. Significance was determined with student's t-test (n = 3).

RESULTS

MOF was knocked down in both conditions with 50%–80% transduction efficiency (see Figure 1A). With MOF silencing, Cox2 (an inflammatory marker) gene expression decreased in the inflammatory condition (see Figure 1B). With MOF silencing, LDHB (converts lactate to pyruvate) gene expression decreased in both inflammatory and non-inflammatory conditions, whereas MCT4 (lactate exporter) gene expression decreased in noninflammatory conditions (see Figure 1C). Under both inflammatory and non-inflammatory conditions, MOF silencing resulted in decreased histone lactylation and acetylation (see Figure 2); however, this decrease was not significant.

DISCUSSION

MOF silencing has differential effects on expression of genes regulating matrix homeostasis and lactate metabolism in both inflammatory and noninflammatory conditions. These changes may reflect the changes in histone lactylation in AF cells, but further confirmatory experiments are needed to determine the principal lactate writer in AF.

REFERENCE

1. Zhang D et al. *Nature.* 2019;574:575-80.

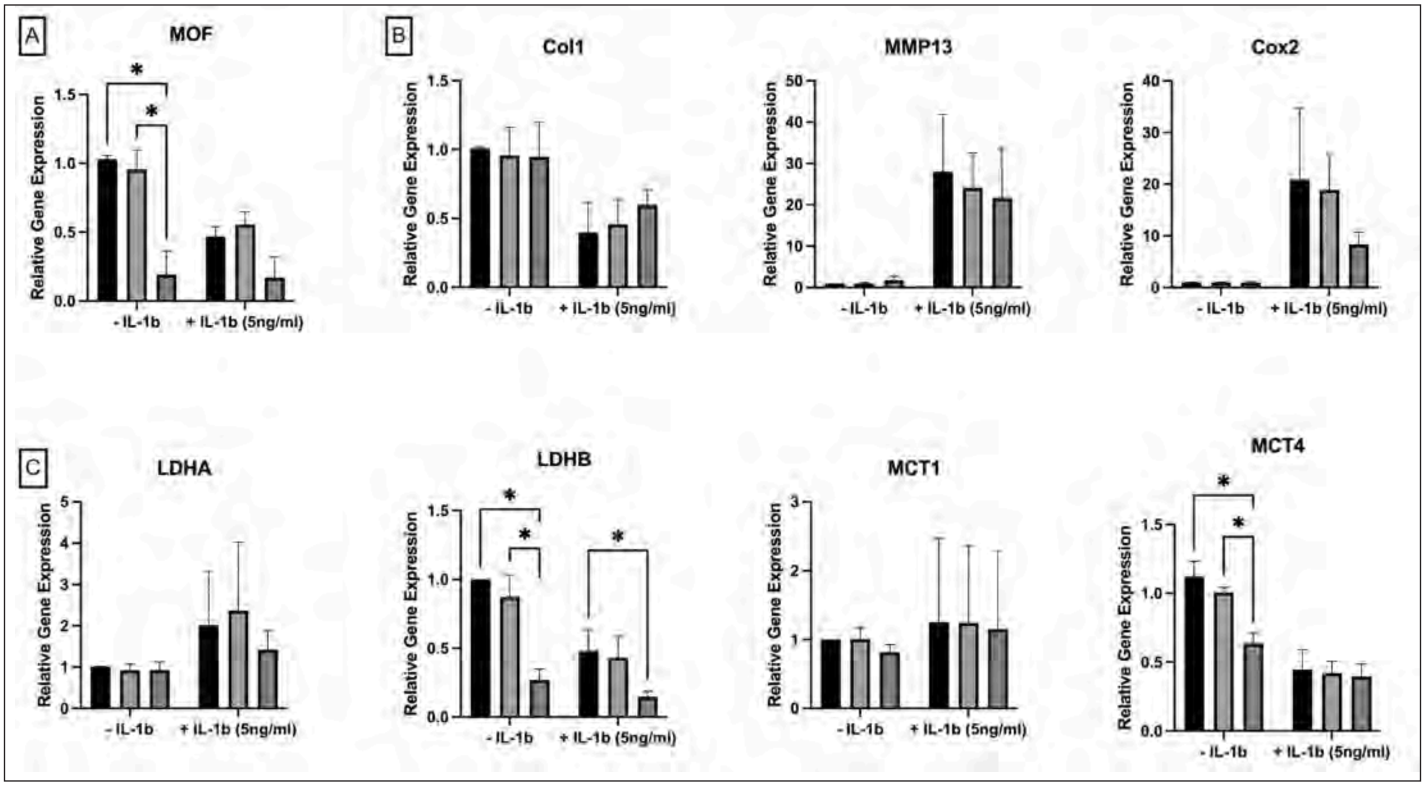


Figure 1. Expression of a) MOF, b) matrix homeostasis genes, c) lactate metabolism genes after MOF silencing
*** = p < 0.05**

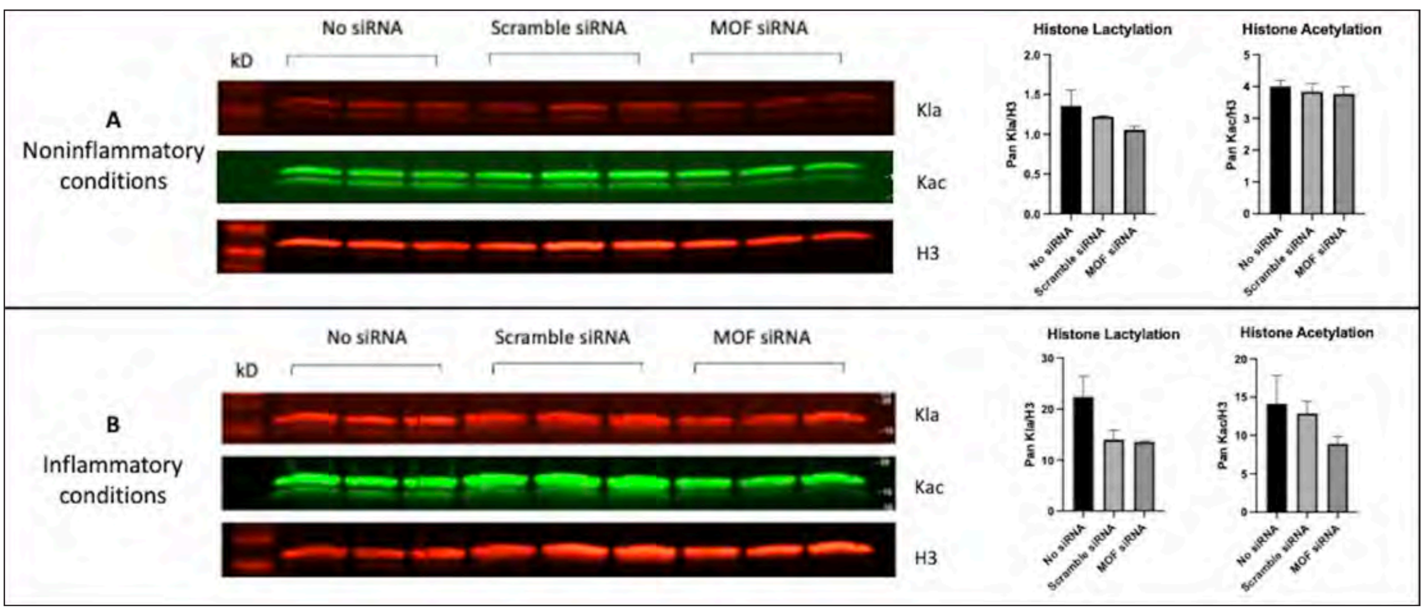


Figure 2. Protein expression of histone lactylation and acetylation normalized to H3 in a) absence of IL-1β and b) 5 ng/mL IL-1β

ORTHOPAEDIC ENGINEERING AND SPORTS MEDICINE LABORATORY

Patrick Smolinski, PhD, engineering director
Monica Linde, MSIE, RN, technical manager

The lab has had an exciting year with many new faces, including both students and medical researchers. The lab's main research area is the study of human joint and tissue behavior using mechanical engineering technologies to evaluate joint function, the effects of tissue injury, and surgical treatments. Approaches such as robotic testing, materials testing, advanced digital imaging, and the development of novel devices are being applied. There are also ongoing studies on the description and characterization of joint anatomy and the analysis of tissue histology and mechanical behavior using experimental methods.

This year, we were honored to have Matthieu Ollivier, MD, PhD, associate professor of orthopaedic surgery at the Institute for Locomotion at Aix-Marseille University, Marseille, France, visit the lab to give a technical demonstration on tibial osteotomy. Dr. Ollivier was the 2023 Freddie H. Fu, MD, Visiting Lecturer and spoke on the "Modern Vision of Knee Osteotomy." The lab also welcomed a visit by the International Society of Arthroscopy, Knee Surgery, and Orthopaedic Sports Medicine Travelling Fellows.

Medical Research Fellows

Camila Grandberg, MD, was born in Guaratinguetá, São Paulo, Brazil, where she grew up between the city and a farm in the countryside. She finished her medical degree at the Pontifícia Universidade Católica de São Paulo in Sorocaba, São Paulo, Brazil. She is currently a sports medicine research fellow with Volker Musahl, MD, as well as in the lab. Her main interests include dancing and reading.

Svenja Höger, MD, has returned to being a resident of orthopaedic surgery at the University Hospital rechts der Isar in Munich, Germany. She will continue her work in the area of sports medicine.

Armin Runer, MD, has returned to the Department of Sports Orthopaedics at the Technical University of Munich (Germany), where he practices sports medicine. When not working, Dr. Runer can be found on the fistball court.

Anja Wackerle, MD, has joined the lab. She was born in Munich and grew up in the Alps in southeastern Germany. She is a third-year resident in the Department of Sports Orthopaedics at the Technical University of Munich. She has an interest in injuries of the knee and shoulder, and her hobbies include outdoor activities.

Students

Michael DiNenna, MS, was born in Palmdale, Florida, and graduated from the University of Florida. He is currently a master's degree student in the Department of Mechanical and Materials Science in the Swanson School of Engineering, with an interest in the area of solid mechanics with application to biomechanics.

Josh Franz is from Bethal Park, Pennsylvania, and did his senior design project in the lab. He is now a graduate student in mechanical engineering.

Isabella Kuhn was a summer visitor and is currently in her final year of medical school at Ludwig-Maxmilians University in Munich. She plans to specialize in orthopaedic surgery.

Ben Moyer is from Oak Park, Illinois, and was a mechanical engineering graduate and summer intern. He is a Chicago Cubs fan.

Eric Schwanke is from York, Pennsylvania, and started at Pitt during the COVID-19 pandemic in the fall of 2020. He is majoring in materials science and engineering. During the past summer, he enjoyed the Taylor Swift concert in Pittsburgh.

Yiding Wen is a senior mechanical engineering student from Sichuan, China, enrolled in the "3+1" program between Sichuan University and the University of Pittsburgh.

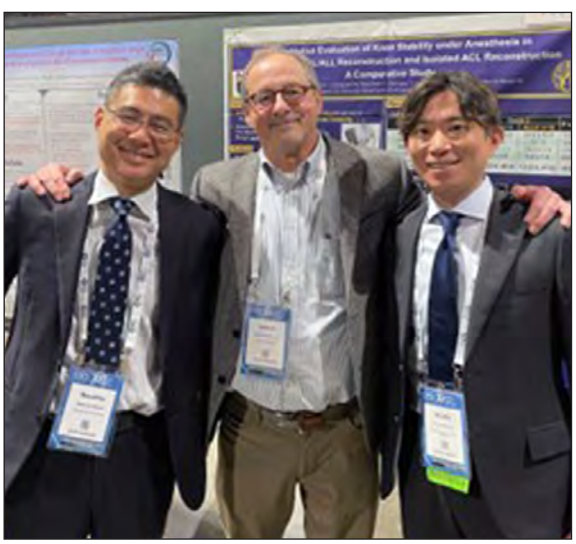
William Gamble is a graduate student in mechanical engineering from West Chester, Pennsylvania, and enjoys running and biking the river trails.

We wish to acknowledge the contributions of undergraduate students Enaly Adikpeto, Shanya Chen, Grant Clark, Xiaohang Ding, Zach Kushner, Zin Meng, Ryan Merkel, Alexander Pierce, Ilana Schimmel, Ryan Tran, and Yifan Wang for their efforts on lab research projects.

Matthieu Ollivier, MD, PhD, gives a technical demonstration on knee osteotomy.

International Society of Arthroscopy, Knee Surgery, and Orthopaedic Sports Medicine Travelling Fellows visit the lab. Pictured are Giovanna Medina, Claudia Arias, Niv Maron, Umile Giuseppe Longo, Svenja Höger, Armin Runer, Patrick Smolinski, and Eric Swanke.

Munich research meeting with Svenja Höger and Armin Runer



Seeing former fellow Masahiro Nozaki and colleague Shun Hanaki of the Nagoya City University Hospital at the 2024 Orthopaedic Research Society meeting in Long Beach, California

Pittsburgh bike tour with European Society of Sports Traumatology, Knee Surgery, and Arthroscopy/American Orthopaedic Society for Sports Medicine Travelling Fellows

MENISCAL SUTURE SPACING INFLUENCES BIOMECHANICS OF MENISCAL REPAIR

Höger SA[1,2], Runer A[1,2], Schwanke E[3], Moyer B[3], Özbek EA[1,4], Linde MA[1], Smolinski MP[3], Miller MC[3], Smolinski PJ[3], Musahl V[1,3]

[1]Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.
[2]Department of Orthopaedic Sports Medicine, Klinikum rechts der Isar, Technical University of Munich, Munich, Germany
[3]Department of Mechanical and Materials Science, Swanson School of Engineering, University of Pittsburgh, Pittsburgh, Pa.
[4]Department of Orthopedic Surgery and Traumatology, University of Ankara, Ankara, Turkey

INTRODUCTION

There is consensus that preserving the meniscus is preferable to meniscectomy to prevent degenerative changes in the knee. Longitudinal meniscus tears are common in practice and are considered a standard indication for meniscus repair. The most effective suture spacing in terms of cost and performance is not well described in literature. This study hypothesized that there would be a maximum spacing beyond which mechanical performance would decrease.

METHODS

Meniscus roots were removed from 50 bovine menisci and divided radially into two samples. In each sample, a full longitudinal meniscal tear was created 5 mm from the peripheral meniscal rim. The tears were repaired with two vertical 2-0 braided mattress sutures 3 mm from the torn edges with five different suture spacings: 3, 5, 7, 9, and 11 mm. The sutures were tied to the meniscus base with a sliding knot. Additionally, five alternating half-hitch simple knots were performed. For radial loading of the repair, three braided loading sutures were placed at the peripheral meniscal rim, spaced equally at intervals of 10mm (see Figure 1). Each sample underwent 5-20 N load for 1,000 cycles. The tear opening gap at the 1,000th cycle was measured. Analysis of variance with a Bonferroni correction was performed to determine differences in gap opening displacements.

RESULTS

The tear gap for each repair spacing is shown in Figure 2. Groups with suture distances of 3 mm, 5 mm, and 7 mm demonstrated 36% smaller displacements (1.6 ± 0.3 mm, 1.7 ± 0.5 mm, 1.7 ± 0.5 mm, respectively) compared to the groups with suture distances of 9 mm and 11 mm (2.5 ± 0.3 mm and 2.7 ± 0.6 mm, respectively). Displacement among suture distances of 3 mm, 5 mm, and 7 mm exhibited no significant differences. Similarly, no significant difference in displacement between groups of 9 mm and 11 mm was observed. Failure mode did not correlate with suture distance. Sutures broke in 76% (38 of 50) and cut through the meniscus tissue in 22% (11 of 50), whereas a combination of one suture breakage and one tissue transection was observed in 2% (1 of 50).

DISCUSSION

The main finding of this study is that meniscal repairs with a suture distance greater than 9 mm demonstrated significantly higher opening displacements compared to those at 7 mm or below. Based on the current data, a suture distance of 9 mm or higher appears to result in a larger displacement and may hinder the healing of a meniscus tear.

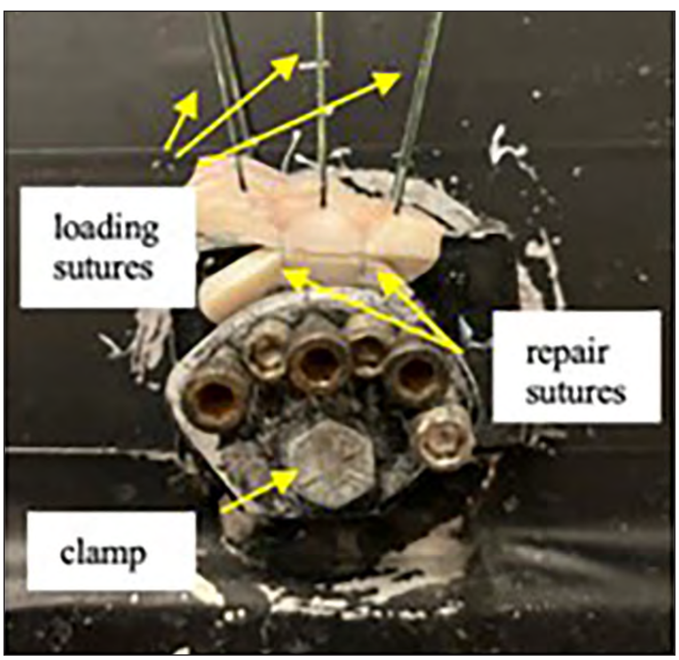


Figure 1. Clamped inner edge of meniscus wedge with three loading sutures placed at the peripheral rim

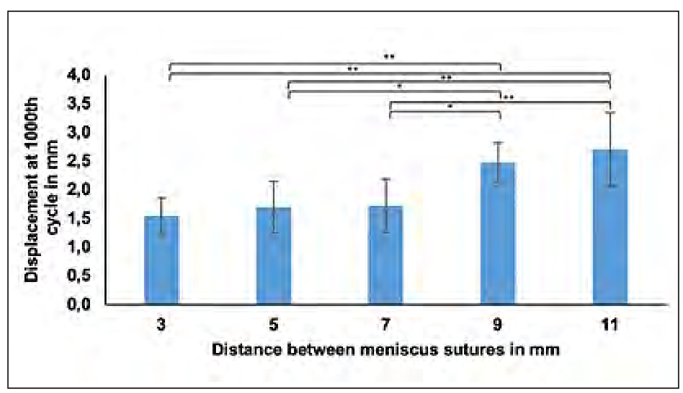


Figure 2. A gap opening increases from unloaded state to 1,000th loading cycle
*** p < 0.05, ** p < 0.01**

EFFECT OF FIXATION ANGLE AND TENSION ON KNEE KINEMATICS IN MEDIAL MENISCUS POSTERIOR ROOT REPAIR

Kodama Y[1, 2], Linde M[1], DiNenna M[3], Furumatsu T[4], Smolinski P[1,3]

[1]Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.
[2]Department of Orthopaedic Surgery, Okayama Rosai Hospital, Okayama, Japan
[3]Department of Mechanical and Materials Science, Swanson School of Engineering, University of Pittsburgh, Pittsburgh, Pa.
[4]Department of Orthopaedic Surgery, Okayama University Hospital, Okayama, Japan

INTRODUCTION

Medial meniscus posterior root tear (MMPRT) leads to extrusion of the medial meniscus (MM). Transtibial pullout is a treatment for MMPRT; however, its effect on knee kinematics with meniscotibial ligament (MTL) lesions remains unclear. This study assessed fixed tension and knee flexion angle in pullout repair on kinematics and MM extrusion.

METHODS

With institutional approval, the researchers tested 13 knees in six states: (1) intact MM, (2) MMPRT + MTL, and (3) four different MMPR repairs. MMPRT and MTL were created arthroscopically, and transtibial pullout repair was performed. For MMPR repair, four different fixation tensions and flexion angles (20N at 0°, 20N at 90°, 60N at 0°, and 60N at 90°) were used. Kinematics were analyzed by robotic testing under an 89 N anterior tibial translation (ATT) load and a 5 Nm external (ER) torque. MM extrusion was evaluated with ultrasound.

RESULTS

With MMPRT, ATT, ER, and MM extrusion were greater in intact knees. At 0° flexion, no method restored the intact condition ATT (see Figure 1). At 60° and 90° of flexion, all methods except for repair 90° 20 N restored the intact behavior. At 0° flexion, no method restored the intact ER and showed significantly greater values compared to knees with MMPRT (see Figure 2). At 30°, the repair 90° 20 N fixation method did not restore the intact condition. At 60° and 90° of knee flexion, all fixation methods restored to the intact condition. At both 0° and 30° of flexion, all fixation methods except for the repair 90° 20 N fixation method restored MM extrusion to the intact condition (see Figure 3).

DISCUSSION

This study found that transtibial pullout repair did not improve kinematics in knee extension with both MMPRT and MTL lesions, and that higher tension fixation was the most effective in improving MM extrusion.

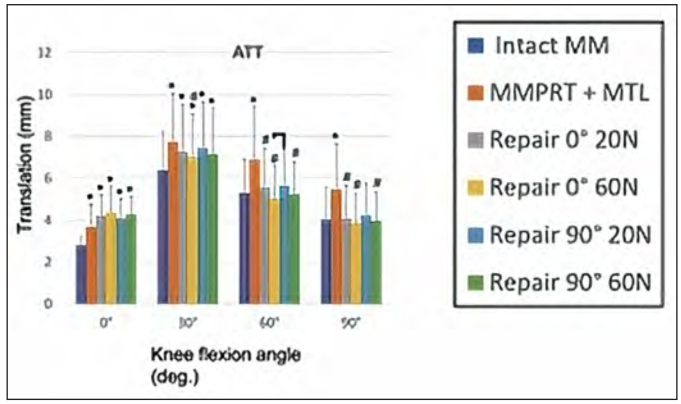


Figure 1. Left: anterior tibial translation (mm) under an 89 N anterior tibial loading
*** p < 0.05 versus intact**
 # p < 0.05 versus medial meniscus posterior root tear + meniscotibial ligament

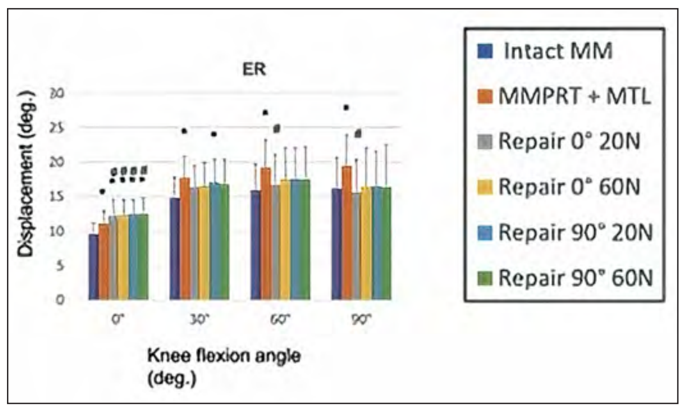


Figure 2. Middle: external rotation under a 5 Nm torque
*** p < 0.05 versus intact**
 # p < 0.05 versus medial meniscus posterior root tear + meniscotibial ligament

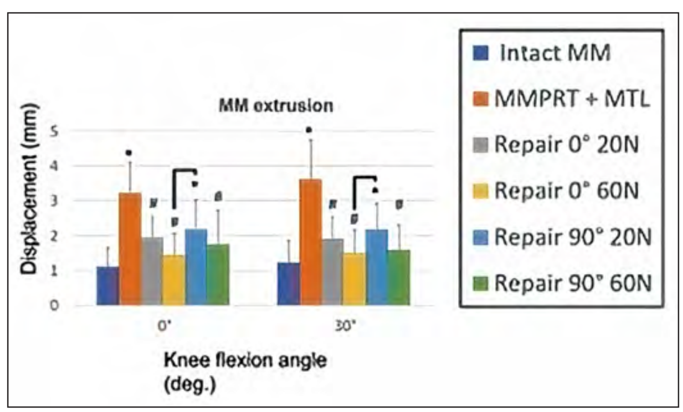


Figure 3. Right: MM extrusion under a 10 Nm varus torque evaluated with ultrasound
*** p < 0.05 versus intact**
 # p < 0.05 versus medial meniscus posterior root tear + meniscotibial ligament

BIODYNAMICS LABORATORY

Faculty
William Anderst, PhD, lab director

Staff
Lori Freund, administrative assistant
Tom Gale, MS, research engineer
Edward Godbold, BS, research technician
Cate Gray, BS, research technician
Clarissa LeVasseur, MS, research engineer
Sabreen Megherhi, BS, research technician
Shelley Oliveira Barbosa, MS, lab manager
Patrick Smith, BS, BA, research technician

Research residents:
Cortez Brown, MD
Chris Como, MD

Research fellows:
Kenzo Cotton, BS
Frank Fang, MD
Koji Nukuto, MD, PhD
Yoshiyuki Yahagi, MD, PhD
Tetsuya Yamamoto, MD, PhD

Medical students:
Nick Aloi, BS
Elizabeth Heidenreich, BS
Kimberly Hua, BS
Nathan Hyre, BS
Gillian Kane, BS
Sarah Lopez, BS
Ajinkya Rai, BS
Romano Sebastiani, BS
Raghav Ramraj, BS
Kenzo Cotton, BS

Graduate students:
Camille Johnson, MS
Paige Paulus, DPT

Gap-year students:
Eva Heidinger, BS
Connor Luck, BS

Undergraduate students:
Sam Lord,
Swanson School of Engineering
Aditya Padmanabhan,
Dietrich School of Arts and Sciences

Lab members, summer 2023 (left to right): Edward Godbold, Justin Elder, Koji Nukuto, Yoshi Yahagi, Frank Fang, Tetsu Yamamoto, William Anderst, Tom Gale, Clarissa LeVasseur, Paige Paulus, Shelley Oliveira-Barbosa, Ajinkya Rai, Camille Johnson, Romano Sebastiani, Kim Hua, Devon Scott, and Cate Gray

Lab Overview
The Biodynamics Laboratory is a core research facility within the Department of Orthopaedic Surgery. The Biodynamics Laboratory has three primary missions: (1) investigate relationships between dynamic joint function and joint disease, injury, aging, and treatment to improve diagnosis and care of orthopaedic conditions; (2) develop innovative technologies and methods for assessing the dynamic function of joints and musculoskeletal tissues; and (3) provide unique training opportunities for students, residents, and visiting fellows to conduct orthopaedic research.

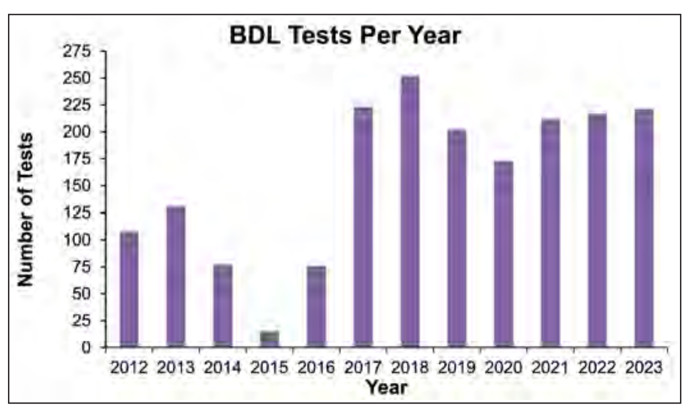
Our research program is highly translational and thrives on strong collaborations with clinicians. The central theme of our laboratory research is the identification and treatment of mechanical disorders that drive musculoskeletal disease progression. Our research lab uses state-of-the-art equipment and software in order to address these research questions.

Personnel
The Biodynamics Lab added several new members in 2023. Cortez Brown and Chris Como joined as research residents, Patrick Smith and Kate Gray joined as research technicians, Frank Fang and Raghav Ramraj joined as full-time research assistants, Eva Heidinger and Connor Luck are new gap-year students, Kenzo Cotton is a new visiting research fellow, and Sam Lord is our newest undergraduate research assistant.

New Capabilities
The Biodynamics Lab continues to build upon current strengths and develop new research capabilities. Tom Gale's dynamic filter, which is used to prevent over-exposure during radiographic imaging, recently completed the patent process.

Lab Utilization
The biplane radiography system within the Biodynamics Lab was used to perform 221 data-collection sessions this year.

Manuscript Publications
Biodynamics Lab personnel contributed to 16 manuscripts that were published in 2023. The manuscripts fell within the following topic areas: spine (five), foot and ankle (one), knee (seven), shoulder (two), methods (one).



Biplane radiography data collection since 2012

Conference Presentations
The Biodynamics Lab had 39 conference presentations in 2023. These included:
- Orthopaedic Research Society (20)
- International Society of Arthroscopy, Knee Surgery, and Orthopaedic Sports Medicine (four)
- American Academy of Orthopaedic Surgeons (three)

Competitions
Dr. Anderst and Sabreen Megherhi teamed to win the Second Annual Biodynamics Lab Cornhole Tournament.

Research Projects
The Biodynamics Lab collected data for 10 research projects in 2023. Those research projects focused on *in vivo* joint mechanics in the spine, knee, shoulder, thumb, and the socket of transfemoral and transtibial amputees.

Study Topic	Funding	Collaborators
Spine		
Cervical spine arthrodesis	NIH R01 (expired)	Donaldson, Lee, Shaw, Silvaggio, Smith, Kanter, Okonkwo
Chronic low-back pain	NIH U19	Sowa, Vo, LB3P Team
Knee		
Navio knee arthroplasty	Smith & Nephew	Urish
ACL reconstruction/tibial osteotomy	AOSSM	Hughes, Musahl
Shoulder		
Dynamic glenoid track	NIH R01	Lin
Rotator cuff tear	NIH R01	Debski, Irrgang
Thumb		
Trapeziectomy	NIH R21	Fowler
Amputee		
Transfemoral socket fit	DOD	Fiedler
Transtibial socket fit	NIH-SBIR	Lui (Assist Development Inc.)

AOSSM = American Orthopaedic Society for Sports Medicine, DoD = Department of Defense, NIH = National Institutes of Health, SBIR = Small Business Innovation Research

Cornhole tournament, summer 2023 (left to right): Tom Gale, Clarissa LeVasseur, Tetsu Yamamoto, Aditya Padmanabhan, Sabreen Megherhi (winner), Connor Luck, William Anderst (winner), Paige Paulus, Patrick Smith, Cate Gray, Yoshi Yahgi, Cortez Brown, Koji Nukuto, Kenzo Cotton, Raghav Ramraj, Edward Godbold, Shelley Oliveira-Barbosa, and Frank Fang

BEST-FIT CIRCLE MISSING-AREA METHOD SHOWS GOOD ACCURACY AND INTERRATER RELIABILITY WHEN ASSESSING GLENOID BONE LOSS

Brown CL[1], Scott DM[1], LeVasseur C[1,2], Tecle N[1], Como CJ[1], Karimi A[1], Badon J[1], Hughes JD[1], Lin A[1], Anderst W[1]

[1]Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.
[2]Bethel Musculoskeletal Research Center, University of Pittsburgh, Pittsburgh, Pa.

INTRODUCTION

Glenoid bone loss (GBL) is a well-known risk factor for anterior shoulder instability.[1] If GBL is present, management is determined by the amount of bone loss.[2] To date, the most-used system to measure GBL, best-fit circle, has more than 15 iterations.[3] Unfortunately, there is no consensus on which best-fit circle method accurately measures GBL.

OBJECTIVE

The objective of this study was to assess the accuracy and interrater reliability of three common methods for measuring GBL where the true GBL was known. The authors hypothesized that the best-fit circle missing-area method would have better accuracy and interrater reliability than diameter and ratio methods.

METHODS

Individuals who participated in this study approved by the Institutional Review Board had no prior shoulder instability or surgery. Computed tomography (CT) scans of bilateral shoulders were collected. The researchers made 3D models of the scapula by segmenting the CT scans (Mimics). Five bone-loss models were created by varying levels of bone loss in the anteroinferior region of the glenoid from 5% to 30%. Glenoids were aligned with principal component analysis of the native glenoid. Ground-truth GBL was determined with the glenoid fossa edge and the best-fit circle of the inferior edge. Six blinded reviewers, with varying levels of expertise, measured bone loss for all 20 randomized models using three different best-fit circle methods (see Figure 1). Accuracy was assessed by root mean square error (RMSE) and obtained by comparing measured and ground-truth bone loss for each model. Interrater reliability was assessed with intraclass correlation coefficients (ICCs) with two-way random-effects models with consistency. ICCs between 0.75–0.90 were classified as good.[3]

RESULTS

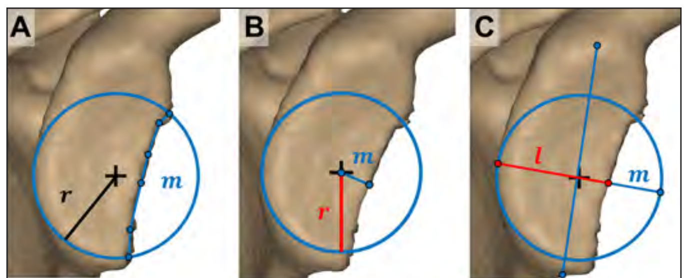
Four male, right shoulders were used to create the 20 bone-loss models. Age was 22.5 ± 3.4 years old, and average body mass index was 24.8 ± 5.5 kg/m^2. The reviewers were two orthopaedic surgery residents, two sports medicine fellows, and two sports medicine attendings. The missing-area method was the most accurate (see Table 1); however, average errors did not change with changing bone loss.

DISCUSSION

At all three levels of surgical experience (resident, fellow, and attending), the best-fit circle missing-area method was more accurate than the ratio and diameter methods. To the authors' knowledge, this is the first study to determine accuracy of glenoid bone-loss measurements when the true glenoid bone loss percentage was known. Inaccuracy in measuring GBL can negatively impact surgical planning.

REFERENCES

1. Russo et al. *Arthroscopy*. 2021.
2. Maiotti et al. *JSES*. 2023.
3. Portney & Watkins. *Foundations of Clinical Research*. 2020.



$$\frac{m}{\pi r^2} * 100 \qquad \frac{1}{\pi}\left(cos^{-1}\left(\frac{m}{r}\right) - \frac{m}{r}\sqrt{1-\left(\frac{m}{r}\right)^2}\right) \qquad \frac{m}{m+l} * 100$$

Figure 1. Three best-fit circle methods used to assess glenoid bone loss: (A) missing-area method, (B) ratio method, and (C) diameter method. Reviewers created all measurements in blue.

		Missing Area Method	Ratio Method	Diameter Method
RMSE	Total	3.6%	5.0%	7.9%
	Residents	3.5%	4.6%	6.3%
	Fellows	4.2%	6.3%	8.4%
	Attendings	3.1%	2.4%	8.9%
ICC		0.89	0.91	0.90

Table 1. Root mean square error, average error (percentage of glenoid bone loss), and intraclass correlation coefficients for all reviewers for each best-fit circle method

IN VIVO CHANGES IN DYNAMIC ADJACENT SEGMENT MOTION THREE YEARS AFTER ONE- AND TWO-LEVEL CERVICAL ARTHRODESIS

Como CJ[1,2,3], LeVasseur CM[1,3], Hua K[1], Oliveira Barbosa S[1], Sebastiani R[1], Pitcairn SW[1], Shaw JD[1,2,3], Donaldson WF[1,2,3], Lee JY[1,2,3], Anderst WJ[1]

[1]Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.
[2]Pittsburgh Orthopaedic Spine Research Group, Pittsburgh, Pa.
[3]Bethel Musculoskeletal Research Center, University of Pittsburgh, Pittsburgh, Pa.

INTRODUCTION

The etiology of adjacent segment disease (ASD) after cervical arthrodesis remains unknown. Cadaveric biomechanical studies consistently demonstrate increased motion and stress at adjacent segments immediately following anterior cervical discectomy and fusion (ACDF) with two-level fusions exacerbating these effects.[1] However, studies evaluating *in vivo* adjacent segment range of motion (ROM) are far less conclusive.[1-2] Additionally, all prior *in vivo* studies have had limited measurements to static end-range positions during flexion/extension, thus failing to evaluate axial rotation or mid-range motion—where patients predominantly spend their time.[3-4]

Therefore, this study aims to longitudinally asses the effects of one- and two-level cervical arthrodesis on adjacent segment end-range and mid-range motion during dynamic flexion/extension and axial rotation movements. The authors hypothesized that adjacent segment motion would be greater three years postoperatively compared to preoperatively, and that increases in adjacent segment motion would be greater after two-level compared to one-level arthrodesis.

METHODS

The study included patients undergoing one-level C56, two-level C456, or two-level C567 cervical arthrodesis. Presurgical, one-year postsurgical, and three-year postsurgical testing were conducted, alongside age-matched controls. There were 11 patients who received one-level C56 (four men and seven women, age = 46.9 ± 5.8 years), five who received two-level C456 (three men and two women, age = 49 ± 8.2 years), and 11 who received two-level C567 (four men and seven women, age = 49.2 ± 9.6 years). There were 22 asymptomatic, age-matched controls (12 men and 10 women, age = 47.6 ± 8.6 years). Biplane radiographs were collected during full ROM tests, allowing for the calculation of three-dimensional vertebral motion. Intervertebral ROM, head motion, and mid-range motion were assessed and normalized to the static neutral position before surgery. Statistical analyses were conducted to identify differences in motion over time and between arthrodesis groups.

RESULTS

The interim analysis included data from 27 patients and 22 controls. Significant findings indicate increased mid-range axial rotation in the superior and inferior adjacent segments three years postoperatively in patients with two-level arthrodesis. However, no changes in adjacent segment motion were detected during rotation after single-level arthrodesis or during flexion/extension after either procedure. Control-group comparisons revealed differenced in head flexion/extension and axial rotation ROM compared to arthrodesis patients.

DISCUSSION

This study suggests that axial rotation may be more sensitive than flexion/extension in detecting early changes in adjacent segment motion after cervical arthrodesis. This finding contradicts prior short-term studies focusing only on flexion/extension.[3-4] The results are specific to C56, C456, and C567 arthrodesis with three-year follow-up, emphasizing the need for longer-term observations to unveil additional changes in adjacent segment ROM.

SIGNIFICANCE

Mid-range ROM and axial rotation appear to be more valuable than end-range ROM or flexion/extension in identifying midterm changes in adjacent segment motion following cervical spine arthrodesis. This insight has potential implications for understanding the pathophysiology of developing ASD.

REFERENCES

1. Park DK et al. *Spine*. 2011.
2. Reitman CA et al. *Spine*. 2004.
3. Bible JE et al. *J Spinal Disord Tech*. 2010.
4. Cobain DG et al. *Spine*. 2009.

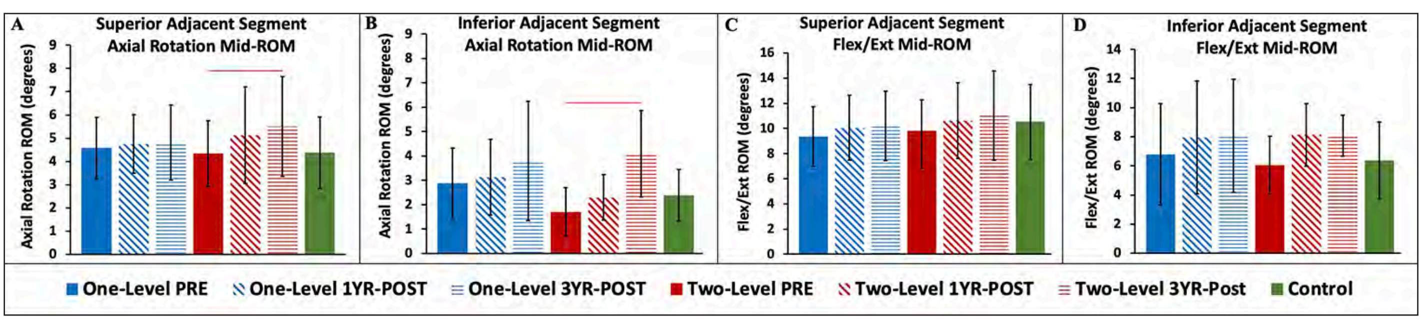


Figure 1. (A) Superior and (B) inferior adjacent segment axial rotation mid-range range of motion (ROM). (C) Superior mid-range ROM and (D) inferior flexion/extension end-range ROM. Red bars indicate differences in the two-level arthrodesis group time between before and three years after. Trends in increased adjacent segment motion during flexion/extension (C and D) were not significant.

THE ASSOCIATION BETWEEN DIFFERENT FOOT-TYPING METHODS AND FOOT LOADING: EVIDENCE FROM GENERALIZED ESTIMATING EQUATIONS—A PRELIMINARY STUDY

Cotton K[1], Dan X[1,2], Godbold E[1], Ma Y[2], Hogan M[1], Anderst W[1]

[1]Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.
[2]School of Public Health, University of Pittsburgh, Pittsburgh, Pa.

INTRODUCTION

The shape of a foot or foot type is of interest to clinicians and researchers due to its impact on injury risk.[1] Several classification methods have been developed to better characterize and understand the impact of foot type on injury risk. The interest in foot type has led to an equal interest in plantar loading characteristics due to its dynamic nature versus the static measurements of conventional foot typing methods.[2] Several studies have investigated the relationship between foot loading and foot type.[3-4] However, these studies tend to limit analysis to one foot-typing method. This has led to a fragmentation of the literature and makes comparison of different studies impossible. Determining which foot-typing method correlates best with foot function may help researchers and clinicians decide on which foot-typing method is most useful for linking morphology to loading. This study aims to investigate different methods of assessing foot type and their relationship to plantar loading.

METHODS

Ninety-two participants had their foot type assessed by five orthopaedic surgery residents (postgraduate years two through five). The methods included calcaneal pitch, X-ray arch type, Meary's angle, varus/valgus angle, arch index, and foot posture index. Average scores for each method were calculated from the five graders.

All participants walked on a treadmill at a self-selected pace. Peak force and the force-time integral were measured in nine foot regions of an in-shoe plantar loading system (Novel Pedar system) and normalized to participant body weight (BW). Generalized estimating equations with an unstructured working matrix was used to analyze foot loading data while accounting for the association between peak force and force-time integral at different regions with each foot type measure, adjusted for sex, age group, and treadmill speed. Significant associations are identified by Wald test with robust estimator for standard error at $\alpha = 0.05$.

RESULTS

Preliminary analyses reveal a negative association between Meary's angle and peak force. For every one degree increase in Meary's angle, there is an average decrease of 0.128 BW in the peak force (SD = 0.036, $p < 0.001$), with a 95% confidence interval of 0.059, 0.201. The observed decrease in the outcome with varus/valgus angles (–0.127 BW) approached significance ($p = 0.06$). The other foot-typing methods demonstrated non-significant impacts on peak force or force-time integral once adjusted for sex, age, and treadmill speed.

DISCUSSION

The study provides evidence of a significant association between Meary's angle and the maximum force exerted on the foot during gait, independent of sex, age, and treadmill speed. This insight underscores the importance of considering foot structure, specifically Meary's angle, in clinical assessments and potential interventions aimed at optimizing foot function. The nonsignificant findings regarding the other foot-typing methods highlight the complexity of foot biomechanics and the need for further investigation into other structural factors influencing foot loading.

REFERENCES

1. Levy J et al. *Foot Ankle Int*. 2006;27(12).
2. Buldt A et al. *Gait Posture*. 2018;62.
3. Mootanah R et al. *Gait Posture*. 2013;37(3).
4. Jonely H et al. *Clinical Biomechanics*. 2011;26(8).

Results of GEE on Foot Typing Methods and Foot Loading Variables		
	Value (95% CI)	P-Value
Foot Posture Index	0.095 (-0.129, 0.319)	0.406
Meary's Angle	-0.128 (-0.199, -0.057)	<0.001
Calcaneal Pitch	-0.012(-0.097, 0.074)	0.791
Varus/Valgus Angle	-0.127(-0.265, 0.01)	0.068
Xray Arch Type	-0.562(-1.56, 0.435)	0.269
Arch Index	-1.687(-9.957, 6.583)	0.689
GEE = Generalized Estimating Equations, CI = Confidence Interval		

Table 1. Results of generalized estimating equations on foot typing methods and peak force

DIFFERENCES IN GLENOHUMERAL MORPHOLOGY BETWEEN HEALTHY INDIVIDUALS AND PATIENTS WITH GLENOHUMERAL OSTEOARTHRITIS

Fang Z[1], LeVasseur CM[1,2], Hyre N[1], Hughes JD[1], Lin A[1], Anderst WJ[1]

[1]Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.
[2]Bethel Musculoskeletal Research Center, University of Pittsburgh, Pittsburgh, Pa.

INTRODUCTION

It is not well understood what represents clinically significant variations in glenohumeral bone morphology, which is important for anatomical reconstruction. Previous analyses of glenoid morphology have utilized computed tomography (CT) scans and magnetic resonance imaging,[1-2] which may be affected by slice orientation and resolution.

Few studies have measured glenohumeral bone morphology using 3D bone models reconstructed from CT,[3] and no studies have directly compared 3D measurements between healthy and pathologic shoulders. Therefore, the aim of this study was to compare glenohumeral bone morphology in young, healthy shoulders to patients with varying levels of glenohumeral osteoarthritis (OA).

METHODS

Patients scheduled to undergo scapular capsule reconstruction or reverse shoulder arthroplasty and healthy individuals consented to participate in studies approved by the Institutional Review Board. Patients received a CT scan of their affected shoulder (0.47 x 0.47 x 0.625 mm) while controls received a bilateral shoulder CT scan. Bone tissue was segmented from CT scan to create 3D models of the humerus and scapula. OA grade was established intraoperatively by a clinician with Outerbridge classification. Anatomical coordinate system of humeral head and scapula was manually created according to International Society of Biomechanics standards.[5] The articulating surface of the humeral head and glenoid surface were identified with previously established methods.[6] Glenoid and humerus bone morphology were all measured on the 3D models. Radial glenoid width was measured from the center to the edge of the glenoid at every 1° around the glenoid. One-way analysis of variance was used to identify differences in scapular and humeral bone morphology between OA groups and controls with Tukey's post-hoc tests. Differences in radial glenoid width between patients and controls were identified with statistical parametric mapping unpaired t-tests. Significance was set at $p < 0.05$ for all tests.

RESULTS

Forty-three shoulders of 43 patients with OA (24 men and 19 women) and 60 shoulders of 30 healthy volunteers (15 men and 15 women) were included in this analysis. The OA group was older with a higher body mass index than the healthy group. The glenoid was wider, deeper, larger, and more retroverted in patients, and greater OA severity exacerbated these findings. No differences were detected in glenoid version, tilt, or critical shoulder angle. The radius of the glenoid in OA groups was greater than in controls at varying points on glenoid clockface (see Figure 1A). The enlargement was more pronounced in patients with severe OA (see Figure 1B). The radius of the humeral head was greater in patients; however, no differences in humeral retroversion nor humeral inclination were detected.

DISCUSSION

This analysis demonstrated consistencies in glenoid bone morphology between groups: The middle glenoid was the deepest and widest, and the superior portion was narrower and shallower. These findings suggest that glenohumeral degeneration in the setting of irreparable rotator cuff tears leads to a larger, wider, and deeper glenoid. Better understanding of significant variations of glenohumeral bone morphology may lead to improved diagnostic strategies or new anatomically based implants and surgical approaches to common disease states.

REFERENCES

1. Matsumura N et al. *J Shoulder and Elbow Surg*. 2014;23(11):1724-30.
2. Iannotti JP et al. *JBJS*. 1992;74(4):491-500.
3. Gauci MO et al. *JSES*. 2020;29(3):541-9.
4. Heuberer PR et al. *BMC*. 2017;18(1):259.
5. Wu G et al. *J Biomech*. 2005;38(5):981-92.
6. Ghafurian S et al. *J Orthop Res*. 2016;34(4):692-8.

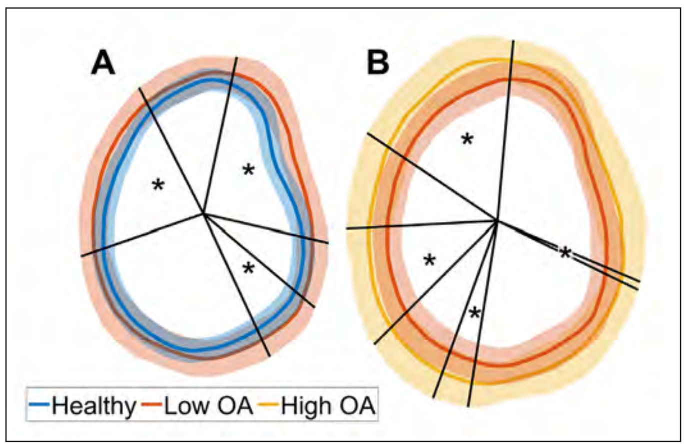


Figure 1. Radial width of the healthy (blue), low osteoarthritis (red), and high osteoarthritis (yellow) cohort. Shaded area represents ± one standard deviation, with lines and asterisks representing areas of significant differences.

PERCEIVED SOCKET COMFORT AND FUNCTION DO NOT CORRELATE WITH RESIDUAL LIMB SKIN SHEAR DURING GAIT IN PATIENTS WITH TRANSFEMORAL AMPUTATION

Gale T[1], Paulus P[1], Buffat D[3], Fielder G[2], Anderst W[1]

[1]Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.
[2]School of Health and Rehabilitation Science, University of Pittsburgh, Pittsburgh, Pa.
[3]Union Orthotics & Prosthetics Co., Pittsburgh, Pa.

INTRODUCTION
Increased residual limb skin strain is associated with decreased prosthetic use (Gale, 2021).[1] However, it is not known how well individuals with transfemoral amputation can perceive changes in residual limb skin shear during gait. This ongoing study aims to determine whether skin shear strain within the socket correlates to the prosthetic user's perception of socket comfort and function. The authors hypothesized that increased skin shear strain during gait would correlate with a decrease in patient-reported socket comfort and function.

METHODS
Following Institutional Review Board approval and informed consent, seven people with transfemoral amputations were each casted and fitted to six different check sockets by a licensed prosthetist (standard of care, 6% decreased volume, lowered brim, ischial containment, quad, and pliable material). Approximately 45 radio-opaque beads were glued to the distal residual limb. The limb-socket interface was imaged with biplane radiography (90 kV, 160 mA, 1 ms pulse) during treadmill walking at a self-selected gait speed (7.7 ± 0.20 m/s) for each socket. Bead locations were tracked with radiostereometric analysis,[2] and changes in relative bead position during walking, relative to a no-load condition, were used to compute skin shear strain. Shear strain was averaged in four anatomic regions in the distal residual limb. The participants were asked to rate the comfort and function of each socket against their own socket using the 15-point Global Rate of Change (GROC) scale, where –7 is considered greatly worse and +7 is considered greatly better. Correlations between GROC scores and maximum regional skin shear strains were tested with Spearman's correlation.

RESULTS
Data from 27 sockets across five subjects were included in this interim analysis. The typical pattern for the strain waveform during gait consisted of a peak strain during late swing phase and a decrease in strain after foot strike (see Figure 1). Regions with the greatest amount of strain differed among participants and socket types. No correlation was found between GROC scores (range = –7 to +2) and maximum skin shear strain per region (range = 0.01 to 0.20).

DISCUSSION
Results suggest that patient-reported comfort and function of the socket may not be related to maximum skin shear strain during gait. Explanations for these results include: coverage of the averaged strains may have been too large to capture focal strains associated with comfort and function; other factors may be primarily driving socket comfort and function, such as residual bone motion, localized pressure, and pain sensitivity; and the duration of wear may have been insufficient to elicit discomfort associated with changes in skin strain. Further analysis considering anatomical differences such as residual limb length and known pressure-tolerant/-intolerant sites may also elucidate new results. Quantitative measures of skin strain, in addition to patient feedback, may help inform socket design to minimize skin problems.

REFERENCES
1. Gale T et al. *J Biomech*. 2021;129:110826.
2. Anderst W et al. *J Biomech Eng*. 2003;125(2):238-45.

ACKNOWLEDGMENTS
This work was supported by the Department of Defense Office of the Congressionally Directed Medical Research Programs through the Restoring Warfighters with Neuromusculoskeletal Injuries Research Award.

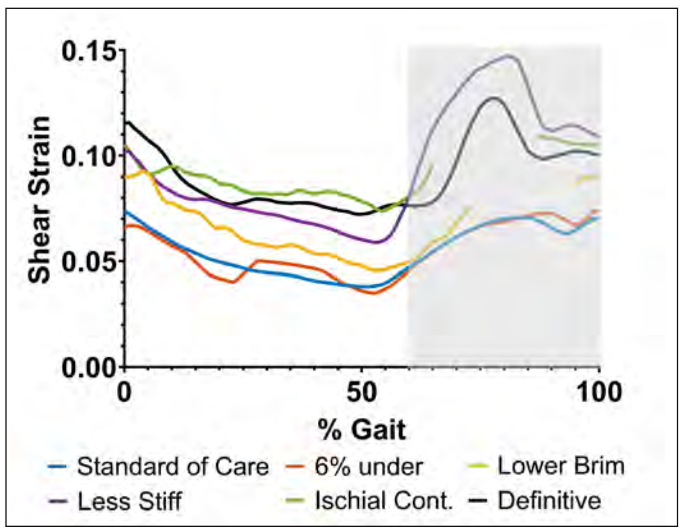


Figure 1. Example shear strain over the gait cycle. Data are from the anterior region of the residual limb from one participant wearing six different sockets. The non-shaded area represents stance phase, and grey-shaded area represents swing phase.

USING DYNAMIC BIPLANE RADIOGRAPHY TO ASSESS THE RELATIONSHIP BETWEEN POST-TRAPEZIECTOMY FIRST METACARPAL SUBSIDENCE AND THUMB FORCE DURING FUNCTIONAL TASKS

Godbold E, Setliff J, Munsch M, Fowler J, Anderst W

Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.

INTRODUCTION

The thumb carpometacarpal (CMC) joint is the most common site of osteoarthritis (OA) in the upper extremity.[1] Trapeziectomy was the historical surgical treatment.[2] Concerns that the first metacarpal (MTC1) could subside into the trapezial space and contribute to a reduction in grip and pinch strength led to the introduction of soft-tissue modifications, such as ligament reconstruction and tendon interposition (LRTI) and suspensionplasty.[3] LRTI attempts to reconstruct the anterior oblique (volar beak) ligament; however, no biomechanical evidence supports the utility of reconstructing the ligament.[4]

The long-term goal of this study was to quantify the relationship between three-dimensional MTC1 subsidence and thumb force during functional tasks after trapeziectomy, as no such *in vivo* data currently exist.

METHODS

Twelve adults scheduled for unilateral trapeziectomy followed by either LRTI or suspensionplasty (surgeon preference) were included in this interim analysis. Synchronized dynamic biplane radiographs of the thumb CMC joint were collected (120 frames per second) before and after surgery while participants performed three functional tasks: can grasp, key pinch, and jar twist. Three trials of each task per hand were performed. Force was continually measured throughout the trials using a load cell (1,200 frames per second). Preoperative computed tomography scans of each participant's hands and wrists were segmented to create subject-specific bone models of the MTC1, trapezium, scaphoid, and radius. A validated volumetric model-based tracking technique was used to track the bones with submillimeter accuracy during each trial.[5] Participants returned six months postoperatively to perform the same functional tasks.

RESULTS

The study collected and analyzed data on the participants (nine women, age = 62.3 ± 6.1 years), including seven for whom postoperative data were available (five women; age = 59.0 ± 5.3 years; two LRTI, five suspensionplasty). Qualitatively, peak force during key pinch decreased in all participants' affected hands from preoperative to postoperative testing. The change in gap distance between the MTC1 and scaphoid as force increased was inconsistent among subjects (see Figure 1), as was the location of minimum gap between MTC1 and scaphoid (see Figure 2).

DISCUSSION

This interim analysis demonstrates that MTC1 subsidence and thumb force can be measured simultaneously with dynamic biplane radiography, and that the effect of trapeziectomy on the relationship between peak force and subsidence may be dependent upon functional activity. The key pinch task appears to be most reliable for testing this relationship.

REFERENCES

1. Van Heest AE et al. *JAAOS*. 2008.
2. Gervis WH et al. *JBJS Br*. 1973.
3. Shonuga et al. *Hand*. 2021.
4. Lui et al. *J Hand Surg Eur*. 2023.
5. Munsch et al. *J Biomech*. 2022.

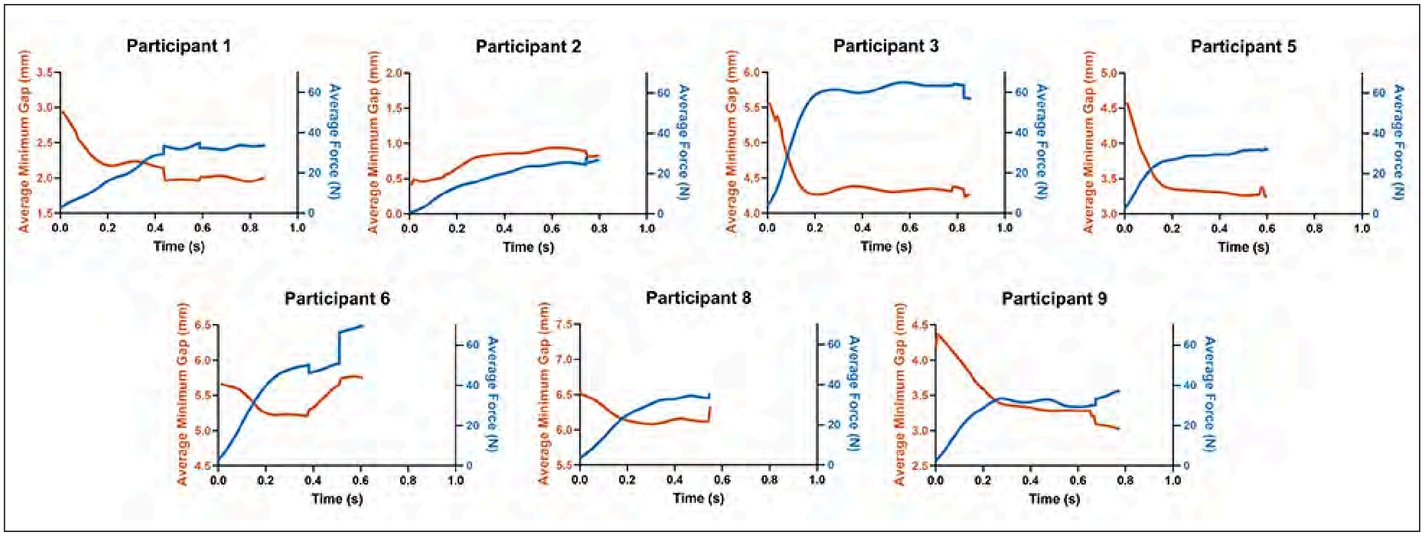


Figure 1. Force generation (blue) appears to be inversely related to trapezial space (orange) during key pinch, the task that has been most reliable for testing the relationship between subsidence and force.

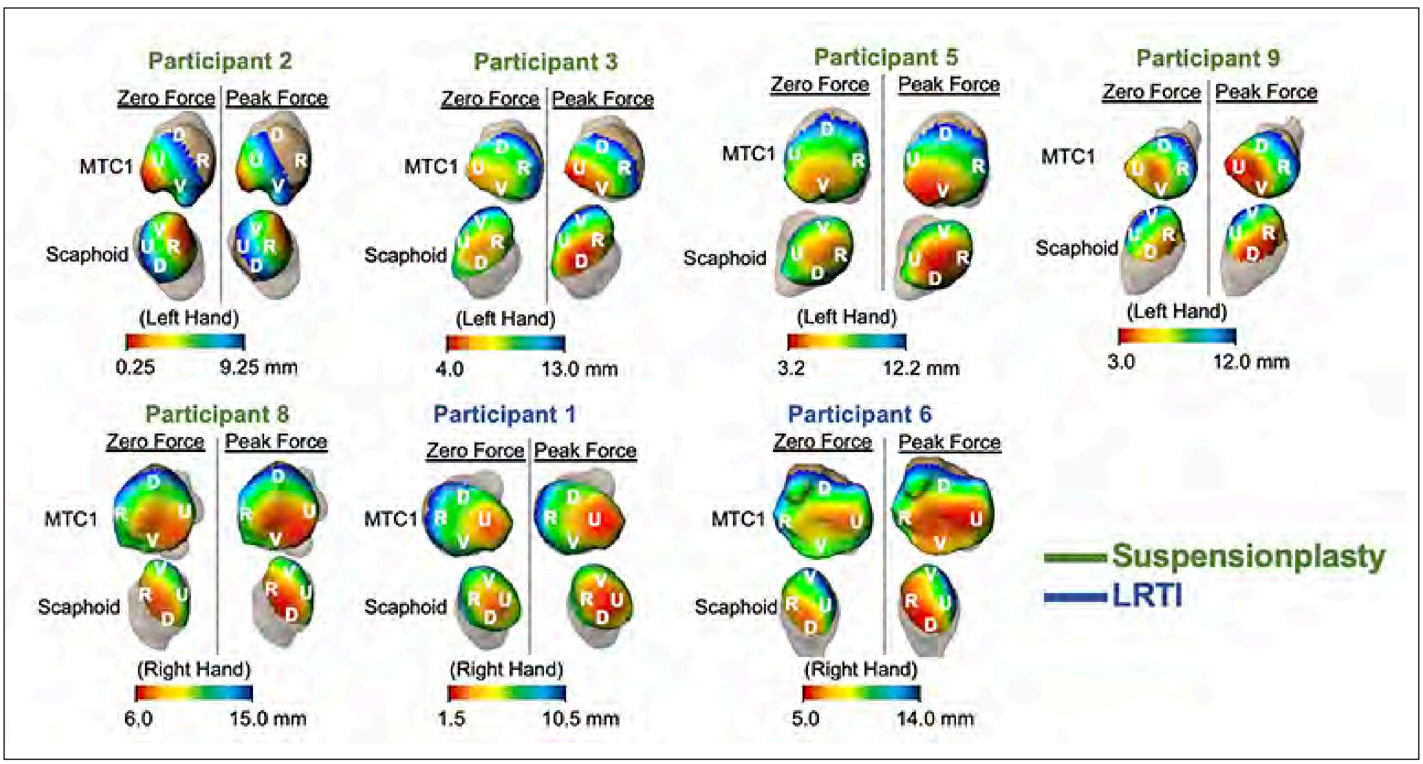


Figure 2. Distance between the first metacarpal and scaphoid bone during key pinch. D = dorsal, V = volar, R = radial, U = ulnar

USING WRAPPING SURFACES TO ESTIMATE HIP MUSCLE MOMENT ARMS DURING ACTIVITIES OF DAILY LIVING

Johnson C, Ruh E, Frankston N, Charles S, Mauro C, McClincy M, Anderst W

Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.

INTRODUCTION

Hip muscle function is important when considering postoperative rehabilitation.[1] Marker-based motion-capture studies have associated dysplastic hip anatomy with shorter abductor moment arm length (MAL) during walking,[2] but these measurements are subject to soft-tissue artifact.[3] Biplane radiography is an accurate technique for measuring *in vivo* bone motion[4] and has been utilized to estimate dynamic MAL,[1] an important factor influencing torque-generating capability. Accurately estimating MAL during deep hip flexion requires muscle models that wrap around bone.[5-6]

The purpose of this study was to estimate normative *in vivo* MAL of select hip muscles during standing, walking, and squatting in an asymptomatic cohort. The authors hypothesized that maximum MAL during squatting would be longer than during walking and standing.

METHODS

Twenty-four healthy young adults stood, walked, and squatted while synchronized biplane radiographs were collected (50 frames per second). Subject-specific bone models were created from computed tomography scans. Coordinate systems[7] and muscle origin and insertion points for the gluteal muscles, pectineus, and grouped external rotators[1] were established. Cylindrical wrapping surfaces were established for each gluteal muscle.[5-6] *In vivo* bone motion was determined via model-based tracking.[4] MAL was calculated as the perpendicular distance between the joint center and each muscle line of action and interpolated to gait cycle or percentage maximum hip flexion. Differences in maximum MAL between movements were assessed within each muscle group with analysis of variance.

RESULTS

Data from 205 trials of 47 hips from 24 individuals were analyzed (13 women; age = 21.9 ± 2.2 years, body mass index = 21.5 ± 4.9 kg/m^2). Average walking velocity was 1.1 ± 0.2 m/s, and average maximum hip flexion during squatting was 98.0 ± 16.6°. MAL differed by activity for all muscles except the external rotators (see Table 1). MAL of the abductors was shorter during squatting compared to other motions (Figure 1).

DISCUSSION

This study demonstrates the *in vivo* torque-generating capabilities of muscles surrounding the hip (reflected by their MAL) during changes from standing to active functional positions. Muscles involved in hip abduction and stabilization have less mechanical advantage at greater hip flexion, highlighting the importance of strengthening during rehabilitation. Knowledge of these changes in mechanical advantage can be useful in improving function after surgical intervention.

REFERENCES

1. Hu et al. *J Ortho Surg and Res*. 2020.
2. Song et al. *J Biomech*. 2020.
3. Fiorentino et al. *Gait Posture*. 2017.
4. Martin et al. *J Arthroplasty*. 2011.
5. Catelli et al. *35th ISBS Conference Proceeding*. 2017.
6. De Pieri et al. *PLOS ONE*. 2018.
7. Wu et al. *J Biomech*. 2002.

Trial Type	Gluteus Maximus	Gluteus Medius	Gluteus Minimus	Pectineus	External Rotators
Standing	74.3±3.9*	50.9±5.6*	46.1±5.6*	36.2±2.3*	33.9±9.9*#
Walking	80.5±3.0*	53.6±4.3*	49.4±4.6*	40.8±2.4*	40.2±8.6*
Squatting	86.8±8.4*	47.8±1.7*	44.4±3.7*	42.0±2.7*	39.4±3.2#

Table 1. Average maximum moment arm length (mm) during standing, walking, and squatting (mean ± standard deviation). Matching symbols indicate significant differences between motions.

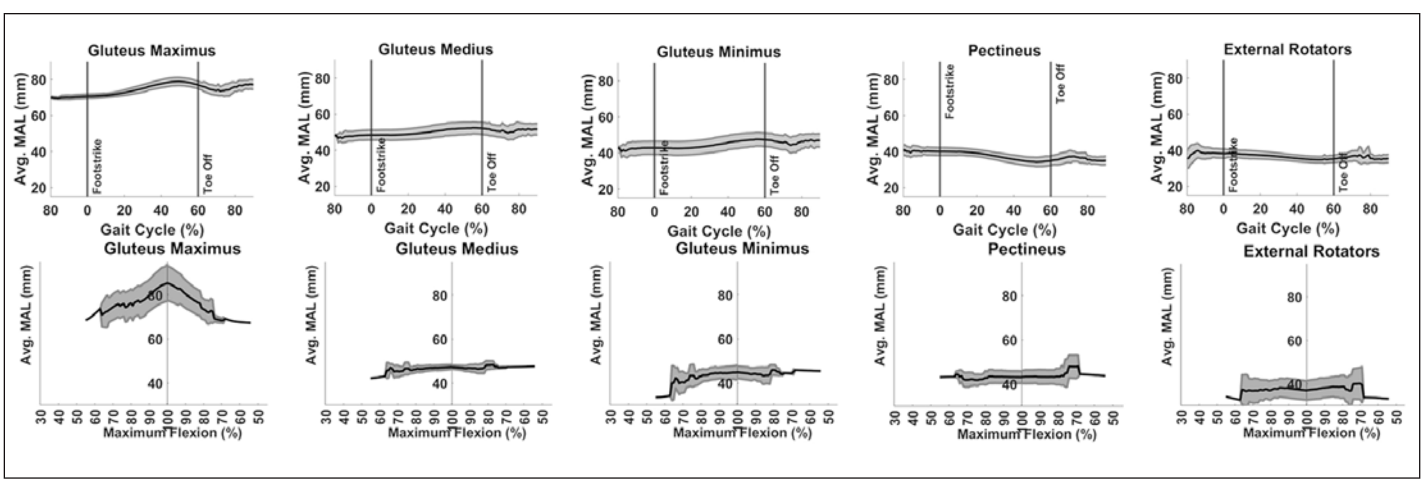


Figure 1. Average moment arm length (mm) across gait cycle and squatting. Solid lines indicate averages, and shaded areas indicate standard deviations.

THE EFFECTS OF ABDUCTION ANGLE AND LOAD ON GLENOID TRACK SIZE AND LOCATION

LeVasseur CM[1,2], Fang Z[1], Scott D[1], Brockhoff J[1], Hughes JD[1], Lin A[1], Anderst WJ[1]

[1]Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.
[2]Bethel Musculoskeletal Research Center, University of Pittsburgh, Pittsburgh, Pa.

INTRODUCTION

Simultaneous defects of the humeral head and glenoid occur with instability;[1] therefore, understanding the dynamic articulation between the bones is vital. Current treatment guidelines are based upon the glenoid track concept, which was developed from glenohumeral (GH) articular contact patterns in cadavers and static imaging of healthy individuals.[2-3] No work has been done to quantify the glenoid track dynamically, nor to evaluate the effect of an additional load on the glenoid track. The aim of this ongoing study was to characterize the effects of GH abduction, GH external rotation (ER), and load on the glenoid track area and location.

METHODS

Healthy individuals gave consent prior to participating in this study, which was approved by the Institutional Review Board. Participants received bilateral computed tomography (CT) and magnetic resonance imaging (MRI) scans and performed two trials with each arm of internal/external rotation in 30°, 60°, 90°, and 120° of humerothoracic abduction while synchronized biplane radiographs were collected at 50 images per second. One of each trial was performed with a 5 lb weight. Digitally reconstructed radiographs of the CT-based bone models were matched to the biplane radiographs with a validated technique to determine GH kinematics.[4] Bone and cartilage were segmented from MRI and co-registered to the CT models. The boundary of the glenoid to humeral cartilage overlap was determined and expressed in spherical coordinates. Data from corresponding trials (same side, weight condition) were used to interpolate the dynamic glenoid track at 5° increments of GH abduction and ER. Both the area and the center of the glenoid track were evaluated at 10° increments of GH abduction between 40° and 70° and at 5° increments of ER between 5° and 50°. Absolute side-to-side differences (SSDs) in location and area of the glenoid track were determined at corresponding angles of abduction and ER.

RESULTS

Data processing is complete for eight of the 30 participants who completed the study (eight men, 30.3 ± 11.9 years old). The glenoid track moved superior and posterior and decreased the contact area during ER (see Figure 1). Each 10° increase in GH abduction resulted in the glenoid track primarily being 4.2 ± 2.6 mm more superior while decreasing the contact area by 76.0 ± 94.9 mm^2 (see Figure 1). Adding the 5 lb weight moved the average glenoid track location 1.7 ± 2.7 mm more posterior while decreasing the contact area by 23.1 ± 52.2 mm^2 (see Figure 1). Average SSDs in glenoid track location were 4.7 ± 4.0 mm anteroposterior (AP) and 3.2 ± 2.6 mm superior-inferior (SI) while the area SSD was 124.0 ± 122.8 mm^2.

DISCUSSION

Increased abduction, ER, and the addition of load all made the glenoid track more posterior while decreasing the contact area, which may lead to a higher chance of dislocation. SSDs are large in this small cohort, suggesting that a patient's contralateral side may not be a good reference for comparison. Measurements of the glenoid track during physiological loading may provide novel insights into GH joint stability and the potential for dislocation.

REFERENCES

1. Lemme NJ et al. *JBJS Rev.* 2019;7(11).
2. Yamamoto N et al. *JSES.* 2007;16(5):649-56.
3. Omori Y et al. *AJSM.* 2014;42(6):1290-5.
4. Bey MJ et al. *J Biomech.* 2006;128(4):605-9.

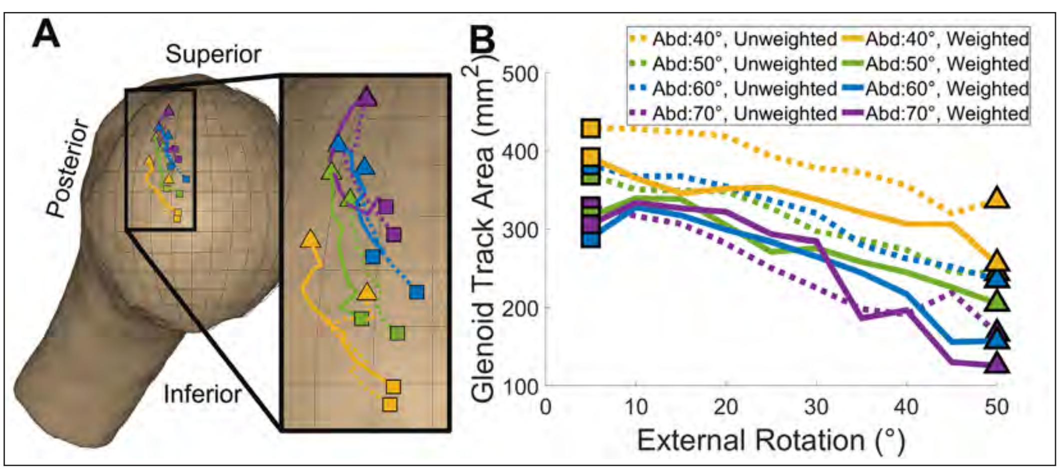


Figure 1. a) Average center of glenoid track location and b) glenoid track area during external rotation (ER) at 40° glenohumeral (GH) abduction (yellow), 50° GH abduction (green), 60° GH abduction (blue), and 70° GH abduction (purple) with a weight (solid lines) and without a weight (dashed lines). Squares indicate 5° ER, and triangles indicate 50° ER.

THE RELATIONSHIP BETWEEN CARTILAGE STRAIN DURING DOWNHILL RUNNING AND CARTILAGE DEGENERATION AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

Nukuto K, Gale T, Irrgang JJ, Musahl V, Anderst W

Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.

INTRODUCTION
There are no reports of an association between cartilage strain during high-demand activity and cartilage degeneration after anterior cruciate ligament reconstruction (ACLR). The purpose of this study was to evaluate the relationship between cartilage strain during downhill running and cartilage degeneration after ACLR. The authors hypothesized that cartilage strain during running and cartilage degeneration would increase with time after ACLR and that localized increases in cartilage strain during running would be associated with localized increases in cartilage degeneration after ACLR.

METHODS
Patients who underwent anatomic ACLR were enrolled following Institutional Review Board approval. ACLR knees were imaged within a biplane radiographic system (150 images per sec, 90 kV, 160 mA, 1 ms exposure) for three trials during downhill running. Tibiofemoral motion was tracked with a validated volumetric model-based tracking process[1] and was analyzed during 0%–10% of the gait cycle.[2] Patient-specific cartilage models, derived from three-dimensional double-echo steady-state magnetic resonance imaging (MRI), were registered to computed tomography–based bone models, and cartilage strain was calculated from the tibiofemoral cartilage thickness and overlap distance.[3] T2 relaxation time was calculated from a seven-echo sagittal T2-weighted MRI. Both biplane radiography and MRI data were collected at six and 24 months after ACLR. The tibial plateau was divided into nine sub-regions, the femoral condyle was divided into 18 sub-regions, and the average cartilage strain and the average T2 relaxation time were calculated within each region, per compartment. Wilcoxon signed rank test was used to test for differences in cartilage strain and T2 relaxation time between six and 24 months after ACLR. The correlation between changes in cartilage T2 relaxation time and cartilage strain between six and 24 months after ACLR was evaluated with Spearman's rho, with significance set at $p < 0.05$.

RESULTS
The study included 36 patients (24 male, 12 female; age = 21.3 ± 7.1 years, body mass index = 25.4 ± 3.4 kg/m^2). Cartilage strain decreased from six to 24 months in eight regions of the medial compartment and four regions of the lateral compartment (see Figure 1A). T2 relaxation time increased in one region of the femur and in two regions on the tibia and decreased in four regions on the tibia. A positive correlation between the change in T2 relaxation time and the change in cartilage strain from six to 24 months was found in the central region of zone 2 in the lateral tibia, whereas a negative correlation was observed in the central region of zone 2 in the medial tibia and in the central region of zone 3 in the lateral tibia (see Figure 1B).

DISCUSSION
Contrary to the hypotheses, the authors did not find consistent increases in cartilage strain or cartilage degeneration. These results may be related to the fact that all surgeries were anatomic ACLR, which has a lower risk of post-traumatic osteoarthritis compared to non-anatomic ACLR.[4] Although changes in cartilage health and changes in cartilage contact after ACLR have been previously reported, the association between cartilage contact and cartilage health remains unclear.

REFERENCES
1. Anderst W et al. *Med Eng Phys*. 2009;31(1):10-6.
2. Grood ES & Suntay WJ. *J Biomech Eng*. 1983;105(2):136-44.
3. Liu F et al. *J Biomech*, 2010;43(4):658-65.
4. Rothrauff BB et al. *KSSTA*. 2020;28(4):1072-84.

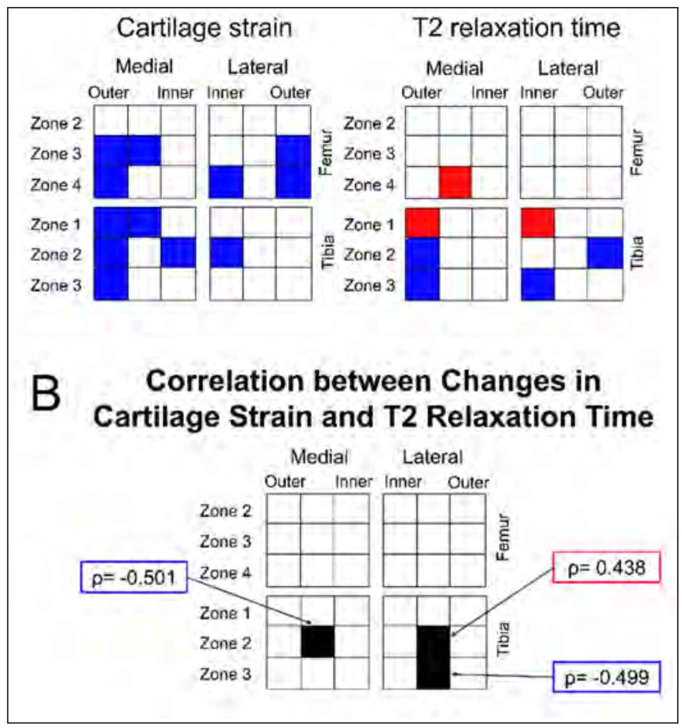


Figure 1. (A) Changes from six to 24 months in cartilage strain and T2 relaxation time and (B) correlation between changes in cartilage strain and T2 relaxation time. Red = significant increase, blue = significant decrease

PATIENT PERCEPTION OF SOCKET FIT MAY NOT BE ASSOCIATED WITH GAIT AND LOADING CHARACTERISTICS IN INDIVIDUALS WITH TRANSFEMORAL AMPUTATIONS

Paulus P[1], Gale T[1], Yatsenko Y[1], Elder J[1], Mroz K[1], Buffat D[2], Fielder G[3], Anderst W[1]

[1]Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.
[2]Union Orthotics & Prosthetics, Pittsburgh, Pa.
[3]School of Health and Rehabilitation Science, University of Pittsburgh, Pittsburgh, Pa.

INTRODUCTION

Secondary musculoskeletal conditions commonly occur after lower-limb amputation due to compensatory gait changes, which have been linked to poor prosthetic fit.[1] Current methods for evaluating prosthetic fit are dependent upon clinician expertise and qualitative patient feedback.[2] However, it can be difficult to justify this practice due to the paucity of literature investigating the relationship between patient feedback and gait characteristics.

The aim of this interim analysis was to determine whether a patient's perception of socket fit is associated with their gait kinematics and kinetics. The authors hypothesized that individuals with transfemoral amputation would demonstrate greater lateral trunk lean, greater asymmetry in lower-extremity kinematics, and greater contralateral limb loading with poorly rated sockets compared to highly rated sockets.

METHODS

Individuals with unilateral transfemoral amputations who had been ambulating with their prosthesis for more than a year provided written informed consent to participate in this study, which was approved by the Institutional Review Board. Participants were casted and fitted by a licensed prosthetist with check sockets which varied in stiffness, brim height, cross-sectional area, and shape. During lab visits, participants wore a set of 53 reflective markers placed on their trunk and lower extremities. They then walked across a 10 m lab walkway at a self-selected pace four times per socket. Trunk and sagittal plane lower-extremity kinematics were collected with a 12-camera Vicon motion capture system (100 Hz). Ground reaction forces were collected when participants stepped onto a dual-belt instrumented treadmill centered in the lab walkway (1000 Hz).

Participants rated each socket's comfort and function on a scale of –7 to +7 using the Global Rate of Change (GROC) scale, with 0 being their definitive socket.[3] Kinematics and kinetics were calculated in Visual3D, interpolated to percent stance, and averaged per participant and socket type. The highest, lowest, and mid-rated sockets based on summed GROC scores were identified. Differences in trunk kinematics, joint moments and forces, and side-to-side differences in lower-extremity kinematics among the three socket ratings were evaluated with statistical parametric mapping one-way repeated-measures analysis of variance ($p < 0.05$) with post-hoc Bonferroni corrections ($p < 0.017$).

RESULTS

Six individuals with traumatic unilateral amputations (five men, one woman, age = 56 ± 17 years, height = 179.5 ± 7.7 cm, weight with prosthesis = 80.8 ± 18.2 kg) were included in this interim analysis. The average combined GROC scores used to classify the high-, mid-, and low-rated sockets were–0.5 ± 3.1, –3.7 ± 1.4, and –9.2 ± 2.6, respectively. The researchers found a between-socket difference of up to 11.7° lateral trunk bend and 21.9° trunk flexion within a participant. They also found between-socket differences in lower-extremity asymmetry of up to 12.5° in hip flexion, 14.3° in knee flexion, and 9.9° in ankle dorsiflexion within a participant. Finally, they found between-socket differences in resultant joint forces of up to 1.0 body weight in the sound hip and 0.6 body weight in the sound knee and in internal joint moments of up to 0.4 Nm/kg in the sound hip and knee within a participant. However, no differences in trunk kinematics, lower-extremity kinematic asymmetry, or contralateral limb forces or moments were found based on patient-reported socket rating during stance phase of gait.

DISCUSSION

Although the peak between-socket differences were relatively large, no differences in kinematics or kinetics were found based on patient feedback in this preliminary analysis. Given the small sample size, further testing is required to verify these findings.

Patient-reported socket comfort and function may not correspond to differences in kinematics and kinetics during gait.

REFERENCES

1. Gailey R et al. *J Rehabil Res Dev*. 2008;45(1):15-29.
2. Wernke M et al. *Adv Wound Care (New Rochelle)*. 2017;6(7):233-9.
3. Jaeschke R et al. *C Clin Trials*. 1989;10:407-15.

ACKNOWLEDGMENTS

The research was supported by the Department of Defense Office of the Congressionally Directed Medical Research Programs through the Restoring Warfighters with Neuromusculoskeletal Injuries Research Award under award number W81XWH2010914.

HUMERAL RETROVERSION AND GLENOID TILT INFLUENCE IMPLANT IMPINGEMENT AFTER REVERSE SHOULDER ARTHROPLASTY

Rai A[1], LeVasseur C[1], Kane G[1], Munsch M[1,2], Hughes J[2], Anderst W[1], Lin A[2]

[1]Biodynamics Laboratory, University of Pittsburgh, Pittsburgh, Pa.
[2]Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.

INTRODUCTION
Internal rotation (IR) is not reliably improved after reverse shoulder arthroplasty (RSA), as only 36% of patients can wash their back with the affected arm after RSA. Impingement of the humeral implant with the scapula is commonly cited as the limiting factor of IR. Computer models suggest that less retroverted humeral implants and less inferior glenoid tilts are associated with less impingement.

The purpose of this study was to determine which surgical parameters predict impingement during the hand-to-back motion after RSA. The authors hypothesized that less inferior tilt, more lateralization, and less humeral retroversion would predict less impingement during the hand-to-back motion. Additionally, they hypothesized that patients who impinge during the hand-to-back motion would have poorer patient-reported outcomes (PROs) and less clinical IR range of motion (ROM).

METHODS
All participants received RSA with a standard 145° onlay humeral implant (Wright) or a 135° inlay humeral implant (Arthrex). Synchronized biplane radiographs were collected during three trials of the hand-to-back motion. Scapular and glenohumeral kinematics were determined with a validated technique that matched 3D models to radiographs with sub-millimeter accuracy. A 3D model of the humeral liner was fit into the computed tomography (CT)-based humeral tray, and the humerus kinematics were used to drive the humeral tray kinematics. The minimum distance between the bone portion of the scapula/implant model and the humeral liner was calculated at every frame of data, interpolated to the percentage of the motion trial, and averaged across all three trials at corresponding percentages of the motion cycle. Impingement was then defined as the first instance in the motion cycle when the minimum distance fell below 0.5 mm (the accuracy of the researchers' measurement system), and the position of the six kinematics rotations were saved for analysis. Unpaired t-tests compared surgical parameters between patients who did versus those who did not impinge. Lateralization, glenosphere size, and eccentricity were recorded from surgical notes. Humeral retroversion and glenoid tilt were measured on postoperative CT. The researchers collected PROs via the American Shoulder and Elbow Surgeons Standardized Shoulder Assessment Form; Disabilities of the Arm, Shoulder, and Hand; and Constant-Murley score. Clinical IR ROM was measured as the furthest position participants could place their hand up their back. Multiple linear regression was used to identify implant parameters that predicted scapular or glenohumeral kinematics at impingement. Pearson's correlations were used to identify associations between kinematics at impingement and outcomes, with significance set at $p < 0.05$ for all tests.

RESULTS
The study included 34 patients who were tested 2.2 ± 1.1 years after receiving RSA (17 men, 17 women, age = 72.8 ± 7.3 years). Eleven participants did not reach the 0.5 mm impingement threshold. Humeral retroversion was the only parameter that differentiated between patients who did and did not impinge; those who impinged had higher average retroversion (19.3° ± 11.3°) than those who did not (8.8° ± 7.0°) ($p = 0.008$). Glenoid tilt was the only surgical parameter that predicted kinematics at impingement. A more inferior glenoid tilt predicted a more posterior plane of elevation (see Figure 1A; $p < 0.001$, $b = 2.833$) and more internal rotation (see Figure 1B; $p < 0.001$, $b = –1.421$) at impingement. No associations between kinematics at impingement and PROs or clinical IR ROM were identified.

CONCLUSION
The main findings of this *in vivo* study were that retroversion and glenoid tilt are the surgical parameters that affect impingement during the hand-to-back motion after RSA. The results agree with predictions from computer-based studies on retroversion and glenoid tilt's influence on impingement. This study also considers the effect of healing and rehabilitation on patient outcomes and kinematics. The lack of association between clinical outcomes and impingement or kinematics at the time of impingement suggests that other factors (e.g., pain, ability to perform other activities of daily living) may influence PROs to a greater degree than impingement. These results are limited to the hand-to-back motion.

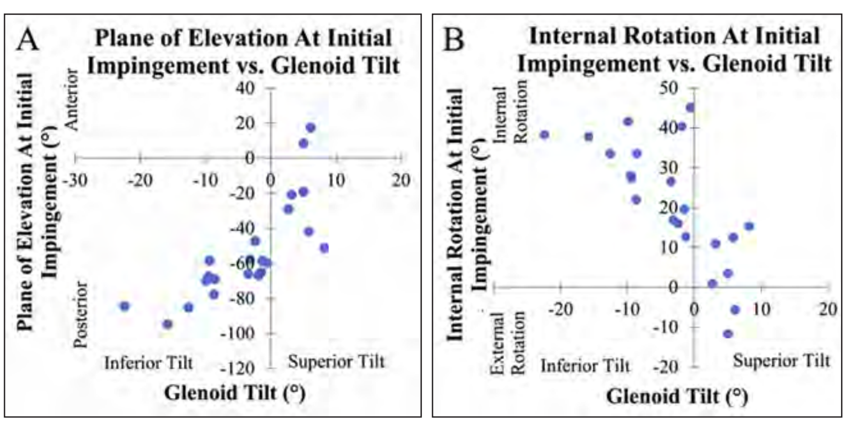


Figure 1. Plane of elevation (A) and internal/external rotation (B) reached at impingement with respect to glenoid tilt. Each blue dot represents data from one patient.

POSTERIOR STABILIZED TOTAL KNEE ARTHROPLASTY RESTORES NATIVE KNEE KINEMATICS BETTER THAN CRUCIATE-RETAINING TOTAL KNEE ARTHROPLASTY

Ramraj R, Gale T, Tanabe Y, Byrapogu K, Copp E, Scarton E, Urish K, Anderst W

Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.

INTRODUCTION

Knee arthroplasty is an effective procedure for end-stage osteoarthritis, yet 20% of patients report limited function, persistent disability, and reduced quality of life.[1] Total knee arthroplasty (TKA) is the most common knee arthroplasty procedure, but the type of TKA prosthesis is determined by surgeon preference. Previous studies have compared tibiofemoral kinematics to healthy knees but not to the contralateral knee.[2] The purpose of this study was to determine how well CR (cruciate-retaining) and PS (posterior stabilized) TKAs restore native tibiofemoral kinematics during chair rise and stair ascent, activities of daily living that require deep flexion and are correlated with patient satisfaction.[3] The authors hypothesized that CR would resemble native knee kinematics more closely than PS.

METHODS

The study was approved by the Institutional Review Board and recruited 21 participants (12 men, nine women; age = 64.9 ± 6.8 years) undergoing unilateral total knee arthroplasty, who provided informed consent to participate. All participants had Kellgren-Lawrence (KL) scores > 2 on the operated knee and KL scores < 2 on the contralateral knee. Synchronized biplane radiographs were collected for each knee during three trials of each motion (preoperatively: 2.2 ± 1.5 months, postoperatively: 10.5 ± 2.4 months). Tibiofemoral kinematics were obtained via a previously validated volumetric model-based tracking system[4-6] and synchronized according to knee flexion. Average absolute side-to-side differences (SSD_A) of the kinematics waveforms (postoperative surgical knee minus contralateral knee) at corresponding knee flexion angles were calculated. Group differences between implant types were identified with unpaired t-tests, with significance set at $p < 0.05$. Side-to-side difference (SSD) waveforms for each participant were compared with statistical parametric mapping.[7]

RESULTS

Overall, 17 participants—seven who received CR (Journey II CR, Smith & Nephew) and 10 who received PS (Journey II PS, Smith & Nephew)—completed postoperative testing. Average SSD_A showed that PS knees were more symmetrical than CR knees in valgus/varus rotation and lateral medial translation. SSD waveforms during chair rise showed that CR knees were more medially translated relative to contralateral than PS knees from 57° to 65° flexion (p = 0.048) (see Figure 1A). During stair ascent, CR knees were more valgus (p = 0.034) and medially translated (p = 0.019) relative to contralateral than PS knees from 25° to 66° flexion (see Figure 1B).

DISCUSSION

The most important finding of this study was that PS TKA appears to restore tibiofemoral kinematics more closely to that of the contralateral knee than CR. Future analysis comparing PS and CR TKA SSDs to healthy controls will provide context for the observed asymmetry. These results are limited to the specific knee replacements and activities tested.

REFERENCES

1. Fingar K et al. *Agency for Healthcare Research and Quality*. 2006.
2. Ishibashi T et al. *JOR*. 2022;40(7):1547-54.
3. Furu M et al. *JOS*. 2016;21(1):38-43.
4. Anderst W et al. *Med Eng and Phys*. 2008;31(1):10-6.
5. Gale T et al. *JOR*. 2019;37(3):609-14.
6. Grood ES et al. *J Biomech Eng*. 1983;105(2):136-44.
7. Pataky TC et al. *Journal of Biomechanics*. 2010;43(10):1976-82.

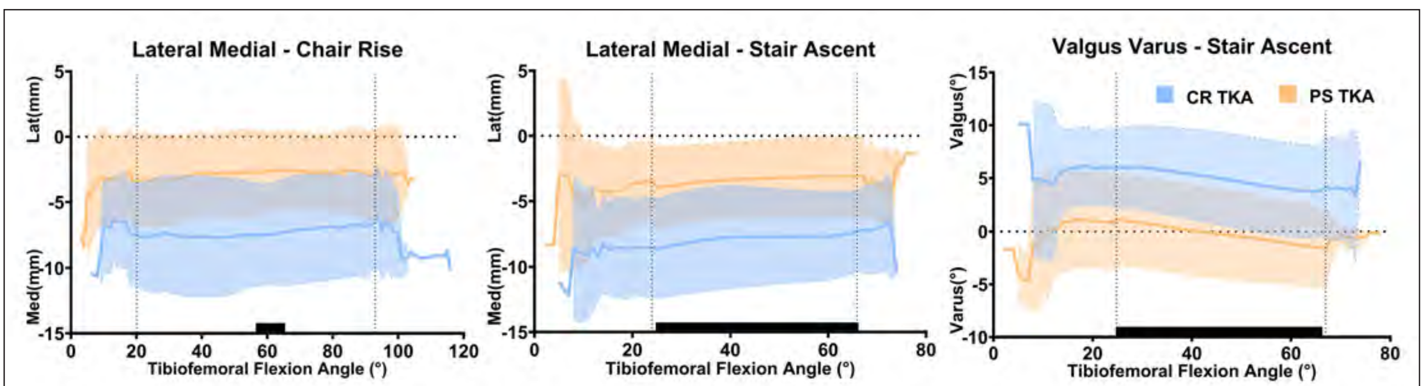


Figure 1. Group average side-to-side difference in cruciate-retaining and posterior stabilized total knee arthroplasty knees during stair ascent and chair rise. (A) Lateral/medial translation during chair rise, (B) lateral/medial translation and valgus/varus rotation during stair ascent. Solid lines indicate group means; shaded area represents one standard deviation. Dotted vertical lines indicate where statistical parametric mapping was performed. The solid black bar on the X axis identifies period of significant differences between groups (p < 0.05).

TIBIAL SPINE VOLUME IS CORRELATED WITH ACL INJURY RISK

Yahagi Y[1,3], Gale T[3], Musahl V[2,3], Anderst W[3]

[1]Nihon University School of Medicine, Department of Orthopaedic Surgery, Tokyo, Japan
[2]UPMC Freddie Fu Sports Medicine Center, Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.
[3]Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.

INTRODUCTION

The tibial spine is important for knee stability because it is attached to the anterior cruciate ligament (ACL) and has been shown to cause abnormal knee kinematics for individuals with small tibial spines.[1-2] Previous reports have indicated that small tibial spine area,[3] width,[4] and medial tibial spine volume[5] are risk factors for ACL injury. No previous literature has assessed the association between whole tibial spine volume and ACL injury risk. The aim of this study was to investigate whether whole tibial spine volume is a risk factor for ACL injury.

METHODS

Fifty-one athletes undergoing anatomical ACL reconstruction (17 female, 34 male; average age = 22.0 ± 7.5 years) and 19 healthy collegiate athletes with intact ACL (eight female, 11 male; average age = 20.1 ± 1.3 years) were included. The researchers created 3D subject-specific bone models by computed tomography images using Mimics (Materialise). They measured tibial spine volume from the 3D bone models using Mimics by creating a plane based upon three manually placed points and measuring the volume of bone tissue above the plane (see Figure 1). Tibial spine volume and normalized tibial spine volume by tibial plateau area were compared between the ACL-injured group and ACL-intact group with Mann-Whitney U-test.

RESULTS

Tibial spine volume was 20.7% smaller in the ACL-injured group (2.14 ± 0.52 cm^3) than in the ACL-intact group (2.70 ± 0.72 cm^3) ($p = 0.005$). Normalized tibial spine volume for the ACL-injured group (0.59 ± 0.14 mm^3/mm^2) was 23.4% smaller than for the ACL-intact group (0.77 ± 0.16 mm^3/mm^2) ($p < 0.001$).

DISCUSSION

The whole tibial spine volume of the ACL-injured group was significantly smaller than in the ACL-intact group, which reflects previous reports of tibial spine height, width, area, and partial volume, which found a correlation between tibial spine morphology and risk for ACL injury.[1,3-7] The result of this study confirms that the observed differences in tibial spine volume were not due to differences in overall size of the knee, as the normalized volume showed similar differences between groups. The small tibial spine volume may predispose individuals to ACL injury. Measurement of tibial spine volume may be useful in prospectively assessing ACL injury risk so that patients can receive appropriate injury-prevention training.

REFERENCES

1. Levins JG et al. *Am J Sports Med*. 2016;44(10):2537-45.
2. Lansdown D et al. *Clin Sports Med*. 2018;37(1):127-36.
3. Iriuchishima T et al. *Knee Surg Sports Traumatol Arthrosc*. 2022;30(1):78-83.
4. Iriuchishima T et al. *Knee Surg Sports Traumatol Arthrosc*. 2020;28(11):3625-30.
5. Sturnick DR et al. *J Ortho Res*. 2014;32(11):1451-7.
6. Uhorchak JM et al. *Am J Sports Med*. 2003;31(6):831-42.
7. Xiao WF et al. *J Int Med Res*. 2016;44(1):157-63.

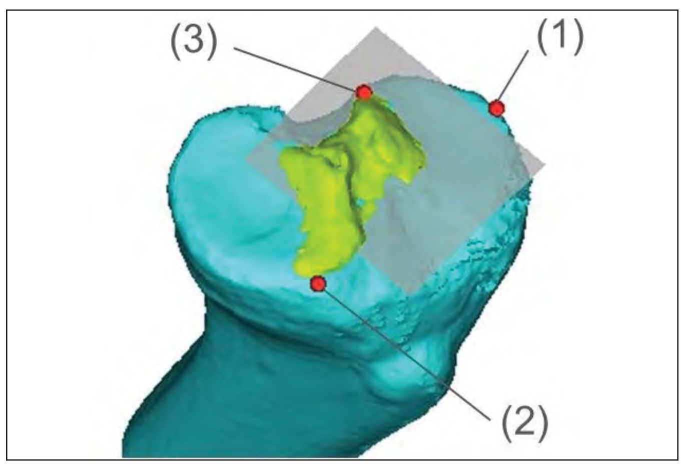


Figure 1. Tibial spine volume. The researchers measured whole tibial spine volume by creating a plane based upon three points: (1) the most convex point on the edge of the lateral tibial plateau, (2) the intersecting point of the medial tibial spine slope and the medial tibial plateau, and (3) the intersecting point of the posterior tibial spine slope and the lateral tibial plateau. Volume of bone tissue above the plane was determined as the tibial spine volume.

THE CURVATURE OF THE POSTERIOR FACET OF THE TALUS CORRELATES WITH SUBTALAR INVERSION-EVERSION RANGE OF MOTION DURING THE STANCE PHASE OF GAIT

Yamamoto T, Paulus P, Setliff JC, Hogan MV, Anderst W

Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.

INTRODUCTION

Subtalar instability is challenging to diagnose accurately due to limitations in clinical measures.[1] Recent advancements in high-resolution medical imaging and biplane fluoroscopy have made it possible to measure *in vivo* kinematics of the subtalar joint more precisely. However, there is a lack of *in vivo* data to confirm that kinematics are related to morphology under physiologic loading. Understanding this relationship between morphology and kinematics is crucial for identifying risks of subtalar instability, and this knowledge could also be applied to improve the design of total talus replacements.

Thus, the purpose of this study was to investigate the association between bony morphology and kinematics in the subtalar joint during walking. The authors' hypothesis was that bone shape would be associated with subtalar inversion-eversion and internal-external rotation range of motion (ROM) during the stance phase of gait.

METHODS

Twenty participants walked on a raised laboratory walkway while synchronized biplane radiographs were collected (100 frames per second, 1 ms pulse width), and ground reaction forces were recorded. Computed tomography scans of the distal tibia, talus, and calcaneus (0.68 x 0.68 x 1.25 mm) of each participant were segmented to create three-dimensional, subject-specific bone models with Mimics software (Materialise, Leuven, Belgium). Digitally reconstructed radiographs, created from the subject-specific segmented bone tissue, were matched to the biplane radiographs with submillimeter accuracy. Anatomical coordinate systems for each bone were defined independently for both ankles and hindfeet of each participant.[2] Joint kinematics were calculated and averaged over two walking trials for each foot, and subtalar joint ROM during the stance phase was determined. The bone shapes and modes of variation of the talus and calcaneus were characterized with ShapeWorks software (ShapeWorks, University of Utah). Principal component analysis (PCA) was used to reduce the high-dimensional shape data to a smaller set of linearly uncorrelated components, or "modes." Pearson correlation was used to assess the relationship between subtalar range of motion and the PCA component score for each mode of shape variation in the talus and calcaneus.

RESULTS

A shallower posterior facet of the talus (mode 5) was associated with greater subtalar inversion-eversion ROM ($r = -0.42$, 95% confidence interval –0.65, –0.13], $p = 0.006$) (see Figure 1). No correlations were found between calcaneus morphology and subtalar joint range of motion.

DISCUSSION

The results suggests that a shallow posterior facet of the talus might contribute to greater inversion-eversion motion in the subtalar joint during the stance phase of gait. This link between bone morphology and kinematics suggests a potential mechanical origin for chronic ankle instability, as previous qualitative observations indicate that patients with chronic ankle instability tend to have flatter talar joint surfaces.[3] Additionally, posterior facet shape may be an important consideration in designing total talar replacements to replicate *in vivo* subtalar inversion-eversion.

REFERENCES

1. Rubin G et al. *Am J Orthop*. 1962;4:16-9.
2. Brown JA et al. *J Biomech*. 2020;109:1-17.
3. Tümer N et al. *J Orthop Res*. 2019;9:28-30.

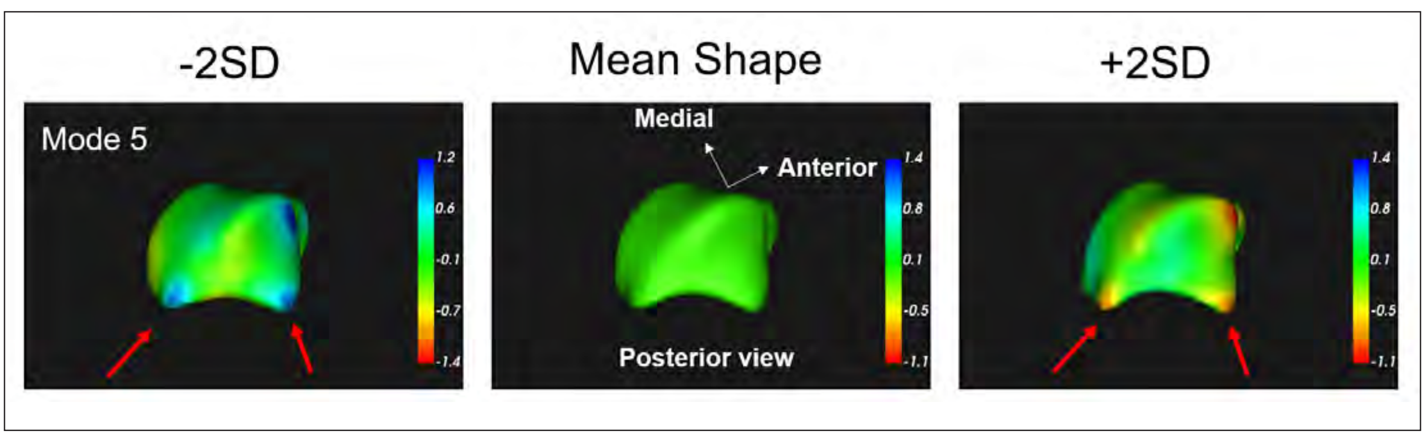


Figure 1. Talus principal component analysis mode 5 obtained from ShapeWorks. The fifth mode of variation was the curvature of the posterior facet, shown by the mean shape (middle) and shapes ± 2 standard deviations from the mean.

UPMC SPORTS MEDICINE CONCUSSION PROGRAM AND CONCUSSION RESEARCH LABORATORY

FACULTY
Micky Collins, PhD, clinical and executive director
Anthony P. Kontos, PhD, research director
Nathan Kegel, PhD, fellowship director
Alicia Trbovich, PhD, fellowship research coordinator
Vanessa C. Fazio Sumrok, PhD, staff neuropsychologist
Jonathan E. French, PsyD, staff neuropsychologist
Anne Mucha, DPT, director of vestibular therapy
Sarah Ostop, DPT, director of exertion therapy
Victoria Kochick, DPT, physical therapist
Raymond Pan, MD, psychiatrist

FELLOWS AND STUDENTS
Aaron Zynda, PhD, research postdoctoral fellow (2023–2025)
Ted Albrecht, PsyD, neuropsychology fellow (2021–2023)
Dean Gomes, PhD, neuropsychology fellow (2021–2023)
Bindal Mehmel, PhD, neuropsychology fellow (2021–2023)
Chris Burley, PhD, neuropsychology fellow (2022–2024)
Shan Patel, PsyD, neuropsychology fellow (2022–2024)
Heather Guercio, PsyD, neuropsychology fellow (2023–2025)
Nacona Bunker, PsyD, neuropsychology fellow (2023–2025)
Nathan Ramirez, PsyD, neuropsychology fellow (2023–2025)

RESEARCH STAFF
Cyndi Holland, MPH, research lab coordinator
Hannah Bitzer, MPH, research coordinator (UPMC Concussion Network–Ireland)
Courtney Perry, MS, project coordinator
Marisa Hirsh, BS, project coordinator
Aidan Reed, BS, research assistant
Katelyn Walzer, BS, research assistant
Maddie Todd, BS, research assistant
Maggie Miller, BS, research assistant

ADMINISTRATIVE STAFF
Amber Kramer, practice manager

OVERVIEW
The UPMC Sports Medicine Concussion Program, directed by Micky Collins, PhD, is the top concussion clinical and research program in the United States. Our research program and Concussion Research Laboratory (CRL) in the Department of Orthopaedic Surgery at the University of Pittsburgh (Pitt), directed by Anthony Kontos, PhD, continues to be at the forefront of clinical concussion research. The CRL includes eight research staff who oversee 15 funded research studies. The clinical program includes 25+ faculty and staff at seven sites in the Pittsburgh area, with about 20,000 patient visits annually. Our team continues to advance concussion care using an evidence-based, clinical profile approach.

YEAR IN REVIEW
This was a productive year for our program. Our faculty continue to lead the field of sport-related concussion, with Drs. Kontos and Collins the first- and fourth-ranked researchers in the field (Tang et al., *World Neurosurgery*, 2022). Since 2020, we have averaged 38 publications and 2,000 citations annually, or a publication every 10 days and 5+ citations per day. In 2023, we were involved in 15 externally funded research projects and our faculty and fellows published numerous high-impact papers in the field. We grew our UPMC Concussion Network in Ireland and received multiple awards for research. We also hosted nationally renowned speakers for our Concussion Grand Rounds Series, including Allen Sills, MD, medical director of the National Football League.

RESEARCH GRANTS
Our research is funded by the Centers for Disease Control and Prevention, National Institutes of Health, Department of Defense, National Football League, and Chuck Noll Foundation. In 2023, we enrolled 500+ subjects in our studies, including clinical trials examining the effectiveness of early prescribed activity, vestibular rehabilitation, as well as multidomain and pharmacological treatments.

PUBLICATIONS
Our publications appeared in high-impact journals, including *Sports Medicine* (11.93), *American Journal of Sports Medicine* (6.1), and *Journal of Neurotrauma* (5.3). Below are several impactful papers from 2023:

- “Changes in the Retina Following Concussion” (Albrecht et al., *J Neurotrauma*, 2023)
- “Using Network Analysis to Understand Concussion Symptoms (Preszler et al., *Neuropsych Child*, 2023)
- “Dynamic Exertion Test (EXiT): a more effective assessment for concussion” (Sinnott et al., *J Sci Med Sport*, 2023)

FACULTY/TRAINEE RECOGNITION AND AWARDS
In 2023, Drs. Collins and Kontos delivered lectures highlighting their clinical profile model and research at the 14th World Congress on Brain Injury in Dublin, Ireland. Dr. Kontos was an invited presenter on the effects of soccer heading at the 2023 U.S. Soccer/Major League Soccer/National Women’s Soccer League’s Head Injury Summit II in Chicago, Illinois. Dr. Kontos received the 2023 Distinguished Scientific and Research Contributions to Sport, Exercise, and Performance Psychology Award from the American Psychological Association and was recognized as a fellow in the American College of Sports Medicine. Clinical neuropsychology fellow Shan Patel, PsyD, was awarded the Sports Neuropsychology Society’s Outstanding Trainee Abstract Award for his research comparing sport-related concussion to other types of concussion. Our research on fixational eye movements following concussion was awarded Best Clinical Abstract by the American College of Sports Medicine, and one of our undergraduate mentees, Akimanzi Siibo, and his advisor, Alicia Trbovich, PhD, were awarded Best Poster for their presentation on sex differences in vestibular treatment following concussion at the 2023 University of Pittsburgh Department of Orthopaedic Surgery’s Research Retreat.

CONCUSSION RESEARCH AND CLINICAL OUTREACH IN IRELAND

This was a banner year in our research collaboration and clinical concussion outreach with our UPMC Concussion Network in Ireland. We expanded clinical training efforts in Ireland via weekly virtual case conferences and in-residence training for Irish clinicians in Pittsburgh. We coauthored three papers with collaborators in Ireland, including two studies on concussion in Ladies Gaelic Football Association players. We also cultivated key research partnerships with the Gaelic Athletic Association, Irish Rugby Football Union, Irish Horse Racing Board, Dublin City University, and University of Limerick. In fact, the University of Limerick partnership resulted in a new joint PhD scholar to research concussion using the Irish Rugby Injury Surveillance Program.

ACKNOWLEDGMENT

We would like to thank Art and Greta Rooney and the Pittsburgh Steelers for their generous support of our clinical research programs and staff at the Concussion Research Laboratory. In addition, Ryan Blaney and the Ryan Blaney Family Foundation and NASCAR generously provided support for multiple fellow positions. Thanks also to Dr. Joe Konefal and Mrs. Karen Konefal for their generous support of research on concussions in older adults, as well as Sarah Polley and Jennifer Paisley.

Allen Sills, MD, the National Football League's medical director, presented at the 2023 Concussion Grand Rounds Series.

More than 500 subjects were enrolled in clinical and observation trials in 2023.

Concussion faculty presented numerous invited lectures in 2023.

Our faculty and trainees received several research awards during the past year.

CONCUSSION CLINICAL OUTCOMES AND RECOVERY TIME IN INDIVIDUALS WITH PRE-EXISTING ANXIETY AND/OR DEPRESSION

Anish EJ, Zynda AJ, Giordano EG, Todd MG, Miller M, Collins MW, Kontos AP

University of Pittsburgh, Pittsburgh, Pa.

INTRODUCTION

Anxiety and mood difficulties are common symptoms following concussion.[1] Research has established that post-concussion anxiety and depression are associated with prolonged recovery when not appropriately addressed.[2] However, limited research has explored the impact of anxiety and/or depression history on individuals' clinical outcomes and recovery time post-concussion. The purpose of this study was to determine the influence of anxiety or depression history on individuals' clinical outcomes, as well as examine outcomes of those with both anxiety and depression history. The authors hypothesized that individuals with either anxiety or depression history would have worse clinical outcomes (e.g., higher symptom burden and more time to clearance) than individuals without anxiety or depression history. Furthermore, the authors expected that those with both anxiety and depression would have worse outcomes than those with no mental health history and those with either anxiety or depression history.

METHODS

The researchers conducted a retrospective review of 297 patients aged 9–68 years who presented to a specialty concussion clinic within three months of injury. Participants were excluded if they reported moderate to severe traumatic brain injury, neurological disorder, major psychiatric disorder (e.g., schizophrenia), treatment for substance abuse, additional concussion in prior three months, or a history of three or more concussions. All participants completed a clinical interview, Immediate Post-Concussion Assessment and Cognitive Test (ImPACT), Clinical Profile Screen (CP-Screen), and Vestibular/Ocular-Motor Screening. Participants were categorized into one of three anxiety-depression subgroups—no anxiety or depression history (NONE), anxiety or depression history (EITHER), or anxiety and depression history (BOTH)—based on clinical interviews. The EITHER group also included individuals with a family history of anxiety or depression who had not yet been diagnosed themselves. Recovery time was defined as the number of days from injury to medical clearance. Chi-square tests examined group differences in categorical data, and one-way analyses of variance with Tukey's post-hoc tests examined differences in continuous data. Statistical significance was set at $p < 0.05$.

RESULTS

The final sample included 297 participants (mean age = 16.6 ± 6.63 years, 59.3% male), 188 (63.3%) in the NONE group, 86 (29.0%) in the EITHER group, and 23 (7.7%) in the BOTH group. A greater proportion of the BOTH group was injured during falls or accidents ($p = 0.01$), reported a history of attention-deficit/hyperactivity disorder or learning disorder ($p = 0.001$), and was assigned the anxiety/mood profile ($p = 0.007$) compared to the other groups. Regarding clinical outcomes, the BOTH group reported higher symptom burden (CP-Screen total score; $p < 0.001$) and performed worse on ImPACT Visual Memory ($p = 0.03$) compared to the NONE and EITHER groups. Overall, recovery time differed significantly among groups, $F(2,294) = 5.2$, $p = 0.006$, $\eta^2 = 0.03$. Tukey's post-hoc test revealed that the NONE group recovered significantly faster than the EITHER group (31.8 ± 29.0 days versus 43.8 ± 50.1 days, $p = 0.04$) and the BOTH group (31.8 ± 29.0 days versus 52.6 ± 44.0 days, $p = 0.03$). However, no significant differences in recovery time were noted between the EITHER and the BOTH groups (43.8 ± 50.1 days versus 52.6 ± 44.0 days, $p = 0.58$).

DISCUSSION

Our results suggest that anxiety and depression history are associated with more severe post-concussion symptoms, worse visual memory, and longer recovery times when compared to those with no history of anxiety or depression. Although recovery time was not significantly different between those with anxiety or depression history and those with comorbid anxiety and depression history, this finding could be the result of unequal sample sizes in each group. Overall, these results support prior research, which suggests that pre-existing psychological factors impact post-concussion recovery.[3] The findings highlight the importance of screening for anxiety/depression history in clinical settings and exploring ways to improve concussion recovery for individuals with anxiety and/or depression history.

REFERENCES

1. Kontos AP et al. *Br J Sports Med*. 2016;50(3):139-40.
2. D'Alonzo BA et al. *Am J Sports Med. 2022*;50(8):2258-70.
3. Putukian M et al. *Br J Sports Med*. 2023;57(12):798-809.

PREDICTORS OF BORDERLINE BASELINE NEUROCOGNITIVE SCORES IN GAELIC ATHLETES

Bitzer HB[1], Zynda AJ[1], O'Connor S[2], Windle J[3], O'Neill D[3], Collins MW1, Kontos AP[1]

[1]University of Pittsburgh, Pittsburgh, Pa.
[2]Dublin City University, Dublin, Ireland
[3]UPMC Sports Medicine in Ireland

INTRODUCTION

Baseline neurocognitive testing is a significant component of multidomain concussion assessment, as it provides clinicians with a measurement of an athlete's baseline cognitive function and can be utilized to identify impairments following a concussion. Common concussion neurocognitive tests, such as the Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT), have established score ranges that indicate where an athlete's performance lies in reference to a normative sample. Borderline scores, specifically performance within the third to eighth percentile, indicate that an athlete's performance is below expectations. Understanding which athletes have borderline ImPACT performance and risk factors (e.g., learning disability) that may predispose them to a score within this range is important for interpretation post-concussion. Although predictors related to borderline baseline ImPACT performance have been established in American amateur and professional athletes,[1-3] there is a lack of evidence examining relationships in male and female Gaelic games, including Gaelic football, hurling, and camogie. Therefore, this study examined predictors of borderline ImPACT scores in Gaelic games athletes.

METHODS

A retrospective review was conducted on baseline ImPACT tests administered between 2022 and 2023 to intercounty Gaelic games teams ($\geq$18 years old). ImPACT collects self-reported demographic information, symptoms, and four composite scores of cognitive functioning: verbal memory, visual memory, visual motor speed, and reaction time. Tests were administered onsite to full squads or remotely to individual players. Descriptive statistics were calculated, including means ± standard deviations and medians (interquartile range) for continuous data and n (%) for categorical data. Univariate logistic regressions (LRs) were used to inform follow-up multivariable stepwise LRs to identify the best predictors of borderline composite scores. Statistical significance was set a priori at $p < 0.05$.

RESULTS

A total of 1,171 baseline ImPACT tests were valid and included in analyses. The overall sample had a mean age of 23.8 ± 4.0 years and was 62.2% male, with most athletes playing men's Gaelic football (33.2%), followed by hurling (28.7%), ladies' Gaelic football (27.1%), and camogie (11.0%). Statistically significant multivariable stepwise LR models were observed for each ImPACT composite score ($p < 0.05$) for borderline scores. Variables retained in each model are presented in Table 1. Onsite testing location (odds ratio [OR] = 9.6, 95% confidence interval [CI] =1.3–73.0, p = 0.03), goalkeepers (OR = 4.1, 95% CI = 1.7–9.9, p = 0.002), and treatment for headaches (OR = 3.0, 95% CI = 1.18–7.7, p = 0.021) were significant predictors on verbal memory. A baseline symptom severity score > 20 (OR = 3.1, 95% CI = 1.4–7.2, p = 0.008) was the only significant predictor on visual memory. Onsite testing location (OR = 4.3, 95% CI = 1.3–14.3, p = 0.02), female sex (OR = 0.32, 95% CI = 0.15–0.7, p = 0.004), and diagnosed dyslexia (OR = 3.9, 95% CI = 1.1–14.2, p = 0.04) were significant predictors on visual motor speed. Lastly, although insignificant by itself, years of education (OR = 1.2, 95% CI = 0.98–1.4, p = 0.09) was the most significant predictor of reaction time.

DISCUSSION

Multivariate stepwise LR models with significant predictors were observed across three ImPACT composite scores. Diagnosed dyslexia as a significant predictor for borderline visual motor speed scores is consistent with existing literature, whereas poor performance by females is in contrast to previous work.[1] The results demonstrated that onsite testing location was a significant predictor for borderline composite scores for verbal memory and visual motor speed scores. With the emergence of remote options for medical care, future research should further examine the role of testing environment on neuropsychological testing used for concussion. Clinicians should consider these factors when interpreting ImPACT performance at baseline for intercounty Gaelic games players.

REFERENCES

1. Cottle JE et al. *J Athl Train*. 2017;52(2):77-81.
2. Guty ET et al. *Transl Issues Psychol Sci*. 2023;9(1):41-50.
3. Katz BP et al. *Sports Med*. 2018;48(8):1971-85.

	Variable	*p*	OR	95% CI
Verbal memory	Treatment for headaches	**0.021**	3.009	1.179–7.678
	Plays in goalkeeper position	**0.002**	4.057	1.6710–9.858
	Onsite location	**0.028**	9.673	1.282–72.993
	Diagnosed learning disability	0.051	3.499	0.992–12.342
Visual memory	> 20 total symptom score	**0.008**	3.119	1.351–7.200
	Number of concussions	0.284	1.185	0.868–1.618
	Plays men's Gaelic football	0.144	0.479	0.178–1.285
	Plays midfield	0.126	1.885	0.837–4.244
Visual motor speed	Onsite location	**0.019**	4.272	1.272–14.341
	Diagnosed dyslexia	**0.041**	3.872	1.057–14.192
	Female sex	**0.004**	0.317	0.146–0.688
	Diagnosed learning disability	0.401	1.963	0.407–9.468
	Strenuous activity	0.278	1.827	0.614–5.434
	Meningitis treatment	0.134	8.581	0.516–142.698
	> 20 total symptom score	0.216	1.875	0.692–5.078
Reaction time	Years of education	0.090	1.151	0.978–1.353
	Plays in forward position	0.113	0.510	0.221–1.174

Significant ($p < 0.05$) individual predictors retained in the model are bolded.
OR = odds ratio, CI = confidence interval

Table 1. Predictors of Borderline ImPACT Scores in Gaelic Athletes

FACTORS ASSOCIATED WITH BASELINE NEUROCOGNITIVE PERFORMANCE IN PROFESSIONAL IRISH RUGBY PLAYERS

Bitzer HB[1], Purtill H[2], Zynda AJ[1], van Dyk N[3], Liston M[3], Yeomans C[3], Collins MW[1], Kontos AP[1], McLoughlin R[3], Mulvihill J[2]

[1]University of Pittsburgh, Pittsburgh, Pa.
[2]University of Limerick, Ireland
[3]Irish Rugby Football Union, Ireland

INTRODUCTION
Baseline neurocognitive testing is a crucial component of multidomain concussion assessment, as it enables clinicians to identify cognitive impairments after concussion relative to an athlete's baseline. It is imperative to understand how pre-existing factors, such as a history of attention-deficit/hyperactivity disorder (ADHD), affect baseline neurocognitive testing. Extant evidence has demonstrated that sex, headaches/migraines, mental health disorders, concussion history, learning disability (LD), and ADHD influence performance at baseline on neurocognitive tests,[1] such as the Immediate Post-Concussion Assessment and Cognitive Test (ImPACT). Although factors related to baseline ImPACT performance have been established in American athletes,[1] there is limited research examining these factors in male and female professional rugby, a sport with high concussion rates.[2] Therefore, this study examined factors associated with ImPACT baseline performance in professional Irish rugby players.

METHODS
The authors conducted a retrospective review on initial baseline ImPACT tests administered between 2007 and 2022 to senior and academy Irish Rugby Football Union squads (≥ 18 years old), including players involved in international and European competitions. ImPACT collects self-reported demographic information, symptoms, and four composite scores of cognitive functioning: verbal memory, visual memory, visual motor speed, and reaction time. Descriptive statistics were calculated as medians (interquartile range [IQR]) for continuous data and number (%) for categorical data. Differences in factors between sexes were tested with chi-square tests and univariate quantile regression. Associations between factors and ImPACT composite scores were modeled with multivariate quantile regression.

RESULTS
Participants included 1,232 professional Irish rugby players, 1,100 males (median age = 20 years, IQR = 19,24) and 132 females (median age = 25 years, IQR = 21, 28). Male players were younger ($p \leq 0.001$), had fewer years of education (14 versus 16, $p \leq 0.001$), reported a lower total symptom score (one versus two symptoms, $p = 0.024$), and were more likely to report a previous concussion with retrograde amnesia ($p = 0.011$) compared to female players. Males had lower verbal memory scores ($p = 0.003$) than females, controlled for age. Analyses of medical and concussion history and associations with ImPACT composite scores are presented in Table 1. Almost half of players (49.5%) reported experiencing a previous concussion. Players reporting LD had lower verbal memory ($p = 0.036$) and visual motor speed ($p < 0.001$) scores compared to those without LD, controlled for age and sex. Those who reported having dyslexia had lower verbal memory ($p = 0.001$) and lower visual motor speed ($p < 0.001$) scores compared to those who did not, controlled for age and sex. No statistically significant differences in composite scores were found between the concussion groups.

DISCUSSION
Male sex, LD, and dyslexia were associated with lower baseline neurocognitive performance in professional Irish rugby players, which is consistent with previous literature in American athletes.[3,4] The study did not find an association between factors such as concussion history, headaches/migraines, mental health disorders, or ADHD and differences in ImPACT performance, which contrasts with previous research.[5,6] This could be due to the self-report of items on ImPACT and the low percentage of players reporting histories. Future research should examine these factors in a larger sample and the influence of testing environment. Clinicians should consider these pre-existing factors when interpreting ImPACT performance and developing concussion protocols for professional Irish rugby players.

REFERENCES
1. Cottle JE et al. *J Athl Train*. 2017;52(2):77-81.
2. Kirkwood G et al. *Br J Sports Med*. 2015;49.
3. Covassin T et al. *Neurosurgery*. 2007;61(2):345-50.
4. Zuckerman SL et al. *J Neurosurg Pediatr*. 2013;12(2):103-9.
5. Covassin T et al. *Clin J Sport Med*. 2012;22(2):98-104.
6. Solomon GS et al. *Arch Clin Neuropsychol*. 2008;23(5):563-77.

		n (%)	Verbal Memory (A)	Visual Memory (B)	Visual Motor Speed (C)	Reaction Time (D)	Significance of Difference in Group Medians*
Medical history							
Diagnosed with a learning difficulty	No	1,151 (93.3%)	86 (78, 93)	73 (64, 81)	36.8 (32.7, 41.1)	0.6 (0.56, 0.67)	A, C
	Yes	82 (6.7%)	82 (75, 88)	72 (56, 77)	32.7 (27.6, 37.4)	0.62 (0.58, 0.72)	
Diagnosed with attention-deficit/ hyperactivity disorder	No	1,219 (98.9%)	85 (78, 93)	73 (64, 81)	36.6 (32.2, 41)	0.6 (0.56, 0.67)	
	Yes	14 (1.1%)	85 (76, 93)	75 (69, 80)	38.1 (34.3, 39.8)	0.6 (0.55, 0.62)	
Diagnosed with dyslexia	No	674 (90.6%)	86 (78, 93)	74 (64, 81)	36.8 (32.8, 41)	0.61 (0.56, 0.67)	A, C
	Yes	70 (9.4%)	79 (72, 88)	73 (59, 79)	32.5 (28.6, 37.1)	0.61 (0.58, 0.7)	
Treatment for psychiatric conditions (anxiety, depression)	No	998 (98.4%)	85 (78, 93)	73.5 (64, 81)	36.6 (32.5, 41)	0.6 (0.6, 0.7)	
	Yes	16 (1.6%)	84 (77, 92)	74 (71.5, 78)	37.3 (32.1, 41.9)	0.6 (0.6, 0.8)	
Treatment for headaches or migraines	No	937 (92.1%)	85 (78, 93)	73 (64, 81)	36.6 (32.2, 41.1)	0.6 (0.55, 0.66)	
	Yes	80 (7.9%)	87 (78, 94)	74 (68, 82)	37 (33.9, 40.6)	0.6 (0.55, 0.66)	
Concussion history							
Previous number of concussions	None	517 (50.5%)	85 (78, 92)	73 (64, 81)	36.5 (32.5, 41.2)	0.6 (0.55, 0.66)	
	1-2	394 (38.5%)	85 (78, 93)	74 (63, 81)	36.5 (32.2, 40.8)	0.6 (0.55, 0.66)	
	3+	112 (10.9%)	86 (77, 94)	72 (64, 81)	36.6 (32.2, 40.8)	0.59 (0.55, 0.67)	
Previous loss of consciousness with concussion	None	815 (78.8%)	85 (78, 92)	73 (64, 81)	36.5 (32.3, 40.9)	0.6 (0.56, 0.67)	
	1-2	200 (19.3%)	87 (78, 93)	75 (65, 83)	37.3 (32.7, 41.7)	0.58 (0.54, 0.64)	
	3+	19 (1.8%)	85 (74, 91)	76 (63, 85)	33.9 (29.9, 37.6)	0.63 (0.55, 0.73)	
Previous confusion concussion	None	644 (62.3%)	85 (78, 93)	74 (65, 81)	36.5 (32.5, 41.1)	0.6 (0.55, 0.66)	
	1-2	342 (33.1%)	85 (78, 92)	72 (63, 81)	36.8 (32.3, 40.8)	0.59 (0.55, 0.66)	
	3+	48 (4.6%)	85 (77, 93)	73 (66, 83)	36.7 (32, 44.5)	0.6 (0.54, 0.66)	
Previous post-traumatic amnesia concussion	None	749 (72.4%)	85 (78, 93)	73 (64, 81)	36.3 (32.2, 41)	0.6 (0.56, 0.67)	
	1-2	253 (24.5%)	86 (78, 92)	74 (63, 82)	37.2 (32.7, 41.5)	0.59 (0.55, 0.66)	
	3+	32 (3.1%)	82 (74, 91)	72 (65, 80)	36.5 (32, 40.6)	0.58 (0.54, 0.66)	
Previous retrograde amnesia concussion	None	793 (76.7%)	85 (78, 93)	73 (64, 81)	36.5 (32.2, 40.9)	0.6 (0.56, 0.66)	
	1-2	214 (20.7%)	86 (79, 92)	74 (63, 83)	37.3 (32.5, 41.7)	0.59 (0.55, 0.65)	
	3+	27 (2.6%)	83 (74, 91)	74 (65, 82)	36.3 (32.8, 39.5)	0.58 (0.54, 0.69)	

*Quantile regression models assessed the statistical significance of differences in group medians controlling for age and sex at the 5% significance level.

Table 1. Baseline performance on ImPACT composite scores by medical and concussion history represented by number (%) or median (interquartile range)

THE ROLE OF FAMILY FUNCTIONING ON CONCUSSION RECOVERY IN ADOLESCENTS AND YOUNG ADULTS

Bunker N[1], Zynda AJ[2], Walzer K[2], Hirsh M[2], Guercio H[1], Burley C[1], Patel S[1], Ramirez N[1], Kegel N[1,2], Trbovich AM[1,2], Collins MW[1,2], Kontos AP[1,2]

[1]UPMC Sports Medicine Concussion Program, Pittsburgh, Pa.
[2]Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.

INTRODUCTION

Emerging evidence has suggested that psychosocial factors, including family functioning, play an important role in concussion recovery among adolescents and young adults. Research has demonstrated that parenting style is associated with clinical outcomes following concussion;[1] however, there is limited evidence examining the role of overall family functioning. Therefore, this study examined the role of overall family functioning in concussion recovery among adolescents and young adults. The authors hypothesized that participants with unhealthy family functioning would demonstrate prolonged recovery times compared to participants with healthy family functioning.

METHODS

A prospective cohort study assessed family functioning and concussion recovery in a university laboratory setting. Participants ages 14–30 years within five days of a diagnosed concussion were included. Participants provided demographics, medical history, injury characteristics, symptoms from the Sport Concussion Assessment Tool-5 (SCAT5), and information on family functioning from the General Functioning Scale of the Family Assessment Device (GF-FAD) at an initial and medical clearance visit. Participants were categorized into healthy (< 2) and unhealthy (≥ 2) family functioning groups based on GF-FAD composite score.[2] Chi-square tests compared categorical data, and Mann-Whitney U tests compared continuous data between groups. Quade's test examined differences in recovery outcomes between family functioning groups while controlling for significant covariates. Statistical significance was set at $p < 0.05$.

RESULTS

The study included 101 participants (52 female; age = 20.5 ± 2.5 years), with 63 (62.4%) in the healthy and 38 (37.6%) in the unhealthy family functioning group. A greater proportion of participants in the healthy group were White (72.6% versus 47.4%, $p = 0.01$), did not have a family history of anxiety/depression (82.3% versus 60.5%, $p = 0.02$), had a mother with a bachelor's degree or higher (75.4% versus 52.6%, $p = 0.04$), and had a father with a bachelor's degree or higher (60.0% versus 50.0%, $p = 0.04$). No other differences were noted at the initial visit between groups. When controlling for race, family history of anxiety/depression, mother's education, and father's education, both days to symptom resolution ($F(1, 87) = 4.7$, $p = 0.03$) and days to medical clearance ($F(1, 87) = 5.4$, $p = 0.02$) were significantly different between groups. The unhealthy group experienced significantly longer time to symptom resolution (12.5 days versus eight days, $p = 0.004$) and time to medical clearance (15 days versus 12 days, $p = 0.006$) than the healthy group.

DISCUSSION

Participants in the unhealthy family functioning group demonstrated significantly longer times to symptom resolution and medical clearance compared to those in the healthy family functioning group. These differences remained when the study controlled for sociodemographic factors (i.e., sex, age, race, family history of depression and anxiety, parental education level). Results highlight the importance of assessing sociodemographic factors and family functioning during the initial visit, as these factors may contribute to prolonged recovery. Future studies should examine how additional factors, including access to health care and adherence to treatment, moderate the relationship between family functioning and concussion recovery.

REFERENCES

1. Trbovich AM et al. *Child Psychiatry Hum Dev*. 2022;53(6):1231-9.
2. Epstein NB et al. *J of Marital Fam Ther*. 1983;9(2):171-80.

Variable	Healthy (n = 63)	Unhealthy (n = 38)	Odds Ratio	95% confidence interval	p value
Age (years)	21.0 (3.0)	20.0 (3.0)	-	-	0.33
Sex Female Male	36 (58.1%) 26 (41.9%)	16 (42.1%) 22 (57.9%)	1.90	0.84-4.31	0.12
Race American Indian/ Alaskan Native Asian Black White Other	0 (0%) 1 (1.6%) 15 (24.2%) 45 (72.6%) 1 (1.6%)	1 (2.6%) 3 (7.9%) 10 (26.3%) 18 (47.4%) 6 (15.8%)	-	-	**0.01**
Concussion history No Yes	31 (50%) 31 (50%)	14 (36.8%) 24 (63.2%)	1.71	0.75-3.92	0.20
Headache history No Yes	57 (91.9%) 5 (8.1%)	35 (92.1%) 3 (7.9%)	0.98	0.22-4.34	0.98
Attention-deficit/hyperactivity disorder history No Yes	53 (85.5%) 9 (14.5%)	31 (81.6%) 7 (18.4%)	1.33	0.45-3.93	0.61
Anxiety/depression history No Yes	50 (80.6%) 12 (19.4%)	27 (71.1.%) 11 (28.9%)	1.70	0.66-4.36	0.27
Family history of anxiety/depression No Yes	51 (82.3%) 11 (17.7%)	23 (60.5%) 15 (39.5%)	-	-	**0.02**
Parental marital status Single Married Divorced Separated Widowed Remarried Declined	4 (6.7%) 42 (70%) 8 (13.3%) 1 (1.7%) 1 (1.7%) 3 (5%) 1 (1.7%)	4 (10.5%) 18 (47.4%) 12 (31.6%) 1 (2.6%) 0 (0%) 1 (2.6%) 2 (5.3%)	-	-	0.22
Mother's educational history Middle school High school Some college Associate's degree Bachelor's degree Master's degree Doctoral degree	0 (0%) 7 (11.5%) 2 (3.3%) 6 (9.8%) 33 (54.1%) 11 (18%) 2 (3.3%)	2 (5.3%) 7 (18.4%) 7 (18.4%) 2 (5.3%) 16 (42.1%) 4 (10.5%) 0 (0%)	-	-	**0.04**
Father's educational history Middle school High school Some college Associate's degree Bachelor's degree Master's degree Doctoral degree Declined	0 (0%) 13 (21.7%) 1 (1.7%) 9 (15%) 27 (45%) 7 (11.7%) 2 (3.3%) 1 (1.7%)	2 (5.3%) 9 (23.7%) 6 (15.8%) 1 (2.6%) 12 (31.6%) 6 (15.8%) 1 (2.6%) 1 (2.6%)	-	-	**0.04**
Parental annual income < $10,000 $20,000–$29,999 $30,000–$39,999 $40,000–$49,999 $50,000–$59,999 $60,000–$69,999 $70,000–$79,999 $80,000–$89,999 $90,000–$99,999 $100,000–$149,999 > $150,000 Declined	0 (0%) 1 (1.6%) 1 (1.6%) 0 (0%) 1 (1.6%) 2 (3.3%) 2 (3.3%) 2 (3.3%) 5 (8.2%) 10 (16.4%) 21 (34.4%) 16 (26.2%)	2 (5.3%) 1 (2.6%) 2 (5.3%) 1 (2.6%) 1 (2.6%) 1 (2.6%) 4 (10.5%) 1 (2.6%) 2 (5.3%) 5 (13.2%) 10 (26.3%) 8 (21.1%)	-	-	0.59
Initial visit total number of symptoms	10.0 (11.0)	12.0 (8.0)	-	-	0.23
Initial visit symptom severity	16.0 (32.0)	24.0 (29.0)	-	-	0.18
Days to symptom resolution	8.0 (7.0)	12.5 (7.0)	-	-	**<0.01**
Days to medical clearance	12.0 (7.0)	15.0 (9.0)	-	-	**<0.01**

Continuous data are presented as median (interquartile range), and categorical data are presented as n (%). Significant p values (< 0.05) are bolded. Odds ratios and 95% confidence intervals were not calculated because of continuous data, more than two categories, or zero-count cells in one or more groups. Abbreviations: NA = not available

Table 1. Demographic, medical history, family characteristics, injury characteristics, and clinical outcomes of healthy and unhealthy family functioning groups following concussion

DIFFERENCES IN EXERCISE TOLERANCE AND AUTONOMIC FUNCTION BASED ON CONCUSSION CLINICAL PROFILE

Burley C[1], Zynda AJ[1], Kehinde, F[1], Trbovich A[1], Holland C[1], Womble M[2], Collins MW[1], Elbin RJ[3], Kontos AP[1]

[1]University of Pittsburgh, Pittsburgh, Pa.
[2]Inova Sports Medicine Concussion Program
[3]University of Arkansas

INTRODUCTION

Research supports clustering concussion symptoms into clinical profiles or subtypes (e.g., post-traumatic migraine, vestibular, anxiety/mood, oculomotor, cognitive).[1] Historically, exercise intolerance has been used to evaluate autonomic nervous system (ANS) dysfunction to determine physiological recovery from concussion;[2] however, limited research has studied exercise intolerance among established clinical profiles.[3] This study examined differences in clinical profiles, reasons for stopping the Buffalo Concussion Bike Test (BCBT), and ANS metrics between exercise tolerance groups determined by the BCBT. The authors hypothesized that the exercise-intolerant group would be more likely to have anxiety and/or vestibular profiles and that the exercise-intolerant group would have significantly elevated ANS metrics.

METHODS

Patients aged 18–49 years within eight days to six months of a diagnosed concussion completed demographic and medical history data, the Clinical Profile Screen, Brief Symptom Inventory-18, and BCBT within one week of initial clinic visit. Based on an established adjudication process,[4] participants were adjudicated into one or more clinical profiles (anxiety/mood, cognitive, migraine, ocular, vestibular, and sleep). Participants were classified as exercise tolerant if they achieved age-predicted max heart rate (HR), rated perceived exertion (RPE) $\geq$18 without exacerbation of symptoms, or successfully completed the BCBT.[2] Participants were classified as exercise intolerant if they reported an increase in symptoms $\geq$ 3 or could not meet the tolerance group's thresholds.[2] ANS function was evaluated by symptoms, HR, blood pressure, and RPE before and after BCBT. Independent-sample t-tests and chi-square tests were used to compare demographics, clinical profiles, reasons for stopping the BCBT, and ANS metrics between groups.

RESULTS

The study included 106 participants (mean age = 27.9 ± 8.1 years, 62.3% female), with 71 (67%) in the exercise-intolerant group and 35 (33%) in the exercise-tolerant group. The exercise-intolerant group had a significantly higher body mass index (27.5 versus 23.8 kg/m^2, p = 0.003, d = 0.6) than the exercise-tolerant group. No additional demographic or medical history differences were noted between groups. The exercise-intolerant group had significantly lower odds of having an adjudicated headache profile (odds ratio [OR] = 0.39, 95% confidence interval [CI] = 0.16–0.93, p = 0.03) and significantly greater odds of having an adjudicated autonomic profile (OR = 2.28, 95% CI = 1.01–5.21, p = 0.04). Although no other adjudicated profiles significantly differed between tolerance groups (see Figure 1), a greater proportion of those with the vestibular profile stopped the BCBT due to symptom exacerbation than those without (90.5% versus 9.5%, p = 0.04).

DISCUSSION

Adjudicated clinical profiles and ANS metrics were similar between exercise-tolerant and exercise-intolerant groups. The exercise-intolerant group demonstrated lower odds of having an adjudicated headache clinical profile, though this may have resulted from those with concomitant vestibular symptoms being adjudicated to the migraine profile. Notably, vestibular sensitivities have a considerable contribution to symptom provocation during the BCBT, as a significant proportion of participants with the vestibular profile discontinued the BCBT due to symptom exacerbation. These findings corroborate previous research and suggest that exercise intolerance is pervasive across all concussion clinical profiles, and exercise intolerance should be considered in all evaluations.[3] Future research should consider the influence of vestibular symptoms on exercise tolerance to improve treatment efficacy.

DISCLOSURE

This research was supported by a grant (W81XWH-20-1-0745) from the Department of Defense (DoD) Congressionally Directed Medical Research Program. Opinions, interpretations, conclusions, and recommendations are those of the authors and not necessarily endorsed by the DoD.

REFERENCES

1. Kontos AP et al. *Curr Sports Med Rep.* 2019;18(3):82-92.
2. Leddy JJ et al. *Curr Sports Med Rep.* 2013;12(6):370-6.
3. Antonellis P et al. *J Neurotrauma*. 2023. doi: 10.1089/neu.2023.0168.
4. Durfee KJ et al. *Mil Med*. 2023;188:354-62.

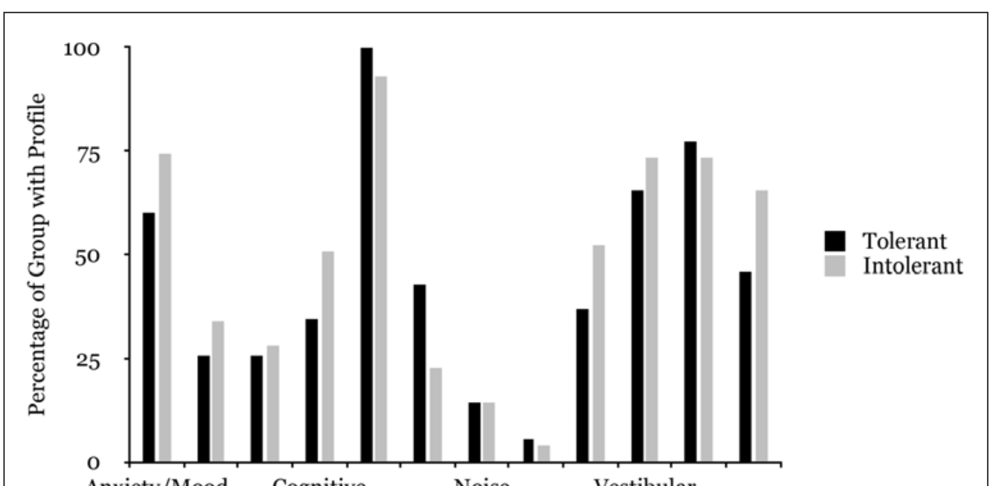


Figure 1. Percentage of the exercise-tolerant and exercise-intolerant groups adjudicated with each clinical profile.
† indicates the exercise-intolerant group had significantly lower odds of having an adjudicated headache profile (odds ratio = 0.39, 95% confidence interval = 0.16–0.93, p = 0.03).
‡ indicates the exercise-intolerant group had significantly greater odds of having an adjudicated autonomic profile (odds ratio = 2.28, 95% confidence interval = 1.01–5.21, p = 0.04).

PREDICTORS OF MORE SEVERE CERVICAL SYMPTOMS AND ASSOCIATION WITH CLINICAL OUTCOMES FOLLOWING CONCUSSION IN OLDER ADULTS

Giordano EG, Zynda AJ, Anish EJ, Todd MG, Reed AR, Collins MW, Kontos AP

University of Pittsburgh, Pittsburgh, Pa.

INTRODUCTION

Prior research has found that adolescents and adults presenting with cervical pain after concussion took an average of 10 days longer to be cleared than those without cervical symptoms.[1] However, research has yet to examine outcomes among older adults with post-injury cervical pain.[2] Although one study found that older adults experienced prolonged post-concussion symptoms compared to controls, no prior studies have focused on the role of cervical pain in persisting symtpoms.[3] Therefore, this study examined pre-injury risk factors for post-injury cervical pain as well as clinical outcomes associated with cervical pain following concussion. The authors hypothesized that more severe cervical symptoms would be associated with days to clinic, mechanism of injury, heightened anxiety/mood difficulties, and functional impairment compared to those with minimal cervical symptoms.

METHODS

This prospective cohort study included older adults ages 50 years or more with a diagnosed concussion in the previous 12 months who presented to an outpatient specialty concussion clinic. It excluded those with a neurological disorder, major psychiatric disorder (e.g., schizophrenia), cervical fracture, or moderate to severe traumatic brain injury. Participants provided demographics, medical history, and a multidomain clinical assessment comprising symptoms (Clinical Profile Screen [CP-Screen]), cognitive functioning (Immediate Post-Concussion Assessment and Cognitive Testing), psychological health (Patient Health Questionnaire-9, Generalized Anxiety Disorder-7), vestibular/ocular screening (Vestibular/Ocular-Motor Screening [VOMS], Functional Gait Assessment), and fear of falling (Falls Efficacy Scale). Participants were categorized into groups with “moderate-severe” (CP-Screen Cervical average ≥ 1.5) and “none-mild” (CP-Screen cervical average < 1.5) cervical symptoms.[1] Independent-sample t-tests and chi-square tests compared demographic, medical history, injury-related, and clinical outcomes between cervical groups. Statistical significance was set a priori at $p < 0.05$.

RESULTS

A total of 70 participants (mean age = 59.4 ± 6.2 years, 55.7% female) were included in the study. Fifty-seven (81.4%) participants reported neck pain or stiffness, 44 (62.9%) reported difficulty moving their necks, and 59 (84.3%) reported either symptom on the CP-Screen. Thirty-seven (52.9%) participants were in the moderate-severe group, and 33 (47.1%) were in the none-mild group. The moderate-severe group presented to the clinic later (44.5 versus 27.9 days, $p = 0.04$), reported more depression (11.5 versus 7.6, $p = 0.002$) and anxiety symptoms (8.8 versus 4.6, $p < 0.001$), and had a greater proportion without family migraine history (81.1% versus 57.6%, $p = 0.03$). Mechanism of injury was not significantly different between groups. The moderate-severe group reported higher symptoms on ocular VOMS items (40.2 versus 27.0, $p = 0.04$) as well as higher VOMS Total (76.8 versus 54.0, $p = 0.04$). The moderate-severe group also demonstrated worse performance in cognitive domains, including verbal memory (66.6 versus 76.2, $p = 0.03$), visual memory (46.6 versus 60.1, $p < 0.001$), visual motor speed (24.5 versus 30.1, $p = 0.005$), and reaction time (1.03 versus 0.85, $p = 0.002$).

DISCUSSION

Findings indicate that older adults with more severe cervical symptoms reported higher levels of anxiety and mood symptoms, reported more symptoms during VOMS, and performed worse across all domains on computerized neurocognitive testing. Prior research has identified a bidirectional relationship between anxiety/mood difficulties and cervical pain,[4] and anxiety and mood difficulties can also have a considerable influence on objective cognitive test performance.[5] Similarly, recent research has identified post-concussion anxiety as a risk factor for higher symptom burden on the VOMS.[6] These results highlight the importance of a multidomain evaluation following concussion to examine the interrelationship among cervical pain, anxiety/mood difficulties, and cognitive functioning in order to develop an appropriate treatment plan to address root causes of reported symptoms. Future research should examine the influence of covariates such as time to clinic, psychiatric history, and post-injury psychological functioning on cervical pain to develop targeted treatment plans after injury.

REFERENCES

1. Oyekan AA et al. *J Head Trauma Rehabil*. 2023;38(6):417-24.
2. Gardner RC et al. *J Neurotrauma*. 2018;35(7):889-906.
3. Sherry NS et al. *Appl Neuropsychol Adult*. 2023:1-8.
4. Elbinoune I et al. *Pan Afr Med J*. 2016;24(89).
5. Spalding DM et al. *Front Psychol*. 2021;747839.
6. Preszler J et al. *Appl Neuropsychol Child*. 2023;12(4):294-303.

IMPACT OF PRE-EXISTING ATTENTION-DEFICIT/HYPERACTIVITY DISORDER ON VESTIBULAR/OCULAR MOTOR OUTCOMES FOLLOWING CONCUSSION

Guercio H[1], Zynda AJ[2], Todd M[2], Bunker N[1], Burley C[1], Patel S[1], Ramirez N[1], Fazio V[1] Kegel N[1], Collins MW[1], Kontos AP[1,2]

[1]UPMC Sports Medicine Concussion Program, Pittsburgh, Pa.
[2]Department or Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.

INTRODUCTION

Medical consensus has identified attention-deficit/hyperactivity disorder (ADHD) as an important pre-existing health condition to consider in concussion management.[1] Prior research indicates that patients with pre-existing learning disorders (LDs) and ADHD report greater overall symptom burden and perform worse on cognitive testing following concussion.[2,3] In addition, previous research indicates that pediatric patients with a history of ADHD have higher rates of abnormal Vestibular/Ocular Motor Screening (VOMS) performance at baseline.[4,5] However, no prior research has examined the influence of ADHD history on post-injury VOMS outcomes. As such, the purpose of this study was to examine differences in post-injury VOMS outcomes in athletes with and without pre-existing ADHD. The authors hypothesized that individuals with pre-injury ADHD would demonstrate greater near point convergence (NPC) distance as well as increased headache and dizziness on the VOMS.

METHODS

This prospective cohort study included patients aged 11–29 years who presented to a specialty concussion clinic within 30 days of a diagnosed concussion. Participants were excluded if they reported moderate to severe traumatic brain injury, a neurological disorder, major psychiatric disorder, or an additional concussion within the past six months. All participants provided demographics, medical history, and a multidomain clinical assessment comprising self-reported symptoms (Concussion Clinical Profile Screening) and vestibular/ocular screening (VOMS) at their initial visit. Participants were categorized into groups with and without pre-existing ADHD. Independent-sample t-tests and chi-square tests examined differences between groups in demographics, medical history, injury mechanism, symptom report, and VOMS outcomes. A follow-up analysis of covariance was performed to determine the influence of significant covariates on VOMS outcomes. Statistical significance was set a priori at $p < 0.05$.

RESULTS

The study included 189 participants (107 male, age = 15.9 ± 2.5 years), 160 (83.3%) without ADHD and 29 (15.1%) with pre-existing ADHD. A greater proportion of participants with ADHD were male (72.4% versus 52.5%, $p = 0.04$), were Black (17.2% versus 14.4%, $p = 0.02$), and had a history of anxiety (62.1% versus 23.1%, $p < 0.01$). No other group differences were noted in demographics, medical history, injury mechanism, or symptom report. Participants with pre-existing ADHD demonstrated significantly greater NPC average (5.29 versus 2.87, $p = 0.04$) and total dizziness (14.32 versus 9.54, $p = 0.03$). When controlling for sex, race, and history of anxiety, only VOMS dizziness total remained significantly different between groups ($F[1, 177] = 4.56$, $p = 0.03$).

DISCUSSION

Results indicate that patients with pre-existing ADHD report higher levels of dizziness during post-injury VOMS when compared to patients without ADHD history. Notably, group differences in NPC were attenuated when the study controlled for demographic information. In addition, patients with pre-existing ADHD were also more likely to present with a pre-injury anxiety diagnosis, though ADHD patients still reported higher dizziness when the study controlled for pre-injury anxiety. Findings reinforce the importance of a comprehensive evaluation and assist in the interpretation of post-injury vestibular screening for patients with ADHD. Future research should examine recovery trajectories, efficacy of targeted treatments, and influence of post-injury anxiety among individuals with ADHD in order to provide effective treatment recommendations.

REFERENCES

1. Giza CC et al. *Neurology*. 2013;80(24):2250-7.
2. Martin AK et al. *J Int Neuropsychol Soc*. 2022;28(2):109-22.
3. Zuckerman SL et al. *J Neurosurg Pediatr*. 2013;12(2):103-9.
4. Iverson GL et al. *Clin J Sport Med*. 2021;31(4):188-92.
5. Moran RN et al. *Appl Neuropsychol Child*. 2021;10(3):276-82.

Variable	No ADHD (n = 160)	ADHD (n = 29)	OR	95% CI	p Value
Demographics					
Age (years)	15.78 ± 2.33	16.74 ± 3.12	-	-	0.06
Sex Male Female	 84 (52.5%) 76 (47.5%)	 21 (72.4%) 8 (27.6%)	0.42	0.18-1.00	**0.04**
Race Black White Asian Indian Other	 23 (14.4%) 133 (83.1%) 3 (1.9%) 1 (0.6%) 0 (0.0%)	 5 (17.2%) 22 (75.9%) 0 (0.0%) 0 (0.0%) 2 (6.9%)	-	-	**0.02**
Medical History					
Concussion history No Yes	 103 (64.4%) 57 (35.6%)	 15 (51.7%) 14 (48.3%)	1.69	0.76–3.74	0.20
Migraine history No Yes	 129 (80.6%) 31 (19.4%)	 21 (75.0%) 8 (25.0%)	1.39	0.54–3.55	0.49
Motion sickness History No Yes	 123 (76.9%) 37 (23.1%)	 19 (67.9%) 9 (32.1%)	1.58	0.66–3.77	0.31
Depression history No Yes Unknown	 137 (85.6%) 22 (13.8%) 1 (0.6%)	 22 (78.6%) 6 (21.4%) 0 (0.0%)	-	-	0.53
Anxiety history No Yes	 123 (76.9%) 37 (23.1%)	 11 (37.9%) 18 (62.1%)	5.44	2.36–12.54	**<0.01**
Injury Mechanism					
Sport Fall Motor vehicle Accident Assault	149 (93.1%) 6 (3.8%) 3 (1.9%) 1 (0.6%) 1 (0.6%)	28 (96.6%) 1 (3.4%) 0 (0.0%) 0 (0.0%) 0 (0.0%)	-	-	0.92
Time to clinic	4.28 ± 1.82	4.25 ± 1.98	-	-	0.97
Clinical Outcomes					
VOMS baseline Total	5.07 ± 4.73	6.39 ± 6.06	-	-	0.19
VOMS Smooth Pursuits total	5.15 ± 4.81	6.79 ± 6.40	-	-	0.12
VOMS Horizontal Saccades total	5.46 ± 5.14	6.93 ± 6.57	-	-	0.18
VOMS Vertical Saccades total	5.62 ± 5.19	6.96 ± 6.53	-	-	0.23
VOMS NPC average	2.87 ± 5.19	5.29 ± 7.36	-	-	**0.04**
VOMS NPC total	5.45 ± 5.19	7.07 ± 6.61	-	-	0.15
VOMS Horizontal VOR total	6.78 ± 5.60	8.89 ± 7.10	-	-	0.08
VOMS Vertical VOR total	6.37 ± 5.58	8.43 ± 7.15	-	-	0.09
VOMS VMS total	8.09 ± 6.20	9.43 ± 7.54	-	-	0.31
VOMS Headache total	22.18 ± 16.32	24.64 ± 19.83	-	-	0.48
VOMS Dizziness total	9.54 ± 11.40	14.32 ± 17.44	-	-	**0.03**
VOMS Nausea total	4.27 ± 10.88	6.61 ± 13.28	-	-	0.32
VOMS Fogginess total	5.93 ± 11.11	8.93 ± 15.94	-	-	0.22
VOMS total	41.92 ± 36.19	54.50 ± 47.13	-	-	0.11

Continuous data are presented as mean ± standard deviation, and categorical data are presented as n (%). Significant p values (< 0.05) are bolded. OR and 95% CI were not calculated because of continuous data, more than two categories, or zero-count cells in one or more groups.

ADHD = attention-deficit/hyperactivity disorder, CP-Screen = Clinical Profile Screen, NPC = near point convergence, OR = odds ratio, VMS = visual motion sensitivity, VOMS = Vestibular/Ocular Motor Screen, VOR = vestibulo-ocular reflex, CI = confidence interval

Table 1. Demographic, medical history, injury characteristics, and clinical outcomes of no ADHD and ADHD groups following concussion

PREDICTORS OF POST-CONCUSSION ANXIETY IN PATIENTS WITHOUT PRE-EXISTING ANXIETY HISTORY

Patel S[1], Zynda AJ[2], Miller M[2], Burley C[1], French J[1], Ramirez N[1], Guercio H[1], Kegel N[1], Bunker N[1], Collins MW[1], Kontos AP[1, 2]

[1] UPMC Sports Medicine Concussion Program, Pittsburgh, Pa.
[2] Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.

INTRODUCTION

Concussion research has established that pre-existing anxiety history may heighten the vulnerability of individuals to post-concussion anxiety symptoms.[1] However, there is limited evidence examining factors associated with post-concussion anxiety in individuals without a pre-existing anxiety disorder. The purpose of this study was to examine predictors, including demographics, medical history, and injury-related characteristics of post-concussion anxiety of patients in this population. The authors hypothesized that age, female sex, non-sport-related concussion (non-SRC), and time to clinic would be associated with post-concussion anxiety.[1-3] By identifying factors contributing to anxiety in individuals without pre-existing anxiety, the researchers hope to broaden understanding of the intricate relationship between concussion and psychological well-being, ultimately contributing to effective interventions for patients facing these challenges.

METHODS

This was a retrospective study of patients aged 9–68 who presented to a specialty concussion clinic within three months of injury. Exclusion criteria included pre-existing anxiety diagnosis, prior brain surgery, moderate to severe traumatic brain injury, a neurological disorder, major psychiatric disorder, treatment for substance abuse, current pregnancy, an additional concussion within the past three months, or a history of three or more concussions. All participants completed a clinical interview and Concussion Clinical Profile Screen (CP-Screen). Post-concussion anxiety group (yes/no) was determined by a positive anxiety/mood clinical profile and symptoms reported on the CP-Screen anxiety subdomain. Independent-sample t-tests and chi-square tests examined differences in demographics, medical history, and injury characteristics between groups. Univariate logistic regressions (LRs) were used to inform a follow-up forward stepwise LR to identify the best predictors of post-concussion anxiety group. Receiver operating characteristic (ROC) analysis of the area under the curve (AUC) was used to identify which predictors retained from the LR model best discriminated anxiety status. Statistical significance was set a priori at $p < 0.05$.

RESULTS

The final sample included 264 participants (mean age = 16.5 ± 7.2, 65.2% male), 215 (79.3%) without post-concussion anxiety and 49 (18.1%) with post-concussion anxiety. Descriptive statistics of each group are reported in Table 1. Results of the forward stepwise LR to identify post-concussion anxiety were significant ($p < 0.001$) and accounted for 19% of the variance. The model accurately classified 82.2% of patients, with non-SRC (odds ratio [OR] = 2.94; 95% confidence interval [CI], 1.45–1.5.98; $p = 0.003$), history of ADHD/learning disability (LD) (OR = 2.85; 95% CI, 1.21–6.71; $p = 0.02$), positive vestibular profile (OR = 2.14; 95% CI, 1.06–4.33; $p = 0.03$), and days to first clinic visit (OR = 1.01; 95% CI, 1.01–1.015; $p = 0.003$) as significant predictors. An ROC analysis of the AUC of this four-factor model discriminated post-concussion anxiety from no anxiety (AUC, 0.77; 95% CI, 0.71–0.85; $p < 0.001$).

DISCUSSION

This study highlights predictors of post-concussion anxiety in individuals without pre-existing anxiety history. Significant associations with non-SRC, history of ADHD/LD, positive vestibular profile, and delayed clinic visit were noted. These findings suggest that circumstances of injury, vestibular dysfunction, and pre-existing cognitive vulnerabilities may exacerbate post-concussion anxiety in this population. By recognizing these predictors, clinicians can tailor interventions to address specific risk factors, ultimately optimizing recovery outcomes. Further research is warranted to clarify underlying mechanisms and refine targeted interventions for individuals presenting with post-concussion anxiety.

REFERENCES

1. Sandel N et al. *Sport Exerc Perform Psychol*. 2017;6(3):304-23.
2. Gillie BL et al. *Appl Neuropsychol Child*. 2022;11(3):253-9.
3. Guerriero RM et al. *J Child Neurol*. 2018;33(2):168-73.

Variable	No Anxiety (n = 215)	Anxiety (n = 49)	OR	95% CI	p Value
Age (years)	15.78 (6.27)	20.14 (9.78)	-	-	**<0.01**
Sex Male Female	 139 (64.7%) 76 (35.3%)	 33 (67.3%) 16 (32.7%)	0.89	0.46–1.72	0.72
Migraine history No Yes	 178 (82.8%) 37 (17.2%)	 44 (89.8%) 5 (10.2%)	0.55	0.20–1.47	0.23
Learning disorder/ADHD No Yes	 192 (90.1%) 21 (9.9%)	 38 (77.6%) 11 (22.4%)	2.65	1.18–5.94	**0.02**
Depression history No Yes	 210 (99.1%) 2 (0.9%)	 45 (93.8%) 3 (6.3%)	7.00	1.14–43.11	**0.02**
Motion sickness history No Yes	 170 (79.4%) 44 (20.6%)	 38 (82.6%) 8 (17.4%)	0.81	0.35–1.87	0.63
Ocular disorder history No Yes	 200 (93.0%) 15 (7.0%)	 44 (89.8%) 5 (10.2%)	1.52	0.52–4.39	0.44
Concussion history No Yes	 152 (70.7%) 63 (29.3%)	 26 (53.1%) 23 (46.9%)	2.13	1.13–4.02	**0.02**
Days since injury	11.23 (36.33)	42.84 (88.68)	-	-	**0.02**
Mechanism Sport Non-Sport	 178 (82.8%) 37 (17.2%)	 28 (57.1%) 21 (42.9%)	3.61	1.85–7.03	**<0.01**
Loss of consciousness No Yes Unknown	 193 (89.8%) 21 (9.8%) 1 (0.5%)	 39 (79.6%) 10 (20.4%) 0 (0.0%)	-	-	0.10
Post-traumatic amnesia No Yes Unknown	 174 (80.9%) 28 (13.0%) 13 (6.0%)	 37 (75.5%) 12 (24.5%) 0 (0.0%)	-	-	**0.04**
Vestibular profile No Yes	 117 (54.5%) 98 (45.6%)	 15 (30.6%) 34 (69.4%)	2.71	1.39–5.26	**<0.01**
Ocular profile No Yes	 152 (70.7%) 63 (29.3%)	 35 (71.4%) 14 (28.6%)	0.97	0.49–1.92	0.92
Post-traumatic migraine profile No Yes	 77 (35.8%) 138 (64.2%)	 27 (55.1%) 22 (44.9%)	0.46	0.24–0.85	**0.01**
Cognitive profile No Yes	 184 (85.6%) 31 (14.4%)	 40 (81.6%) 9 (18.4%)	1.34	0.59–3.02	0.49
CP-Screen total	17.97 (13.36)	29.71 (12.43)	-	-	**<0.01**

Continuous data are presented as mean (standard deviation), and categorical data are presented as n (%). Significant p values (< 0.05) are bolded. OR and 95% CI not reported are either due to continuous data, more than two categories, or zero-count cells in one or more groups.

ADHD = attention-deficit/hyperactivity disorder, CP-Screen = Clinical Profile Screen, OR = odds ratio, CI = confidence interval

Table 1. Demographic, medical history, injury characteristics, and clinical outcomes of patients with and without post-concussion anxiety following concussion

PREDICTORS OF CHANGES IN CLINICAL ASSESSMENT OUTCOMES IN OLDER ADULTS FOLLOWING CONCUSSION

Ramirez NR[1], Zynda AJ[2], Perry C[2], Burley C[1], Patel S[1], Guercio H[1], Bunker N[1], Collins MW[1], Kontos AP[1,2]

[1]UPMC Sports Medicine Concussion Program, Pittsburgh, Pa.
[2]Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.

INTRODUCTION

Concussion is widely recognized as a significant public health issue, specifically among older adults.[1] Older adults typically present in clinical settings with myriad risk factors for protracted recovery;[2] however, there is a paucity of research on clinical outcomes among older adults, as research has primarily focused on sport-related concussion in younger populations.[3] Therefore, the aim of this work was to examine clinical outcomes of older adults through a multidomain evaluation across clinic visits after concussion. The authors hypothesized that older adults would exhibit improvements in neuropsychological, mood, and physical functioning across time.

METHODS

This prospective cohort study included older adults ages 50 years or older who presented to an outpatient specialty concussion clinic within 12 months of a diagnosed concussion. Participants with a neurological disorder, major psychiatric disorder, or moderate to severe traumatic brain injury were excluded. Assessments comprised symptoms (Concussion Clinical Profile Screening [CP-Screen]), cognitive functioning (Repeatable Battery for Assessment of Neuropsychological Status [RBANS]), psychological health (Patient Health Questionnaire-9 [PHQ-9], Generalized Anxiety Disorder-7), vestibular/ocular screening (Vestibular/Ocular-Motor Screening [VOMS], Functional Gait Assessment [FGA]), and fear of falling (Falls Efficacy Scale [FES]) at initial and follow-up visits. Paired-sample t-tests were used to examine differences between initial and follow-up clinic visits. Linear and logistic regression were conducted to determine associations among demographics, medical history, injury mechanism, and functional predictors at initial and follow-up visits. Statistical significance was set at $p < 0.05$.

RESULTS

A total of 76 participants (55.3% females) aged 50–83 years (mean = 59.6 ± 6.3 years) were included in this study, with 51 (73.9%) completing a follow-up visit. Mean time between injury and initial clinic visit was 36.5 ± 34.3 days, and mean time between initial clinic visit and follow-up was 26.8 ± 14.0 days. Results supported significant change ($p < 0.05$) across visits on the following assessment outcomes: CP-Screen Sleep, RBANS Recall, RBANS Fluency, PHQ-9, all VOMS symptom provocation tests, FGA, and FES (see Table 1).

Greater fear of falling on FES ($F[2,42] = 5.48$, $p = 0.008$, Adj $R^2 = 0.2$, $B = -1.2$, $p = 0.02$) and motor vehicle mechanism of injury (odds ratio [OR] = 9.5, 95% confidence interval [CI] = 2.08–43.50, $p = 0.004$) were associated with worsening of the CP Total score. Anxiety history was associated with worsening of VOMS Total Score (OR = 12.9, 95% CI = 1.71–97.94, $p = 0.01$), whereas loss of consciousness was associated with a decrease in ambulation on FGA ($F[3,37] = 5.00$, $p = 0.005$, Adj $R^2 = 0.23$, $B = 4.37$, $p = 0.04$). Males were associated with greater improvement in RBANS Fluency ($F[2,44] = 8.45$, $p < 0.001$, Adj $R^2 = 0.25$, $B = -3.50$, $p = 0.02$), whereas family depression history was associated with worsening RBANS Fluency ($B = 5.56$, $p = 0.005$). Greater fear of falling on FES was associated with worsening RBANS Digits scores ($F[2,49] = 6.53$, $p = 0.003$, Adj $R^2 = 0.18$, $B = 0.19$, $p = 0.01$). Higher CP Total symptoms were associated with worsening RBANS List Recall scores ($F[2,43] = 6.22$, $p = 0.004$, Adj $R^2 = 0.20$, $B = 0.1$, $p = 0.008$).

DISCUSSION

Fear of falling, mechanism of injury, anxiety history, sex, and initial visit symptoms were associated with changes in clinical outcomes in older adults across clinic visits following concussion. The results highlight the importance of assessing demographic, medical history, and injury-related risk factors when interpreting multidomain clinical assessments in at-risk older adults following concussion. Overall, there is a significant need for further research with this population and how clinical outcomes compare to younger individuals in the literature.

REFERENCES

1. Papa L et al. *Curr Transl Geriatr Exp Gerontol Rep.* 2012;1(3):135-42.
2. Bradley SM. *Mt Sinai J Med.* 2011;78(4):590-5.
3. Hume CH et al. *J Int Neuropsychol Soc*. 2022;28(7):736-55.

Assessment	Initial Visit (n = 76)	Follow-Up (n = 51)	Change Score	p Value
GAD-7 total	6.35 ± 5.27	5.24 ± 5.08	1.12 ± 4.19	0.063
PHQ-9 total	9.45 ± 5.47	7.55 ± 5.97	1.90 ± 4.54	**0.004**
CP total score	35.67 ± 16.99	31.53 ± 19.61	4.14 ± 15.98	0.09
CP Anxiety/Mood	5.30 ± 3.94	4.67 ± 3.97	0.63 ± 3.27	0.21
CP Cognitive	4.35 ± 2.00	4.23 ± 2.53	0.12 ± 2.34	0.75
CP Migraine	6.30 ± 3.32	5.42 ± 4.12	0.88 ± 3.28	0.09
CP Ocular	6.72 ± 3.33	5.93 ± 3.73	0.79 ± 3.47	0.14
CP Vestibular	5.84 ± 3.34	5.14 ± 3.54	0.70 ± 3.27	0.17
CP Sleep	4.67 ± 2.98	3.84 ± 3.18	0.84 ± 2.71	**0.04**
CP Neck	2.49 ± 1.93	2.30 ± 1.79	0.19 ± 1.61	0.45
VOMS Pre-Test	8.08 ± 7.65	5.10 ± 5.78	2.98 ± 6.97	**0.005**
VOMS Smooth Pursuits	8.13 ± 7.23	5.76 ± 6.23	2.37 ± 6.02	**0.011**
VOMS Horizontal Saccades	8.41 ± 7.41	5.65 ± 6.07	2.76 ± 6.27	**0.005**
VOMS Vertical Saccades	8.39 ± 7.45	5.72 ± 6.18	2.67 ± 6.29	**0.006**
VOMS Near Point Convergence	8.39 ± 7.30	5.65 ± 6.09	2.74 ± 6.28	**0.005**
VOMS NPC Distance (cm)	3.46 ± 4.52	3.55 ± 5.46	-0.09 ± 5.33	0.906
VOMS Horizontal VOR	9.84 ± 7.89	6.57 ± 6.58	3.27 ± 6.92	**0.003**
VOMS Vertical VOR	10.09 ± 7.82	6.42 ± 6.57	3.67 ± 7.04	**0.001**
VOMS Visual Motion Sensitivity	11.80 ± 7.83	7.36 ± 6.62	4.43 ± 6.51	**<0.001**
VOMS total score	65.83 ± 53.61	43.83 ± 43.96	22.00 ± 42.88	**0.002**
FES total	12.92 ± 5.49	11.20 ± 4.28	1.73 ± 4.09	**0.004**
FGA total	21.70 ± 5.45	23.49 ± 4.11	-1.79 ± 4.40	**0.011**
RBANS Recall total	24.02 ± 5.78	26.90 ± 5.67	-2.88 ± 5.22	**<0.001**
RBANS Fluency total	23.70 ± 5.34	19.46 ± 4.83	4.24 ± 5.53	**<0.001**
RBANS Digits total	11.10 ± 2.61	11.48 ± 2.74	-0.38 ± 2.76	0.334
RBANS Coding total	44.00 ± 9.98	44.72 ± 8.87	-0.72 ± 7.61	0.507
RBANS List Recall	4.67 ± 2.62	5.33 ± 2.63	-0.65 ± 2.65	0.091
RBANS List Recognition	18.43 ± 1.87	18.67 ± 1.92	-0.25 ± 1.76	0.336

Continuous data are presented as mean ± standard deviation. Significant p values (< 0.05) are bolded.

CP-Screen = Concussion Clinical Profile Screening, FES = Falls Efficacy Scale, FGA = Functional Gait Assessment, GAD-7 = Generalized Anxiety Disorder-7, PHQ-9 = Patient Health Questionnaire-9, RBANS = Repeatable Battery for Assessment of Neuropsychological Status, VOMS = Vestibular/Ocular-Motor Screening, VOR = Vestibular Ocular Reflex, VMS = Visual Motion Sensitivity

Table 1. Performance on concussion assessments at initial and follow-up visits in older adults following concussion

EXERCISE TOLERANCE AND AUTONOMIC FUNCTION FOLLOWING CONCUSSION: THE ANXIETY PROBLEM

Zynda AJ[1], Kehinde F[1], Burley C[1], Trbovich A[1], Holland C[1], Perry C[1], Womble M[2], Collins MW[1], Elbin RJ[3], Kontos AP[1]

[1]University of Pittsburgh, Pittsburgh, Pa.
[2]Inova Sports Medicine Concussion Program
[3]University of Arkansas

INTRODUCTION

One in three athletes experience post-concussion anxiety,[1] and 10%–20% report pre-injury anxiety, which can result in dysfunction of the autonomic nervous system (ANS).[2] Concussion is also associated with ANS dysfunction, which is evaluated via exercise tolerance testing.[3] Surprisingly, researchers have yet to examine the effects of anxiety on exercise intolerance and ANS dysfunction following concussion. Therefore, this study examined exercise tolerance and ANS response (e.g., heart rate [HR], blood pressure [BP], ratings of perceived exertion [RPE], symptoms) using the Buffalo Concussion Bike Test (BCBT) between adults with and without pre-existing and post-injury anxiety. The authors hypothesized that adults with pre-existing and post-injury anxiety would have elevated HR, BP, RPE, and symptoms; complete fewer stages of the BCBT; and have a greater proportion who failed the BCBT compared to the without-anxiety groups.

METHODS

Participants 18–49 years old within eight days to six months of a diagnosed concussion provided demographics, medical history, Clinical Profile Screen (CP-Screen), Brief Symptom Inventory-18 (BSI-18), and the BCBT at their initial clinic visit. ANS function was evaluated via symptoms on the visual analog scale (VAS), HR, BP, and RPE pre- and post-BCBT. Participants were grouped based on reported diagnosis of pre-existing anxiety or published criteria from an adjudication process.[4] Mann-Whitney U tests and chi-square tests compared demographics, medical history, symptoms, and exercise tolerance/intolerance. Two-way mixed-effects analyses of covariance (ANCOVA) evaluated the interaction between groups (pre-injury anxiety [yes/no], post-injury anxiety [yes/no]) and time (pre- to post-BCBT) on ANS metrics.

RESULTS

A total of 106 participants were included (age = 25.5 [12.5] years, 62.3% female), 44 (41.5%) with pre-existing anxiety, and 33 (31.1%) with post-injury anxiety. A greater proportion of females were in the pre-existing anxiety group (77.30% versus 50.80%, $p < 0.01$), whereas pre-existing and post-injury anxiety groups reported greater CP-Screen Total and BSI-18 Somatic symptoms than the without-anxiety groups ($p < 0.001$). A greater but insignificant proportion of the pre-existing (72.7% versus 62.3%, $p = 0.26$) and post-injury anxiety (72.7% versus 64.4%, $p = 0.39$) groups were exercise-intolerant compared to the without-anxiety groups. Participants with pre-existing (median = 8, interquartile range [IQR] = 4) and post-injury anxiety (median = 8, IQR = 5) completed fewer BCBT stages than those without pre-injury anxiety (median = 11, IQR = 6, $p < 0.01$) and post-injury anxiety (median = 10, IQR = 6, $p = 0.03$). ANCOVA results supported a significant interaction in participants with pre-injury anxiety for increased diastolic BP ($F[1,97] = 5.03$, $p = 0.03$, partial $\eta^2 = 0.1$) and VAS ($F[1,99] = 5.05$, $p = 0.03$, partial $\eta^2 = 0.1$) while controlling for sex, CP-Screen total, and BSI-18 Somatic score (see Table 1).

DISCUSSION

Participants with pre-existing and post-injury anxiety experience altered physiological responses to exercise testing following concussion, including increases in diastolic BP and RPE, and they complete fewer stages of the BCBT. The findings suggest that anxiety affects ANS function following concussion and should be considered by clinicians when they interpret findings from the BCBT. Future research should include healthy control groups with and without pre-existing anxiety to determine whether anxiety is the underlying mechanism for ANS dysfunction following concussion. This will inform a more accurate evaluation of ANS dysfunction post-concussion and lead to more effective and targeted exercise interventions.

DISCLOSURE

This research was supported by a grant (W81XWH-20-1-0745) from the Department of Defense (DoD) Congressionally Directed Medical Research Program. Opinions, interpretations, conclusions, and recommendations are those of the authors and not necessarily endorsed by the DoD.

REFERENCES

1. Kontos AP et al. *Curr Sports Med Rep*. 2019;18(3):82-92.
2. Hoehn-Saric R et al. *Psychiatr Clin North Am*. 1988;11(2):375-86.
3. Haider MN et al. *Sports Health*. 2019;11(6):492-7.
4. Durfee KJ et al. *Mil Med*. 2023;188:354-62.

Metric	Pre-Existing Anxiety[a]		No Pre-Existing Anxiety[a]		p	Post-Injury Anxiety[b]		No Post-Injury Anxiety[b]		p
	Pre-BCBT	**Post-BCBT**	**Pre-BCBT**	**Post-BCBT**		**Pre-BCBT**	**Post-BCBT**	**Pre-BCBT**	**Post-BCBT**	
Systolic BP (mmHg)	122.8 (2.3)	134.6 (2.6)	121.4 (1.9)	131.4 (2.1)	0.55	123.0 (2.8)	136.9 (3.2)	121.3 (1.9)	130.5 (2.1)	0.17
Diastolic BP (mmHg)	82.1 (1.9)	86.3 (2.0)	83.3 (1.5)	82.4 (1.6)	**0.03**	81.5 (2.2)	83.9 (2.3)	83.5 (1.4)	84.0 (1.5)	0.47
HR (bpm)	75.2 (2.4)	104.6 (3.7)	72.0 (2.0)	98.4 (3.0)	0.51	71.0 (2.8)	92.9 (4.3)	74.4 (1.8)	104.8 (2.7)	0.09
VAS	1.6 (0.2)	3.4 (0.3)	1.9 (0.2)	3.1 (0.2)	**0.03**	1.6 (0.2)	2.8 (0.3)	1.9 (0.2)	3.3 (0.2)	0.72
RPE	7.2 (0.2)	15.9 (0.4)	7.5 (0.2)	16.2 (0.3)	0.94	7.5 (0.3)	15.6 (0.5)	7.3 (0.2)	16.4 (0.3)	0.15

[a]Continuous data are presented as estimated marginal means (standard error [SE]) while controlling for sex, CP-Screen total score, and BSI Somatic score.

[b]Continuous data are presented as estimated marginal means (SE) while controlling for CP-Screen total score and BSI Somatic score. Significant interactions ($p < 0.05$) are bolded.
BP = blood pressure, BSI = Brief Symptom Inventory, CP-Screen = Clinical Profile Screen, HR = heart rate, RPE = rating of perceived exertion, VAS = visual analog scale

Table 1. Autonomic nervous system metrics pre- and post-Buffalo Concussion Bike Test (BCBT) for the pre-existing and post-injury anxiety groups

MECHANOBIOLOGY LABORATORY

Department of Orthopaedic Surgery
University of Pittsburgh School of Medicine

Laboratory Director: James H-C. Wang, PhD

The MechanoBiology Laboratory (MBL) (http://www.pitt.edu/~mechbio/) concentrates its research efforts in the following areas. First, we have identified HMGB1, a known molecule involved in tissue-damage signaling, as a crucial player in the onset of tendinopathy due to mechanical overuse. HMGB1 is known to initiate a chain of inflammatory cascades. By blocking HMGB1 with metformin (Met), a common drug for the treatment of diabetes, we are developing a potential preventive and treatment strategy for tendinopathy. Supported by the Department of Defense, we are investigating the effects of a topical Met lotion on tendinopathy prevention and treatment in our established animal model of tendinopathy. Additionally, we are conducting a clinical trial to explore the use of Met for managing chronic tendinopathy through oral administration.

Second, our research focuses on the positive impacts of exercise on tendinopathy in both young individuals and those related to aging. With an increasing size of aging populations, age-related issues in musculoskeletal tissues have emerged as a significant healthcare issue. Aging tends to diminish the mechanical strength and healing abilities of tendons, making them susceptible to injuries. Given that moderate exercise can enhance the quantity and stemness of tendon stem cells, our goal is to bolster the structural and functional integrity of tendons in both young and elderly populations through moderate exercise combined with anti-inflammatory strategies.

Third, our research now extends to the tendon-bone interface (TBI), a complex transition zone characterized by its unique fibrocartilage structure, crucial for force transmission between tendon and bone, yet vulnerable to injury and limited in regenerative capacity. We are developing novel biomimetic adhesives to enhance healing of TBI injuries, as well as bone fractures.

Finally, in collaboration with MaCalus Hogan, MD, MBA, and Jarrett Cain, DPM, we are investigating the cellular and molecular mechanisms involved in the development of plantar fasciitis and diabetic bone fractures. Plantar fasciitis, also known as “painful heel syndrome,” is a debilitating condition that affects millions of people and costs billions of healthcare dollars. Using an *in vitro* model system, researchers at MBL are currently testing the hypothesis that mechanical loading–induced alterations in human plantar fasciitis (PF) functions disrupt PF homeostasis and therefore are responsible for PF’s pathophysiology, namely the onset of plantar fasciitis. In addition, we are devising novel strategies, including use of small compounds to inhibit excessive tissue inflammation for the effective healing of diabetic bone fractures.

Together with our research collaborators, members of the MBL team are committed to achieving research excellence and eagerly anticipate a productive year in 2024.

Current MBL Personnel
James H-C. Wang, PhD, faculty principal investigator
MaCalus V. Hogan, MD, MBA, faculty collaborator
Allison Bean, MD, PhD, faculty collaborator
Jarrett Cain, DPM, faculty collaborator
Jianying Zhang, PhD, research associate professor
Vasyl Pastukh, MD, research fellow
Soichi Hattori, MD, PhD, research scientist
Umanes Marfred, MD, research fellow
Padma Thampatty, PhD, research staff
Derek Maloney, BS, research assistant
Erica Taylor, undergraduate student researcher
Grant Snyder, undergraduate student researcher
Dylan Reddish, undergraduate student researcher
Michael Copeland, undergraduate student researcher
Satyaj Bhargava, undergraduate student researcher

USE OF BIOMIMETIC POLYMER ADHESIVE TO REGENERATE ACHILLES ENTHESIS INJURIES IN RATS

Pastukh V[1], Hattori S[1], Maloney D[1], Zhang J[1], Wang JH-C[1,2,3]

[1]MechanoBiology Laboratory, Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.
[2]Department of Bioengineering, University of Pittsburgh, Pittsburgh, Pa.
[3]Department of Physical Medicine and Rehabilitation, University of Pittsburgh, Pittsburgh, Pa.

INTRODUCTION

Injury may occur to an enthesis after acute trauma or to a degenerated tendon.[1] The primary challenge in regenerating an enthesis lies in the mechanical intricacies of joining a flexible material (tendon) with a rigid material (bone).[2] Enthesis does not regenerate following surgical repair. Instead, fibrovascular tissue, characterized by reduced biomechanical properties, develops at the repair site.[3] Regenerating the enthesis poses significant challenges in orthopaedic medicine. This study aimed to improve enthesis tissue healing, reparation, and regeneration using a novel biomimetic polymer adhesive.

METHODS

Synthesized in the authors' lab, the polymer LDI-Gly-DOPA-Cys (lysine diisocyanate, glycerol, phenylalanine, and cysteine) exhibits nontoxic, biodegradable, and bioadhesive properties. A foam that forms during polymerization serves as a scaffold for enthesis tissue remodeling. The researchers used a rat Achilles enthesis repair model to assess healing and regeneration after polymer implantation in the repair site on three rats in a group of 8-week-old Sprague Dawley female rats, for control and treatment groups. Enthesis repair following enthesis surgical transection was done by transossal fixation of the Achilles tendon to calcaneus.

RESULTS

In the treatment group, polymer was applied in the enthesis repair site before suturing to calcaneus. New tissue formation in the enthesis repair site was histologically analyzed four weeks after surgery (see Figure 1). Histological images showed the formation of organized gradient transition from bone to tendon through mineralized and demineralized fibrocartilage tissue (Figure 1D–F), compared to formation of disorganized connective tissues in the control group (Figure 1A–C). An increase of glycosaminoglycans and fibrocartilage organized tissue expression in the enthesis repair site was found in the treatment group (Figure 1J–L), compared to formation of disorganized fibrocartilage and connective tissue in the control group (Figure 1G–I). Similar changes demonstrated new enthesis tissue formation in the treatment group (Figure 1P–R), whereas formation of disorganized fibrocartilage and connective tissues were observed in the enthesis repair site in the control group (Figure 1M–O).

DISCUSSION

The authors have developed a novel biomimetic amino acids–based urethane polymer as a tissue/bone adhesive that forms strong bonding with collagen in bony tissues. The biomimetic properties of the polymer stimulate the regeneration of specific enthesis tissue at the repair site. This polymer adhesive, in conjunction with sutures, can facilitate the gradual transfer of physical loading from muscle to bone. In contrast, when sutures are used alone, they form disorganized connective and fibrocartilage tissue, which lacks the necessary mechanical strength. This can lead to repetitive trauma, pain, and long-term disability. The authors are further characterizing the biological, biochemical, and biomechanical properties of the newly formed enthesis in their rat enthesis injury model. The biomimetic polymer adhesive may be used as a new tissue-engineering approach to regenerate injured enthesis effectively.

REFERENCES

1. Derwin KA et al. *J Bone Joint Surg Am*. 2018;100(16):e109.
2. Lu HH & Thomopoulos S. *Annu Rev Biomed Eng*. 2013;15:201-26.
3. Chen W et al. Biomaterials. 2021;271:120714.

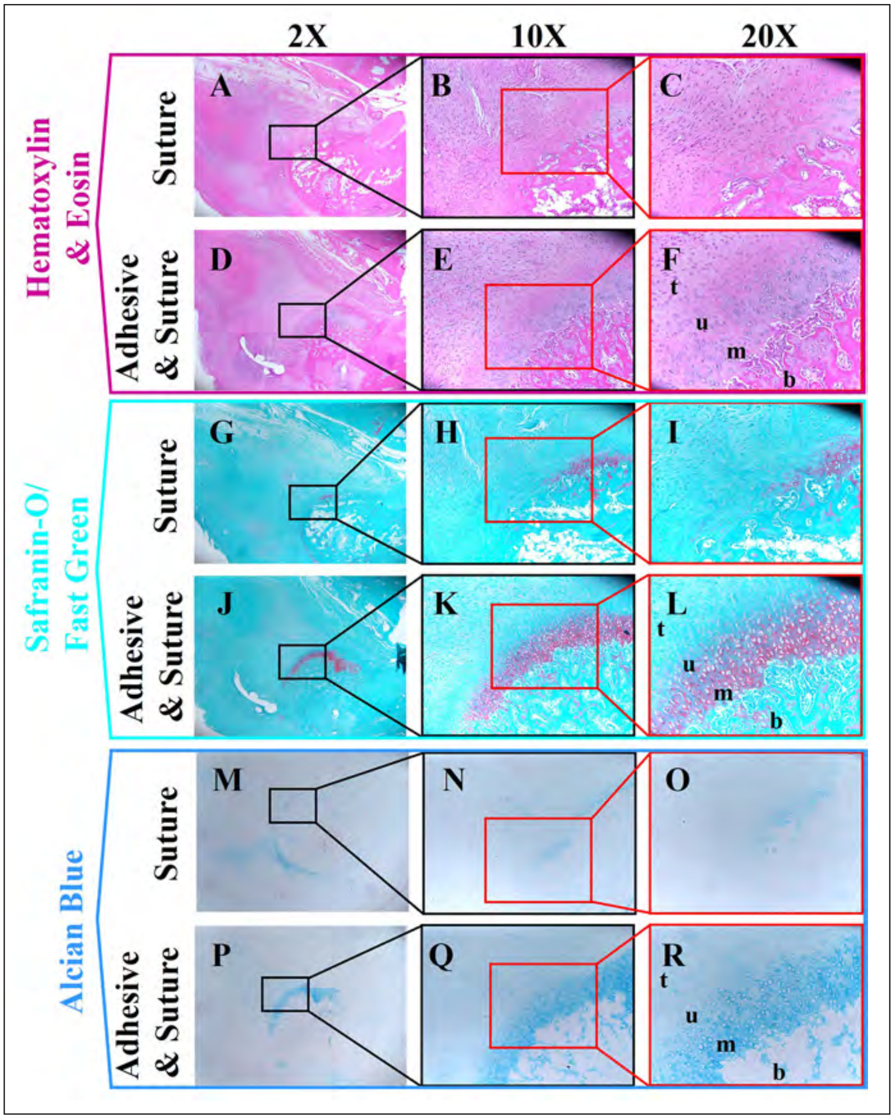


Figure 1. Application of the biomimetic polymer leads to enthesis tissue formation. Rat ankle joint images show the enthesis repair site and surrounding tissues for both control (suture: A, B, C, G, H, I, M, N, and O) and treatment (adhesive + suture: D, E, F, J, K, L, P, Q, and R). Compared to the control group, the treatment group shows the regeneration of the tendon-to-bone interface, characterized by the extensive formation of fibrocartilage zone, as revealed by hematoxylin and eosin and two other staining methods.
t: tendon, u: unmineralized fibrocartilage, m: mineralized fibrocartilage, b: bone

FULLY REDUCED HMGB1 WITH METFORMIN IMPROVES NONUNION BONE FRACTURE HEALING IN DIABETIC RATS

Cain J[1], Zhang J[1], Shimozaki K[1], Brown R[1], Hogan MV[1,2], Wang JH-C[1,2,3]

[1]MechanoBiology Laboratory, Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.
[2]Department of Bioengineering, University of Pittsburgh, Pittsburgh, Pa.
[3]Department of Physical Medicine and Rehabilitation, University of Pittsburgh, Pittsburgh, Pa.

INTRODUCTION

Diabetes mellitus (DM) interferes with bone formation and impairs nonunion fracture healing.[1] Fully reduced high mobility group box1 (frHMGB1) can enhance wound healing,[2] and frHMGB1 can be inhibited by metformin (Met), a drug for the treatment of DM that is known to improve bone healing.[3] However, the effects of frHMGB1 and Met on bone fracture healing of patients taking Met is largely unknown. This study tested the hypothesis that injection of frHMGB1 with Met would improve nonunion bone fracture healing in a diabetic rat model.

METHODS

DM was induced by injection of streptozotocin into 32 Sprague Dawley rats and confirmed by blood glucose levels over 200 mg/dL. The skin at tibia area was opened, tibia bones were fractured, and the muscle and skin wound were sutured. The wounded rats were divided into four groups, with eight rats per group. They were injected with Met (intraperitoneal, 160 mg/kg) and/or frHMGB1 (injection to wound area, 250 µg/kg):

Group 1: no treatment (wound group)
Group 2: Met daily (Met group)
Group 3: frHMGB1 weekly (frHMGB1 group)
Group 4: Met daily and frHMGB1 weekly (frHMGB1 + Met group)

The rats were monitored every day after surgery, and four rats from each group were sacrificed postoperatively on day 28 and day 90. Nonunion bone fracture healing was examined by gross inspection, micro–computed tomography imaging, histochemical staining, and immune staining. HMGB1 and interleukin1-β levels were determined with enzyme-linked immunosorbent assay kits.

RESULTS

frHMGB1-treated wounds had normal tissue color with high-density bone tissue and no gap, indicating much faster healing than the other three groups. The wound group healed much slower than the other groups, with large unhealed wound areas with little bone tissue (yellow dash line area, Figure 1A). The Met group healed much better than the wound-only group, as evidenced by a smaller gap area (black dash line area, Figure 1B). frHMGB1 enhanced bone fracture healing by recruiting cells to the wound area (yellow arrow, Figure 1C). Met slowed the healing, but the healed bone tissue had high cell density and a small gap area (green dash line area, Figure 1D). frHMGB1 enhanced bone fracture healing and produced more functional bone with collagen type I (red in Figure 1K, yellow and red in Figure 1O). High levels of collagen III in the wound area (green in Figure 1O) indicated that these bones were newly formed tissues. Large empty areas were found in untreated wounds (Figure 1I) and Met-treated wounds (Figure 1J). More collagen III was found in the wound areas treated with frHMGB1 + Met (green in Figure 1P), indicating that healing was in process.

DISCUSSION

The results indicate that in wounded diabetic rats, frHMGB1 enhanced nonunion bone fracture healing by promoting cell proliferation, fibroblast migration, and collagen I and III production, but it may form scar tissue. Met inhibited frHMGB1 but may improve healing quality. Met may help to form high-quality bone tissue with reduced scar-tissue formation.

REFERENCES

1. Olokoba A et al. *Oman Med J*. 2012;27(4):269-73.
2. Lee G et al. PNAS. 2018;115(19):E4463-72.
3. Horiuchi T et al. *J Biol Chem*. 2017;292(20):8436-46.

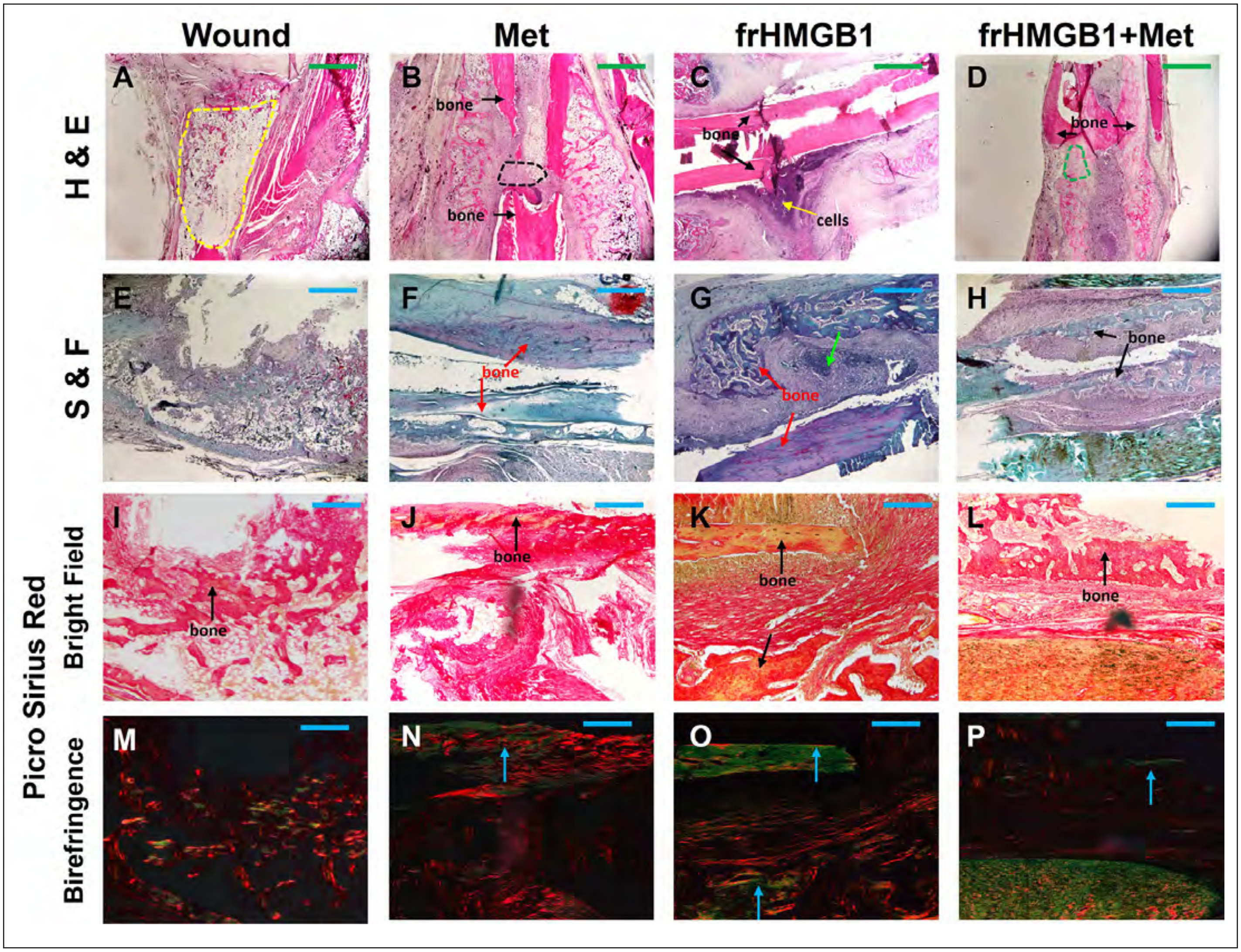


Figure 1. frHMGB1 with Met enhances bone fracture healing: hematoxylin and eosin staining (A-D), Safranin O and Fast Green (S&F) staining (E-H), and Picrosirius Red staining on the bone-tissue sections of the rats at day 28 post-operation under bright light microscopy (I-L) and birefringence microscopy (M-P). Green bars: 500 µm; blue bars: 100 µm

PREVENTIVE EFFECTS OF METFORMIN LOTION ON TENDON DEGENERATION IN MICE SUBJECTED TO MECHANICAL OVERUSE

Zhang J[1], Maloney D[1], Pastukh V[1], Hattori S[1], Wang JH-C[1,2,3]

[1]MechanoBiology Laboratory, Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.
[2]Department of Bioengineering, University of Pittsburgh, Pittsburgh, Pa.
[3]Department of Physical Medicine and Rehabilitation, University of Pittsburgh, Pittsburgh, Pa.

INTRODUCTION

Tendinopathy, a prevalent tendon disorder characterized by inflammation and/or degeneration, affects millions of Americans and costs billions of healthcare dollars every year. Current treatments for tendinopathy are ineffective in regaining tendon structure and function. High mobility group box-1 (HMGB1), an upstream potent inflammatory mediator, has been identified in high levels in early-stage tendinopathy patients.[1] Metformin (Met), an oral drug for the treatment of type 2 diabetes, specifically inhibits the activity of HMGB1.[2] However, Met given orally or as an intraperitoneal injection has systemic side effects, including nausea, diarrhea, etc. Therefore, the authors have initiated a study to develop Met lotion (ML) as a novel topical drug-delivery system for targeted Met administration to the tendon.

METHODS

ML at 3% and 6% concentrations was formulated at the authors' lab. A total of 30 mice were randomly divided equally into three groups: Group 1 ran on a treadmill at 15 m/minute for three hours per day, five days a week for four weeks (ITR).

Groups 2 and 3 were smeared with 3% and 6% ML on the skin surface of the hind legs before ITR daily for four weeks (ITR + 3% ML, ITR + 6% ML, respectively).

Achilles tendon tissues were harvested for histological analysis by Masson's trichrome staining, Picrosirius Red staining, and immunostaining on collagen II and SOX-9 expression, two markers for cartilage tissues.

RESULTS

Masson's trichrome and Picrosirius Red staining showed that ML treatment inhibited ITR-induced degenerative changes as evidenced by dense collagen fibers (data not shown). Loose collagen fibers in the tendons of ITR mice were positively stained with collagen III (green birefringence in Figure 1A–D), whereas ML-treated groups showed yellow or orange birefringence, indicating collagen I fibers with low levels of collagen III (Figure 1E–L). The inhibition effect of ML on collagen III formation was in a concentration-dependent manner (i.e., ITR > ITR + 3% ML > ITR + 6% ML). ML application also decreased collagen II and SOX-9 expression induced by ITR (data not shown).

DISCUSSION

This study has demonstrated the preventive effect of ML on an ITR-induced tendinopathy model in mice. The results have shown that mechanical overloading by ITR-induced typical degenerative changes of tendinopathy in mouse tendons is characterized by the presence of chondrocyte-like cells, increased levels of collagen II and SOX-9, and scar-like tissues, as indicated by disorganized tendon structure and increased collagen III levels. However, ML application at 3% and 6% doses reduced these tendinopathic changes, with 6% lotion more effective than 3% lotion. The results of this study indicate the promising therapeutic potential of ML in preventing tendinopathy. It directly addresses the underlying cause of tendinopathy and provides ease of use, eliminating the common side effects associated with oral administration.

REFERENCES

1. Akbar M et al. *RMD Open*. 2017;3:e000456.
2. Horiuichi T et al. *J Biol Chem*. 2017;292(20):8436-46.

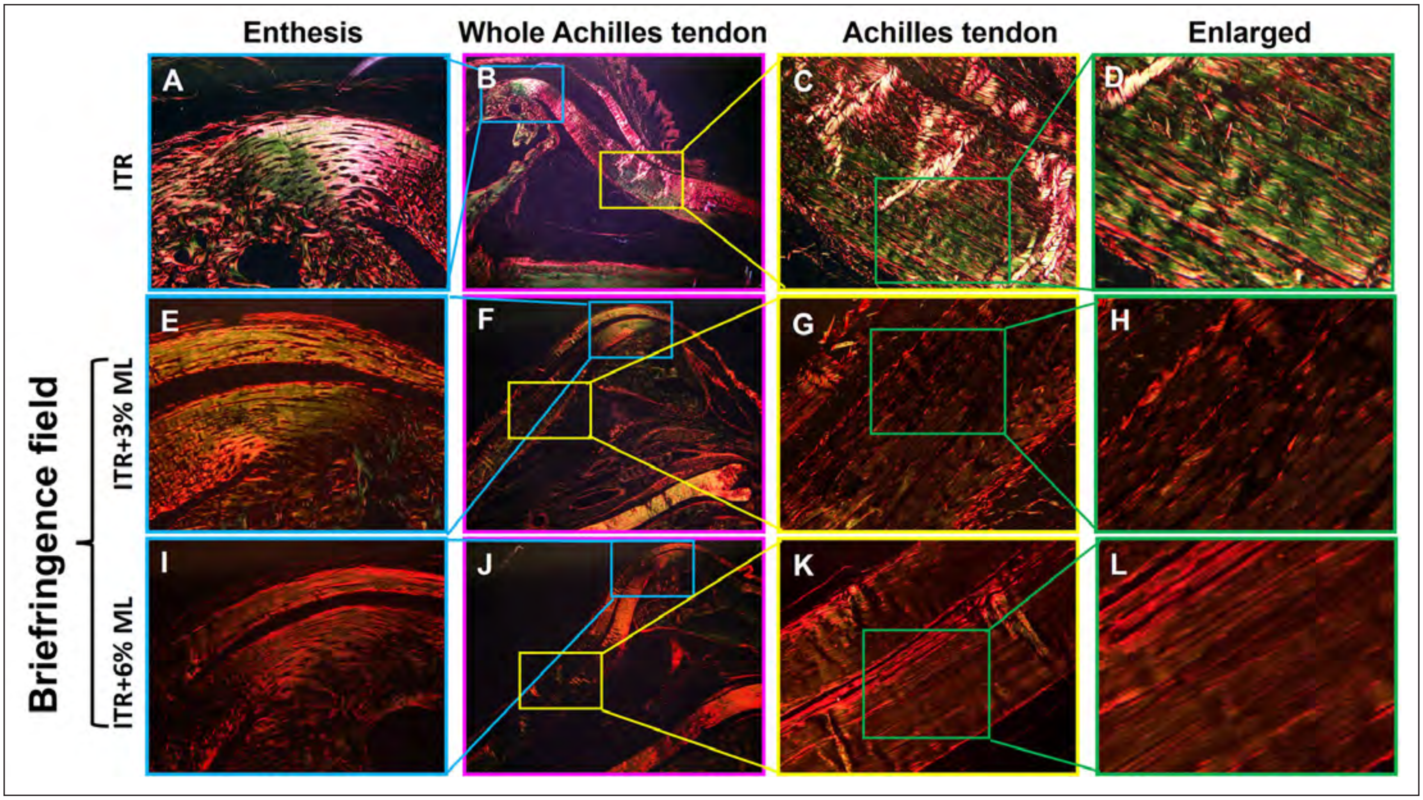


Figure 1. Application of metformin lotion decreases collagen III formation and enhances dense collagen I formation in mouse Achilles tendons, per histological analysis with Picrosirius Red staining.

APPLICATION OF A TOPICAL METFORMIN LOTION REDUCES SYSTEMIC AND LOCAL TENDON INFLAMMATION IN MICE

Zhang J[1], Maloney D[1], Pastukh V[1], Hattori S[1], Wang JH-C[1,2,3]

[1]MechanoBiology Laboratory, Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.
[2]Department of Bioengineering, University of Pittsburgh, Pittsburgh, Pa.
[3]Department of Physical Medicine and Rehabilitation, University of Pittsburgh, Pittsburgh, Pa.

INTRODUCTION

Tendinopathy manifests as tendon inflammation and degeneration, and mechanical overloading is the major causative factor. Key inflammatory and pain mediators in tendinopathy include PGE2, IL1-β, and HMGB1. Notably, HMGB1 levels are elevated in the tendons of patients with tendinopathy.[1] Metformin (Met), an oral drug for the treatment of diabetes, inhibits HMGB1.[2] However, oral Met has systemic side effects on the body. Thus, the authors formulated a Met lotion (ML) as a novel topical drug to deliver Met directly into the tendon area to prevent tendinopathy development induced by mechanical overuse in mice.

METHODS

ML at 3% and 6% concentrations were formulated in the authors' lab. A total of 30 mice were randomly divided into three equal groups and treated as follows:

- Group 1: The mice ran on a treadmill at 15 m/minute for 3 hours per day, five days a week for four weeks (ITR).
- Groups 2 and 3: 3% and 6% ML was smeared on the skin surface of the hind legs before ITR daily for four weeks, respectively (ITR + 3% ML; ITR + 6% ML).

All mice were sacrificed after four weeks of ITR. PGE2, IL1-β, and HMGB1 from serum were analyzed with enzyme-linked immunosorbent assay. Achilles tendon tissues were used for immunostaining and histological analysis. The data underwent analysis with a two-tailed student t-test, with five samples used in each group for every test. A p value below 0.05 was regarded as indicative of significant differences between the two groups.

RESULTS

The immunostaining from Triton X-100-treated samples indicated that ITR induced HMGB1 release from cell nuclei to tendon matrix (red fluorescence in Figure 1A, B) and many nuclei in ITR groups were negatively stained with HMGB1 (white arrows in Figure 1A, B). However, ML treatments inhibited HMGB1 release from the cell nuclei to tendon matrix. The nuclei of most of the cells in the ML-treated groups were positively stained with HMGB1 (yellow arrows in Figure 1C–F). Without Triton X-100 treatment, very low levels of HMGB1 were positively stained in ML-treated tendon matrix (Figure 1I–L); however, high levels of HMGB1 were found in ITR groups (Figure 1G, H). The inhibition effect of ML was in a concentration-dependent manner as evidenced by the expression of HMGB1 in the tendon matrix of all samples: ITR > ITR + 3% ML > ITR + 6% ML. HMGB1 levels in serum agreed with this finding (Figure 1M).

DISCUSSION

The study has demonstrated that ITR induced typical inflammatory and degenerative changes of tendinopathy in mouse tendons, characterized by HMGB1 release from the cell nuclei into tendon matrix, accompanied by elevated levels of PGE2 and IL-1β and presence of chondrocyte-like cells. A topical application of ML could inhibit HMGB1 release from cell nuclei, reduce PGE2 and IL-1β levels, and reduce inflammation and degeneration in Achilles tendon. These results suggest that the transdermal application of Met is an effective yet safe and convenient method for preventing the development of tendinopathy.

REFERENCES

1. Akbar M et al. *RMD Open*. 2017;3:e000456.
2. Horiuichi T et al. *J Biol Chem*. 2017;292(20):8436-46.

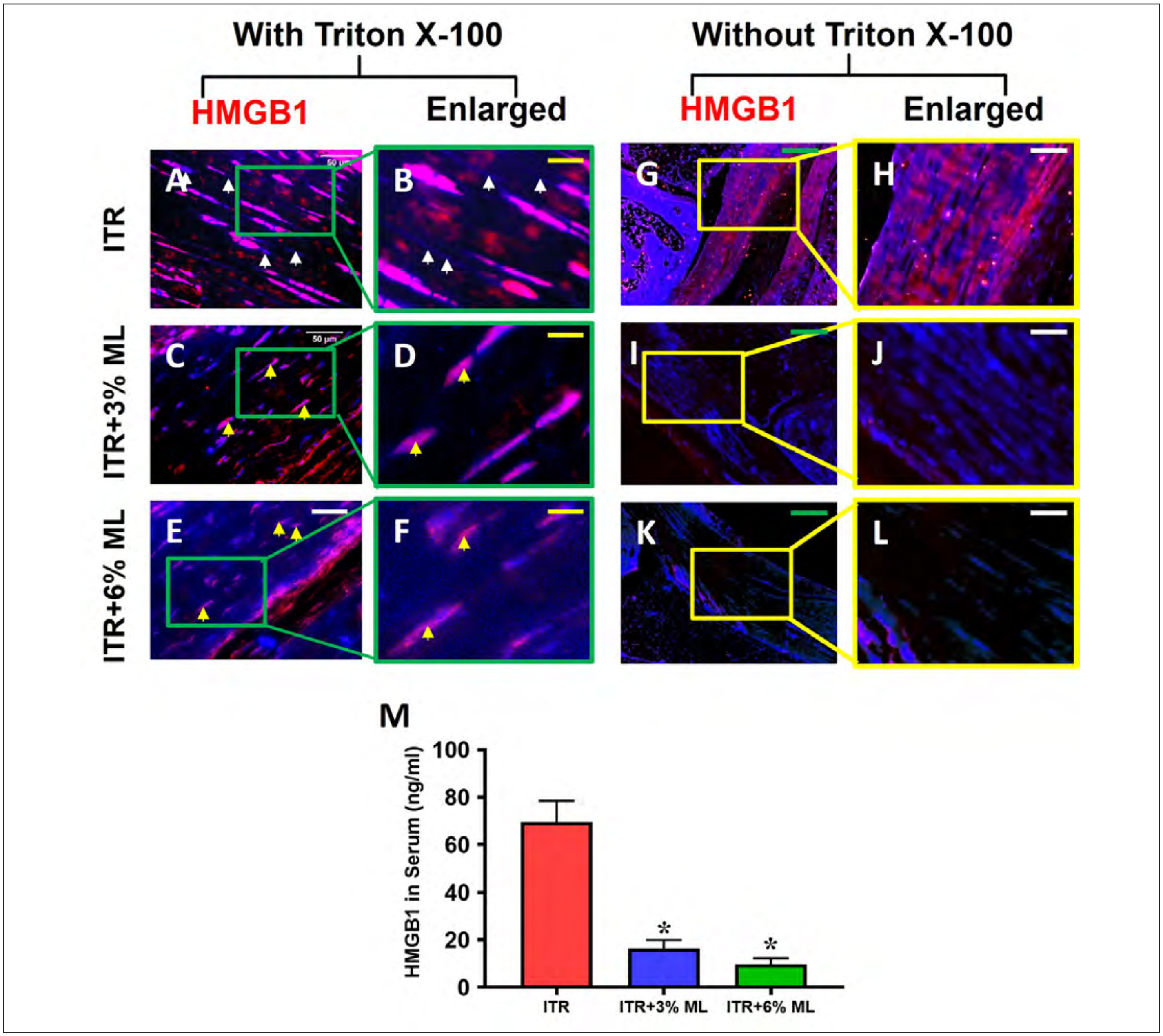


Figure 1. Application of metformin lotion inhibits HMGB1 release in tendon tissue and reduces HMGB1 levels in serum after four weeks of treadmill running.
***p < 0.05 compared to ITR**
White bars: 50 µm; yellow bars: 12.5 µm; green bars: 200 µm

METFORMIN LOTION REDUCES SCAR-TISSUE FORMATION IN THE SKIN OF RATS BY ACTIVATING AMPK AND INHIBITING TGF-β1

Zhang J[1], Shimozaki K[1], Hattori S[1], Pastukh V[1], Maloney D[1], Wang JH-C[1,2,3]

[1]MechanoBiology Laboratory, Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.
[2]Department of Bioengineering, University of Pittsburgh, Pittsburgh, Pa.
[3]Department of Physical Medicine and Rehabilitation, University of Pittsburgh, Pittsburgh, Pa.

INTRODUCTION

Skin wounds and compromised wound healing are major concerns for the public health sector. Commercial wound-healing products fail to initiate skin regeneration. High levels of α smooth muscle actin (α-SMA) and collagen III can result in loose collagen fibers that cause scar formation in skin. AMPK is known to regulate tissue inflammatory signaling, and activation of AMPK can inhibit scar-tissue formation.[1] Metformin (Met), an oral drug for the treatment of type 2 diabetes, can activate AMPK. Met has been shown to prevent lung fibrosis.[2] However, oral Met has side effects on the stomach, liver, and kidneys. Therefore, the authors formulated Met lotion (ML) as a novel topical drug to deliver Met directly into the injured skin area to enhance skin healing. They studied the effect of ML on skin healing by using a rat skin-injury model.

METHODS

ML was formulated in the authors' lab. The researchers made a 2 cm incision on the skin of each Achilles tendon in 10 Sprague Dawley rats. Then the wounds were sutured, and the wound area's skin surface was treated for 10 days as follows:

- Group 1: smeared with 0% ML daily
- Group 2: smeared with 6% ML daily

Then animals were sacrificed on day 10. The researchers investigated Met's effect on healing of the wounded skin by histological analysis of sections of rat skin tissue. They analyzed data with one-way analysis of variance followed by Fisher's least significant difference test for multiple comparisons. A p value less than 0.05 was considered to be a significant difference between the groups.

RESULTS

Normal skin-like tissues with collagen I and without gap were formed at the wound area treated with 6% ML in contrast to control with collagen III and gap in the wound area and dense and thick epidermis (data not shown). ML enhanced AMPK activity, inhibited α-SMA and TGF-β1, decreased collagen III levels, and increased collagen I expression (Figure 1A–E) in wounded skin areas. In contrast, the wounds treated with control lotion expressed lower levels of AMPK; higher levels of α-SMA, TGF-β1, and collagen III; and lower levels of collagen I (Figure 1F–J) compared to 6% ML-treated wounds.

DISCUSSION

This study used ML as a topical drug for the prevention of scar-tissue formation in skin wound healing. The results demonstrate that skin wounds treated with control lotion healed slowly and formed scar-like tissues. In contrast, the wounds treated with ML healed much faster and formed normal skin-like tissues. Moreover, ML application enhanced AMPK activity, decreased TGF-β1 expression, inhibited α-SMA$^+$ cell numbers, and decreased collagen III production. These findings indicate that inhibition of scar-tissue formation by ML is likely through activation of AMPK, reduction of TGF-β1 expression, inhibition of α-SMA-expressing myofibroblasts, and reduction of collagen III production. ML may be used in clinical settings to prevent scar formation in tissues such as skin and connective tissues, such that a high quality of tissue regeneration in wounded skin can be achieved.

REFERENCES

1. Cieslik KA et al. *J Mol Cell Cardiol*. 2013;63(6):823-31.
2. Teague TT et al. *Respiratory Research*. 2022;23-91.

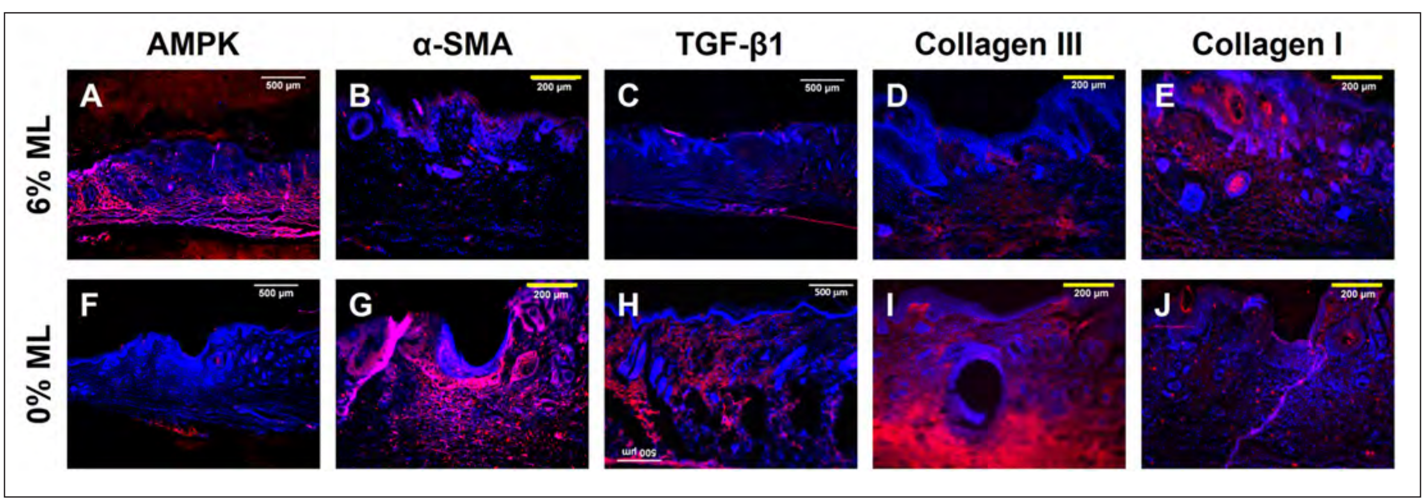


Figure 1. Application of metformin lotion reduces scar-tissue formation in rat skin, with significant effects observed 10 days after wound healing. White bars: 500 μm; yellow bars: 200 μm

PROMOTING TENDON REGENERATION BY ACTIVATING AMPK AND DECREASING A-SMA+ CELL MIGRATION

Zhang J[1], Brown R[1], Shimozaki K[1], Hogan MV[1,2], Wang JH-C[1,2,3]

[1]MechanoBiology Laboratory, Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.
[2]Department of Bioengineering, University of Pittsburgh, Pittsburgh, Pa.
[3]Department of Physical Medicine and Rehabilitation, University of Pittsburgh, Pittsburgh, Pa.

INTRODUCTION

Current strategies for tendon repair typically result in scar-tissue formation or fibrosis, resulting in compromised tendon function. α-SMA and collagen III are two markers of scar-tissue formation. HMGB1, a potent inflammatory mediator, plays a key role in hypertrophic scar formation in skin and scar-forming wounds in fetal mice.[1] AMPK has been linked to the regulation of tissue inflammatory signaling. AMPK activation can inhibit scar-tissue formation.[2] Metformin (Met), an anti-diabetes drug, is known to inhibit HMGB1 and activate AMPK.[3-4] Met also has been shown to prevent lung fibrosis.[5] This study investigated the effect of Met on wounded tendon healing.

METHODS

Triple transgenic α-SMA-Ai9-Scx-GFP mice (Ai9 mice) were used in experiments. A 0.5 mm window defect was created in the Achilles tendon of all mice. Four groups with six mice per group were treated with intraperitoneal injections of saline and Met (160 mg/kg) daily for a total of six weeks as follows:

- Group 1: Saline for 6 weeks (saline group)
- Group 2: Met two weeks before surgery and saline four weeks after surgery (Met-B)
- Group 3: Saline two weeks before surgery and Met for four weeks after surgery (Met-A)
- Group 4: Met two weeks before surgery and four weeks after surgery (Met-B&A)

The animals were sacrificed on day 30 post-surgery. The Met effect on wounded tendon healing was investigated by enzyme-linked immunosorbent assay for HMGB1 levels in mouse serum and histological analysis on mouse tendon tissue sections.

RESULTS

The saline-treated mice serum had high levels of HMGB1, which was significantly decreased in the Met-A and Met-B&A groups, and Met inhibited the migration of α-SMA+ cells in the wounded mouse Achilles tendons compared to saline (data not shown). There was no significant difference of the Scx+ cells in the wound areas of four groups (data not shown). Immunostaining showed an increased number of α-SMA+ cells (brown in Figure 1A, red arrow), low levels of AMPK staining (Figure 1E), and high levels of TGF-β1 (Figure 1I) and HMGB1 (Figure 1M) in the wound area of saline injection mice. However, in Met-treated groups, fewer α-SMA+ cells (Figure 1B–D) and high levels of AMPK staining (Figure 1F-H) were found in the wounded tendons of mice compared to the saline-treated group. Met injection also inhibited the expression of TGF-β1 (Figure 1J–L) and HMGB1 (Figure 1N–P) in mouse tendons.

DISCUSSION

Using an Ai9 mouse model, the authors showed that Met injection reduces scar formation in wounded tendon by reducing HMGB1 levels, inhibiting α-SMA+ cell migration, decreasing collagen III but increasing collagen I production, activating AMPK, and decreasing TGF-β1 expression. With longer treatment of Met, scar-tissue formation was reduced to a larger extent, as evidenced by the wounds treated with Met-B&A healing better than Met-B and Met-A only. The findings indicated that AMPK activation may inhibit myofibroblast differentiation by TGF-β1, supporting a preventive role of AMPK in the development of fibrosis.

REFERENCES

1. Dardenne AD et al. *Wound Repair Regen*. 2013;21(2):282-91.
2. Cieslik KA et al. *J Mol Cell Cardiol*. 2013;63(6):823-31.
3. Horiuchi T et al. *J Biol Chem*. 2017;292(20):8436-46.
4. Zhou G et al. *J Clin Invest*. 2001;108(8):1167-74.
5. Teague TT et al. *Respiratory Research*. 2022;23-91.

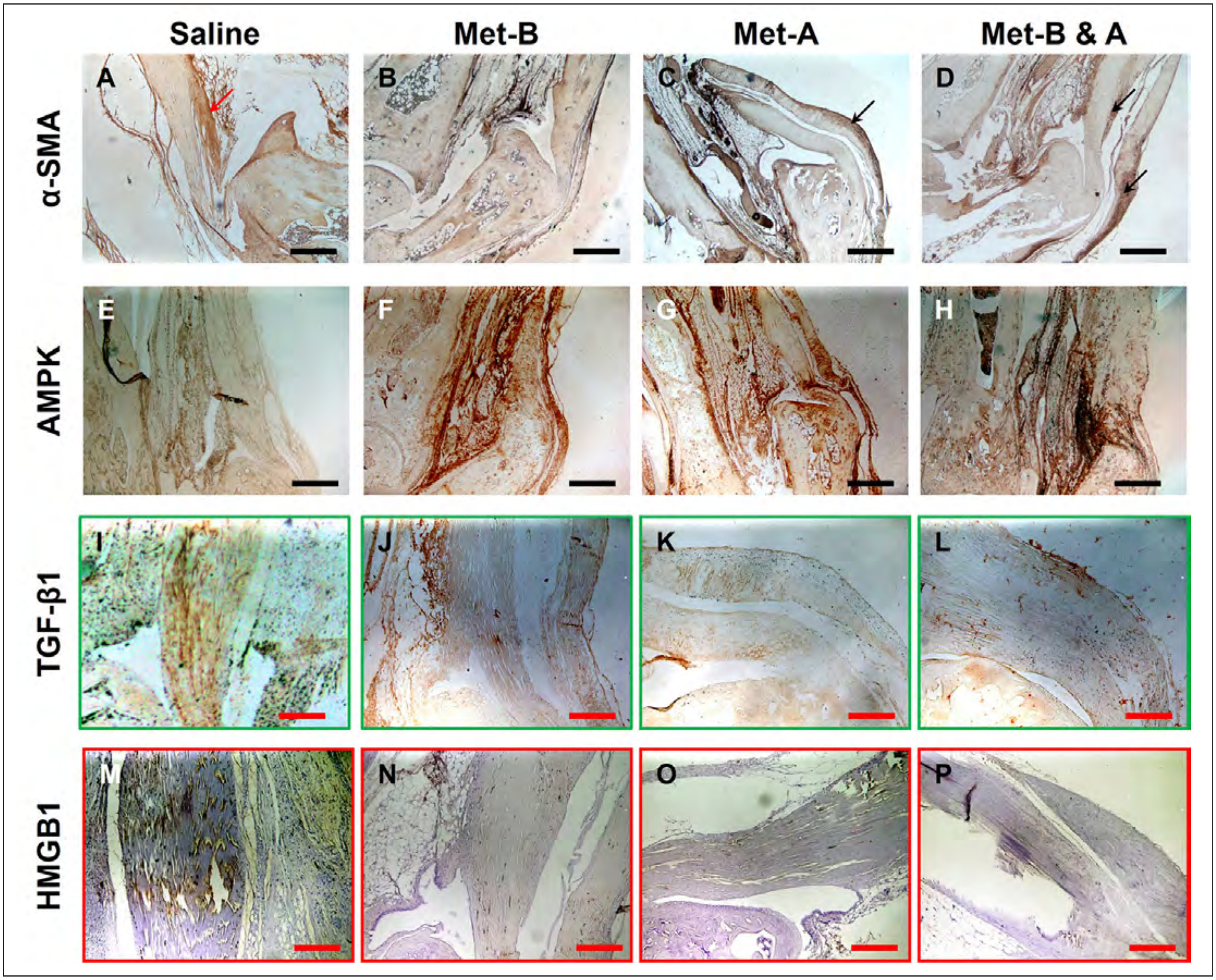
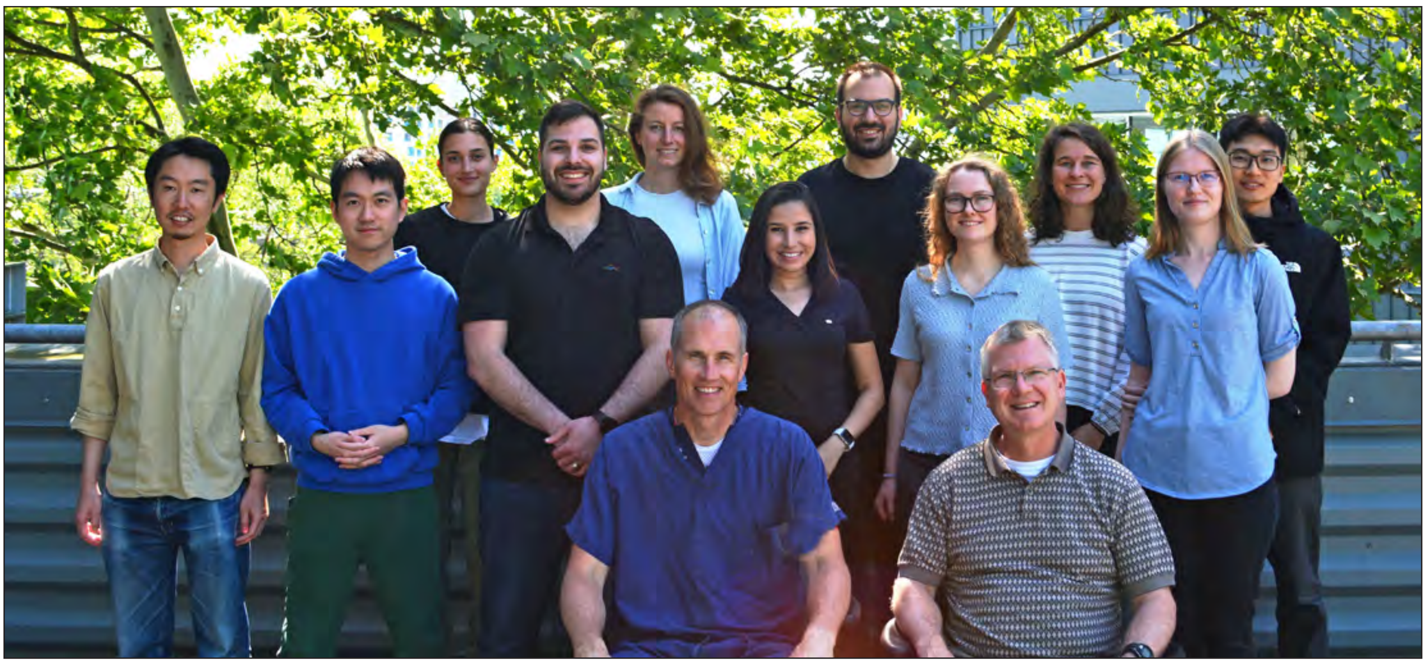


Figure 1. Metformin inhibits α-SMA⁺ cell migration, increases AMPK activity, and decreases HMGB1 and TGF-β1 expression in mouse tendons, as determined by immunohistochemical staining.
Black bars: 500 µm; red bars: 200 µm

Richard Debski, PhD, professor, Department of Bioengineering, codirector
Volker Musahl, MD, professor, Department of Orthopaedic Surgery, codirector

The mission of the ORL is to prevent degenerative joint disease by improving diagnostic, repair, and rehabilitation procedures for musculoskeletal injuries using state-of-the-art robotic technology. Over the past year, the laboratory received an R01 renewal from the National Institutes of Health for a longitudinal study titled "Predicting the Outcomes of Exercise Therapy for Treatment of Rotator Cuff Tears (POETT)." The POETT study is a collaboration between the Departments of Bioengineering, Orthopaedic Surgery, and Physical Therapy, including James Irrgang, PT, PhD (co-principal investigator), William Anderst, PhD, and Adam Popchak, DPT, PhD (funded 2016 to the present). Congratulations to Dr. Musahl for winning the *Video Journal of Sports Medicine* Best Picture Award; joining the Executive Committee of the International Society Of Arthroscopy, Knee Surgery, and Orthopaedic Sports Medicine; and entering the presidential line of the Anterior Cruciate Ligament Study Group. Congratulations to postdoctoral associate Luke Mattar, PhD, for receiving a 2024 New Investigator Recognition Award from the Orthopaedic Research Society.



Volker Musahl, MD, and Richard Debski, PhD, with the Orthopaedic Robotics Laboratory

Happy hour with the ORL

QUANTIFYING CAPSULAR INJURY AND REPAIR TO GUIDE INDIVIDUALIZED CAPSULAR PLICATION AFTER ANTERIOR GLENOHUMERAL DISLOCATION

Ahrendt GM[1], Herman ZJ[1], Newell BW[2], Ionue J[2], Nazzal EM[1], Takaba K[2], Mattar LT[1], Musahl V[1,2], Lin A[1], Debski RE[1,2]

[1]Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.
[2]Department of Bioengineering, University of Pittsburgh, Pittsburgh, Pa.

OBJECTIVES

Anterior glenohumeral dislocation can cause instability due to permanent deformation of the inferior glenohumeral ligament (IGHL).[1] Surgical management involves capsular plication to reduce capsular redundancy.[2,3] However, the location, direction, and magnitude of IGHL injury vary among individuals,[4] emphasizing challenges with current subjective plication techniques.[5,6] An objective injury quantification could guide individualized plication to restore native anatomy and glenohumeral joint stability. Capsular volume increases after dislocation.[7] Capsular surface area could also theoretically increase and provide a surrogate measurement that is applicable to magnetic resonance (MR) arthrograms.

Thus, the objective of this study was to quantify capsular surface area using 3D geometric models derived from MR arthrograms of patients with anterior shoulder instability undergoing plication. It was hypothesized that capsular surface area would increase after dislocation and decrease after plication, with current plication techniques resulting in a non-anatomic surface area compared to controls.

METHODS

Four male patients (mean age = 20.5 years ± 1.0; mean body mass index 23.69 kg/m² ± 0.76) were recruited for this prospective study approved by the Institutional Review Board and provided informed consent. All had sport-related anterior shoulder dislocations but no glenoid defects or rotator cuff tears on preoperative MR arthrogram. All subjects underwent arthroscopic anterior labral repair with capsulorrhaphy. Postoperatively (mean = 4.4 weeks ± 0.75), patients underwent bilateral MR arthrograms. Imaging data from injured, repaired, and control (contralateral) MR arthrograms were obtained and segmented in Materialize MIMICs (version 23.0) to produce 3D geometric models for each state. Surface area of the IGHL in each 3D geometric model was calculated with MESHLab (version 2020.07). Reliability tests showed measurements consistent within 7%. Surface area changes were quantified between each state. To account for individual differences in capsular size and morphology, injured and repaired capsule surface areas were normalized to the control capsule for each patient. Repeated-measures one-way analyses of variance compared means of normalized injured and repaired surface areas. A Bonferroni post-hoc analysis was performed to test significance. Significance was set at $p < 0.05$.

RESULTS

The 3D models illustrate qualitative capsular morphology changes where injured capsules appeared enlarged and deformed versus control, with a qualitative size decrease after plication (see Figure 1). Surface area ranged from 1,985 to 2,540 mm² (injured); 1,858 to 2,388 mm² (control); and 1,785 to 1,944 mm² (repaired). All injured capsules had greater surface areas than respective controls. Capsular surface area decreased after repair for all subjects. For three subjects, repaired capsules were smaller than the control, whereas for one subject the repaired capsule remained larger. Injured capsules demonstrated a 10% ± 5% increase ($p = 0.046$) after normalization to control surface area. Surface area was similar between repaired and control states and between injured and repaired states.

DISCUSSION

The current study demonstrated a novel method for quantifying capsuloligamentous injury measured as change in surface area after anterior shoulder dislocation using 3D geometric models of MR arthrograms. Comparison of injured to uninjured capsules demonstrated an increase in surface area. A decrease in capsular surface area was found postoperatively; however, surface area of injured and repaired capsules was similar. In a cadaveric study, increasing the magnitude of capsular plication was found to significantly decrease glenohumeral translation in a cadaveric model.[8] However, a quantitative method to determine how much tissue to plicate is still needed. Based on the limited data set, capsular surface area can be measured and may change after dislocation and plication. This study aims to enroll more patients to continue investigating changes in capsular surface area following injury and repair. Future studies identifying region-specific changes in surface area of the glenohumeral capsule will further guide plication location and may improve surgical outcomes.

REFERENCES

1. O'Brien SJ. *JSES*. 1995.
2. Mazzocca AD. *AJSM*. 2005
3. Sodl JF. *KSSTA*. 2016.
4. Yoshida M. *JOR*. 2020.
5. Bonnevialle N. *JSES*. 2009.
6. Westerheide KJ. *Arthroscopy*. 2006;
7. Hawk J. *ORS*. 2020.
8. Mayer S. *CORR*. 2018.

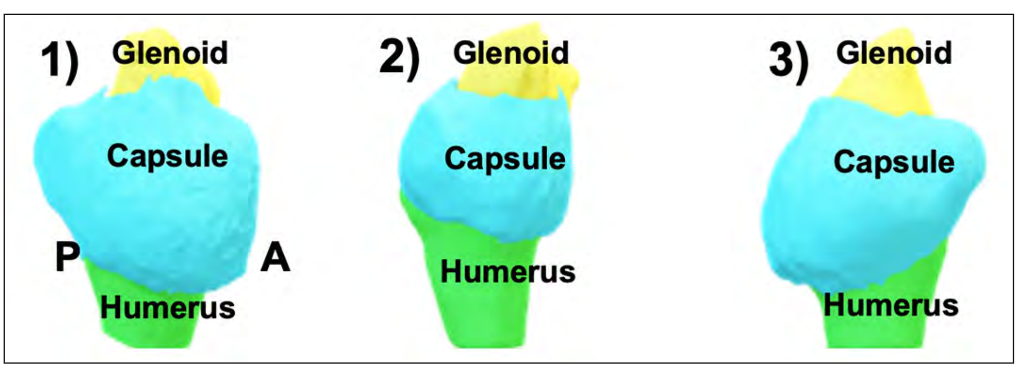


Figure 1. 3D Geometric Models of the Glenohumeral Joint. Injured (1), repaired (2), and control (3) models for a representative subject from an inferior view. All models are depicted in the same anterior-posterior orientation (A,P) as labeled on the Injured (1) model.

RISK FACTORS FOR TEAR PROGRESSION IN ISOLATED SYMPTOMATIC SUPRASPINATUS TENDON TEAR: A PROSPECTIVE STUDY

Inoue J[1,2], Takaba K[1,2], Takeuchi S[1,2], Mattar LT[1,2], Irrgang J[2,4], Musahl V[1,2,3], Debski RE[1,2,3]

[1]Orthopaedic Robotics Laboratory, University of Pittsburgh, Pittsburgh, Pa.
[2]Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.
[3]Department of Bioengineering, University of Pittsburgh, Pittsburgh, Pa.
[4]Department of Physical Therapy, University of Pittsburgh, Pittsburgh, Pa.

INTRODUCTION
Although exercise therapy is an effective treatment for patients with symptomatic rotator cuff tendon tears, tear size can increase. Understanding risk factors for tear progression will help physicians develop treatment plans and monitor tear size. Therefore, this study aimed to identify risk factors for tear progression in isolated symptomatic supraspinatus tendon tears. The authors hypothesized that a history of smoking and full-thickness tears would be risk factors for tear progression.

METHODS
The study prospectively enrolled patients who had a symptomatic isolated tear of the supraspinatus tendon that was more than 50% partial-thickness or full-thickness, as confirmed by ultrasound. There were a total of 109 patients. Seven patients were excluded because they underwent rotator cuff repair during follow-up. In addition, 22 patients did not undergo ultrasound examination at two-year follow-up. The remaining 80 patients (mean age = 60.8 ± 9.2 years, mean body mass index [BMI] = 28.7 ± 5.1, 36 female) were studied.

All patients participated in a standard 12-week exercise therapy program for non-operative management of rotator cuff tears. Tear length and width were measured with ultrasound at baseline and at two-year follow-up. Tear progression was defined by more than a 5 mm enlargement of tear size in length or width or change from partial-thickness to full-thickness tear at two-year follow-up. The risk factors considered included age, height, weight, BMI, hand dominance, onset of shoulder pain, history of smoking, and job type at the time of enrollment. The variables were compared between the progression and non-progression groups via univariate and multivariate analysis.

RESULTS
Fifty-eight patients (72.5%) did not have tear progression at two-year follow-up. BMI and weight were significantly larger in the progression group than in the non-progression group (p = 0.011, p = 0.033, respectively) (see Table 1). In the progression group, the rate of full-thickness tears and history of smoking (current or previous smoker) were significantly higher than in the non-progression group (p = 0.009, p = 0.002, respectively). Body weight, BMI, a history of smoking, and tear type were included in the multivariate analysis, which showed that history of smoking was significantly associated with an increased odds of tear progression (odds ratio = 4.48 [95% confidence interval, 1.44–13.9]; p = 0.009), but no other parameters were found to be significant.

DISCUSSION
The risk factors for progression of an isolated symptomatic supraspinatus tendon tear were 1) a history of smoking, 2) high body weight, 3) high BMI, and 4) a full-thickness tear. These findings were consistent with a previous study investigating rotator cuff tears, including multi-tendon tears, which showed that the risks for tear progression were smoking, medium-sized tear, and full-thickness tear. Smoking has been reported as a risk factor for developing rotator cuff tendon tear and failure for rotator cuff repair. This study revealed that individuals who were current or previous smokers had a 4.5-times higher risk of tear progression than non-smokers. Based on the data of this prospective clinical study, counseling should be done for the progression of rotator cuff tears in patients who smoke.

REFERENCES
1. Kwong CA. 2019. Arthroscopy;35(1):228-34.
2. Fucentese SF. 2012. *JBJS Am;* 94(9):801-8.
3. Safran O. 2011. *AJSM;*39(4):710-4.
4. Maman BE. 2009. *JBJS Am;*91(8):1898-906.
5. Yamamoto N. 2017. *AJSM;*45(11):2524-31.D

Variable	Progression Group (n=22)	Non-Progression Group (n = 58)	P Value
Age (years)	62.5 ± 9.6	60.1 ± 9.1	0.319
Sex (male/female)	15/7	29/29	0.144
Height (cm)	171.9 ± 8.0	171.0 ± 11.7	0.709
Body weight (kg)	91.7 ± 17.0	82.0 ± 18.2	**0.033**
Body mass index	31.0 ± 5.0	27.9 ± 4.9	**0.011**
Hand dominance (dominant side/non-dominant side)	14/8	33/25	0.585
Tear type (partial thickness/full thickness)	5/17	32/26	**0.009**
History of smoking (current or previous smoker/never smoker)	14/8	15/43	**0.002**
Job type (sedentary or light laborer/moderate or hard laborer)	11/11	27/31	0.783
Shoulder pain onset (injury/non-injury)	10/12	22/36	0.540

Data are reported as mean ± standard deviation; statistical significance is shown in bold.

Table 1. Comparison of demographic data between groups

MATERIAL PROPERTIES OF SKELETALLY IMMATURE HUMAN PATELLAR TENDONS AND ASSOCIATIONS WITH AGE AND BMI

Mattar LT[1], Höger SA[1,3], Baggett JJ[2], Runer A[1,3], Shea KG[4], Musahl V[1,2], Debski RE[1,2]

[1]Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.
[2]Department of Bioengineering, University of Pittsburgh, Pittsburgh, Pa.
[3]Department for Orthopaedic Sports Medicine, Klinikum rechts der Isar, Technical University of Munich, Munich, Germany
[4]Department of Orthopaedic Surgery, Stanford University, Stanford, Calif.

INTRODUCTION
The material properties of ligaments and tendons provide biomechanical information regarding their vulnerability to injury but have mostly been characterized in older age groups or throughout development in animal models.[1,2] Given the difficulty of obtaining skeletally immature human ligaments/tendons, porcine models of the knee are often used to investigate developmental changes. However, the translation to humans can be difficult due to differences between porcine and human knees. Furthermore, the material properties of tissue may change with age or body composition (e.g. body mass index [BMI]) given increased functional demands, which has implications for developing representative computational models and understanding injury. The objective of the study was to quantify the material properties of the central region of skeletally immature human patellar tendons and associations with age and BMI. The authors hypothesized that material properties would increase with age and BMI.

METHODS
Eleven skeletally immature human extensor mechanisms were acquired (age = 4.3 ± 3.1 years; BMI = 19.2 ± 5.5 kg/m^2; seven males, four females). The complex consisting of the central region of the patellar tendon and patella was scanned with a 3D laser scanning system (NextEngine 3D Scanner HD, Santa Monica, California) with 2.0% accuracy and 1.8% repeatability to measure cross-sectional area at the midsubstance of the patellar tendon after being dog-boned to a 5:1 ratio.[3] The extensor mechanisms were then mounted in a material testing machine (Instron Model 5965, Norwood, Massachusetts). The patellar tendons underwent a mechanical testing protocol with loading criteria normalized to cross-sectional area based on previous literature values.[3,4] The patellar tendons were preloaded (1% of ultimate stress), preconditioned for 20 cycles (1%–5% of ultimate stress), and then loaded to failure at 10mm/minute. Markers were placed below and above the midsubstance to calculate strain with a custom video tracking system and software[4] (DMAS7, 0.01 mm accuracy). The modulus, ultimate stress, ultimate strain, and strain energy density of the central region of the tendons were quantified from the obtained stress-strain curves. Pearson or Spearman correlations were used to determine associations among age, BMI, and material properties. Significance was set at $p < 0.05$.

RESULTS
Eleven skeletally immature human patellar tendons were loaded to failure. Ten patellar tendons failed at the midsubstance, and one patellar tendon failed at the clamp interface. Overall, the cross-sectional area at the midsubstance of the central region was 7.8 ± 5.3 mm^2. The ultimate stress and strain were 25.5 ± 8.3 MPa and 0.12 ± 0.05, respectively. The modulus and strain energy density were 296.4 ± 97.5 MPa and 1.6 ± 1.0 MPa, respectively. No associations were found among age, BMI, and material properties ($p > 0.05$), with the exception of a positive association between BMI and ultimate strain ($r^2 = 0.45$, $p = 0.02$). Thus, as BMI increased, ultimate strain increased, and changes in BMI accounted for 45% of the variation in ultimate strain.

DISCUSSION
The main findings from the current study were that the material properties of skeletally immature human patellar tendons were not associated with age or BMI, except for the association between BMI and ultimate strain. The association between BMI and ultimate strain indicates that the patellar tendon may adapt to changes in mass and height to accommodate increased range of motion at the knee throughout maturation. The ultimate stress and modulus were greater in the current study compared to previous work, and the ultimate strain and strain energy density were less.[4] Discrepancies between the two studies are likely due to the method used to calculate strain, where the method used in the current study more accurately tracks the deformation at the midsubstance. Compared to the material properties of cadaveric patellar tendons from older age groups (29–50 and 64–93 years),[5] the current study found 44.9% smaller moduli, 39.4% smaller ultimate stresses, 37.2% smaller strain energy densities, and similar ultimate strains. Computational models can utilize the findings of the current study to better represent the pediatric population and provide information to surgeons performing ligament reconstruction in skeletally immature patients. Future work will determine associations within certain age groups, defined as when pediatric patients would be crawling or walking.

REFERENCES
1. Howe D et al. *J Orthop Res*. 2022.
2. Castile RM et al. *JOR*. 2021.
3. Miller RM et al. *KSSTA*. 2017.
4. Schmidt EC et al. *OJSM*. 2019.
5. Johnson GA et al. *JOR*. 1994.

MUSCULOSKELETAL ONCOLOGY LABORATORY (MOL)

Kurt R. Weiss, MD, director
Ines Lohse, PhD, codirector
Tanya Heim, MS, manager/technician
Clark Roth, MD, orthopaedic surgery resident
Pedro Rivera-Puig, DVM, veterinary collaborator
Alma Heyl, LAS, RTR, CCRC, research coordinator
Beata Krawczyk, research coordinator
Rayleigh Richards, administrative staff
Jennifer Smith, administrative staff
Nerone Douglas, medical student
Luke Carlson, medical student
Anya Singh-Varma, medical student
Mare Kaulakis, medical student
Jayanth Kashyap, medical student
Maia Brown, medical student
Amanda Locker, biomedical master's program
Carl Kim, biomedical master's program

The MOL is directed by Kurt R. Weiss, MD, and codirected by Ines Lohse, PhD. Dr. Weiss is a surgeon-scientist in the Division of Musculoskeletal Oncology and the vice chair of translational research. Dr. Lohse is a research assistant professor in the department.

There is nothing as constant as change, and the past academic year has demonstrated this truth once again. The lone constant seems to be our marvelous team of scientific collaborators, which has never been stronger. This is reflected in our publications this year, with an even more productive year in the making. As always, we are grateful to Pittsburgh Cure Sarcoma, whose generosity helps to keep the Musculoskeletal Oncology Tumor Registry and Tissue Bank (MOTOR) up and running.

After approximately seven years of work, we have finally published our manuscript "RNA-Sequencing Predicts a Role of Androgen Receptor and Aldehyde Dehydrogenase 1A1 in Osteosarcoma Lung Metastases," in *Oncogene*. Tanya Heim, MS, was the lead author on this paper, and several former MOL residents (Margaret Hankins, MD, Rebekah Belayneh, MD, and Sumail Bhogal, MD) are also authors. This was absolutely the best science to come out of MOL and has set a very high bar for future work.

Our partnership with Robert Binder, PhD, was reflected in our publication in *JCI Insight* titled "Immunosurveillance Shapes the Emergence of Neo-Epitope Landscapes of Sarcomas, Revealing Prime Targets for Immunotherapy." Karen Schoedel, MD, professor in pathology, has been our friend and collaborator for many years. Nobody outside the lab has been a bigger champion of our work. Dr. Schoedel was the lead author on our manuscript titled "Grade 2, 3 and Dedifferentiated Chondrosarcomas: A Comparative Study of Isocitrate Dehydrogenase-Mutant and Wild-Type Tumors with Implications for Prognosis and Therapy" in *Cancers*. This paper also featured Ms. Heim, Drs. Lohse, Dr. Belayneh, and Dr. Bhogal, and our medical student Anya Singh-Varma. The last collaborative paper we wish to highlight is our first foray into comparative oncology. Pedro Rivera Puig, DVM, led the effort and was first author on the paper titled "Antioxidant 1 Copper Chaperone Gene Expression and Copper Levels in Dog Osteosarcoma Patients," in *Veterinary and Comparative Oncology.* Also listed as authors were former MOL residents Dr. Hankins, Belayneh, and Bhogal, as well as Bill Li, MD. Drs. Li and Weiss had the honor of representing the MOL at Dr. Puig's wedding in Puerto Rico in March.
Dr. Lohse celebrated her one-year anniversary with the lab in January 2024. To say that she is making her presence felt here in Pittsburgh would be quite an understatement!

After getting involved with the UPMC Hillman Cancer Center Summer Academy Cancer Biology Site in 2023, she is now the site codirector together with Deborah Galson, PhD. This appointment allows her to encourage and teach underprivileged students interested in STEAM fields (science, technology, engineering, the arts, and mathematics). This opportunity has allowed Dr. Lohse to dip her toes into teaching here at Pitt and connect with other laboratories and educators. Dr. Lohse has been excited to join the Mothers Leading Science (MLS) 2024 cohort here at Pitt. MLS is a competitive, yearlong leadership-development program that fosters professional and personal growth to develop future institutional leaders. The Drug Sensitivity Testing (DST) platform that Dr. Lohse was instrumental in developing at the University of Miami is gaining traction here at Pitt, with clinical trials on the horizon. Indeed, the DST platform has been invited to join the LifeX accelerator program to facilitate the further development and commercialization of the technology. Drs. Lohse and Weiss joined the accelerator as a team. This is significant progress toward our goal of making the platform available for all patients who are in need of stratification toward chemotherapy treatment. Last but not least, Dr. Lohse has been busy writing grants and received funding from Pittsburgh Cure Sarcoma for her drug-development research.

Dr. Weiss's role as chair of the Musculoskeletal Tumor Society Research Committee came to close at the 2023 annual meeting in Banff, Canada. He has expanded his role on the Connective Tissue Oncology Society (CTOS) Mentorship Committee and gave a podium presentation on indocyanine green fluorescence imaging in sarcoma surgery at the CTOS annual meeting in Dublin, Ireland. Dr. Weiss has been asked to join the Scientific Steering Committee of the Sarcoma Alliance for Research through Collaboration, the largest non-governmental supporter of sarcoma clinical trials. His term on this international committee will begin in October 2024. He was honored to speak at State University of New York Upstate both for the graduate students' scientific retreat and orthopaedic surgery grand rounds. He was also invited to speak at the University of Toronto Residents Research Day by his mentors Jay Wunder, MD, and Peter Ferguson, MD. To be invited back to teach by one's fellowship instructors is deeply humbling, and Dr. Weiss will treasure this memory. In February 2024, Dr. Weiss once again participated in the Orthopaedic Research Society (ORS)/Orthopaedic Research and Education Foundation Art of the Grant workshop at the beginning of the ORS meeting in Long Beach, California. He has been asked to co-chair the workshop next year and has gratefully accepted this prestigious honor. Finally, he has taken an advisory dean position with the medical school. Dr. Weiss describes this rewarding job as equal parts shepherd and cheerleader. On top of all of this, Dr. Weiss is excited to assist his colleagues in Pitt Ortho to help build the Bethel Musculoskeletal Research Center.

Ms. Heim is the lab's senior technician and effectively the MOL manager. If we have a reliable workhorse and Swiss Army Knife of the MOL, she is it! She has continued to be absolutely indispensable as

Drs. Weiss and Lohse have added new responsibilities and projects. The departure of our clinical research specialist has added even more responsibilities to Ms. Heim's plate, but she takes everything in stride and with humor. She continues to direct the MOL's regulatory efforts, which are necessitated by our growing list of scientific collaborators. She did yeoman's work on the *Oncogene* paper, tackling and overcoming one regulatory roadblock after another. Hopefully, her plate can be cleared a bit by Beata Krawczyk taking over more of the regulatory tasks and the (hopefully soon) hiring of a new clinical research specialist to take over the MOTOR-related tasks. A woman of many talents, Ms. Heim is a force on the bocce court and in axe throwing. In summary, we all remain grateful for her steady guidance, unflappable disposition, and attention to detail. A word of warning though: It would be unwise to poke fun at professional wrestling in her presence.

Our lab resident for 2023–24 is our own Mighty Mormon, Clark Roth, MD. "Clarky" has had a singularly interesting year in the MOL. He has been primarily working on the indocyanine green project, which at this stage is in statistical analysis and manuscript preparation. Dr. Roth has been the "closer" on a couple of manuscripts that have both been several years in the making. The "study study" has spanned several lab residents and is a truly multidisciplinary musculoskeletal oncology project that takes a critical look at how patients can be most appropriately and cost-effectively evaluated before they arrive at the surgeon's office. He also helped to finalize a case report on a fantastic osteosarcoma patient who had a humerus reconstruction with a contralateral free fibula graft compliments of the plastic and reconstructive surgery magicians Mario Solari, MD, and Alex Davit, MD. The patient, who presented with metastatic disease, is now a long-term survivor! Finally, Drs. Roth and Weiss wrote a very satisfying review article on the role of palliative care in musculoskeletal oncology. Despite these triumphs, Dr. Roth feels called to a different area of medicine. At the end of this academic year, he will be leaving Pittsburgh to enter a radiology residency at Texas A&M, which is where he went to medical school. We are sad to see him go, but obviously wish him and his family nothing but the best in this new adventure.

Our clinical coordinator Alma Heyl is essentially retired at this point but makes occasional appearances to give Ms. Krawczyk a hand and advice that only several decades of experience in this space can yield. We remain grateful for Ms. Heyl's countless hours of service to our research and remain confident that Ms. Krawczyk can fill some awfully big shoes. Golf shoes, that is. If you're looking for Alma, you might just find her "swinging the wrenches" with her husband, Mark.

For the Pitt medical students, we have a mixture of familiar and new names. The one thing they have in common is that they all make us very proud. Nerone Douglas is the "old man" of the group, which is crazy because we remember him when he was a lowly biomedical master's program (BMP) student trying to get into Pitt Med! How time has flown! He has done a dedicated research year, mainly with plastic surgery but with us as well. He is finishing up work on a sarcoma spheroids project that is funded through the Shadyside Hospital Foundation. Mr. Douglas will begin his final year at Pitt Med, and we selfishly hope that he will match here so that we don't need to say goodbye just yet. Luke Carlson is our second-year Pitt Med student and osteosarcoma survivor. Right now, Mr. Carlson is likely hunkered down somewhere in Minnesota preparing earnestly for Step 1 of the U.S. Medical Licensing Exam. Mr. Carlson has been pivotal on the MOVES and MOVES2 studies and all of our collaborations with Ahmad Tafti, PhD, in artificial intelligence. We wish him the best of luck on Step 1 and the start of his clinical years of Pitt Med! Anya Singh-Varma is a Physician Scientist Training Program (PSTP) student and, like Dr. Roth, is a closer! She has stepped in at the last minute with a couple of time-sensitive figures for abstract and manuscript submissions. We have a dynamic trio of first-year Pitt Med students in the MOL. Mare Kaulakis hails from New Mexico and is helping with the MOVES study. She dutifully interrogates the clinic lists for Drs. Weiss, McGough, and Lee to see whether there are any potential study patients on the horizon. With accrual to MOVES proceeding painfully slowly, this is of tremendous help to the project. Jayanth "Jay" Kashyap, a Pittsburgh lad from Fox Chapel, already has his hands full in the MOL. He is working on the "Polymets" collaboration with our old friend, Lisa Ercolano, MD, who does musculoskeletal oncology down the road at Allegheny Health Network but did her residency with us. He is also initiating a clinical study on metastatic renal cell cancer. Finally, Mr. Kashyap is starting an exciting translational study with Adam Olson, MD, in radiation oncology looking at circulating factors that may portend wound complications in soft-tissue sarcoma patients who receive preoperative radiation. Maia Brown may be from southern Maryland, but this young doctor-in-training has serious Pittsburgh roots. Her father went to high school at Shadyside Academy, and she is a proud Pitt graduate. Ms. Brown is embarking on an ambitious study that is a collaboration between Dr. Schoedel and Tullia Bruno, PhD, in cancer immunology. In another project funded by the Shadyside Hospital Foundation, Ms. Brown will take a deep dive into the immune microenvironment of osteosarcoma and chondrosarcoma metastases. Amanda Locker is in the same BMP program that gave us Mr. Douglas and Mr. Carlson. Ms. Locker is crushing it both in the classroom and in the lab. She is already mastering cell culture thanks to Ms. Heim's instruction. This summer, she will be assisting Dr. Lohse with a Pittsburgh Cure Sarcoma–funded sarcoma exosomes project. The student team is rounded out by Carl Kim, who is also in the BMP program and also helping us with vital cell culture and molecular studies.

We end this review with an update on the clinical trial we announced last year. You may recall that Matteo Trucco, MD, a pediatric oncologist at Cleveland Clinic, has begun enrolling sarcoma patients for a phase 1 clinical trial of liposomal doxorubicin, copper, and disulfiram (the Pittsburgh "triple treatment"). Thanks to a grant from Pittsburgh Cure Sarcoma, we will perform the correlative science here in Pittsburgh. On December 7, 2023, we hosted Kyle Geist and his parents in the lab. Kyle is on the clinical trial and visited the MOL for presentations and a tour. It was our great honor to host Kyle and his family for a memorable evening that we in the MOL won't soon forget. We are reminded of the wisdom of Dr. Freddie Fu, who taught us that everything starts with taking good care of the patient.

In closing, we expect the same excitement for the coming year. With our amazing MOL team, collaborators, and students, we are confident that we'll be ready!

INVESTIGATING MACROPHAGE POPULATIONS IN METASTATIC SARCOMA SAMPLES

Brown M[1], Lohse I[2], Heim T[2], Schoedel K[3], Kunning S[4], Bruno T[4], Weiss K[2]

[1]University of Pittsburgh School of Medicine, Pittsburgh, Pa.
[2]UPMC Department of Orthopaedic Surgery and UPMC Hillman Cancer Center, Pittsburgh, Pa.
[3]UPMC Department of Anatomic Pathology, Pittsburgh, Pa.
[4]UPMC Department of Immunology and Hillman Cancer Center, Pittsburgh, Pa.

BACKGROUND

Sarcomas are tumors of the bone and soft tissues that display high metastatic potential to the lung. Although the specific mechanisms remain elusive, studies in other malignancies have emphasized the role of the tumor microenvironment in metastasis. Macrophages play an imperative role in immunity and tumor progression. Here, the authors investigate the role of M1 (tumoricidal) and M2 (tumor permissive) macrophages in a panel of metastatic sarcoma samples.

METHODS

This study utilizes a set of three tissue arrays containing 69 samples of tumor metastases from the lungs of patients with metastatic sarcoma. Vectra Polaris tumor microarrays were used to investigate immune subsets of macrophages (CD68+/HLADR+/CD163- for M1, CD68+/HLADR-/CD163+ for M2). Cell counts per core and antibody were collected for bioinformatics analysis using R software.

RESULTS

Different subpopulations of macrophages, M1 and M2, were identified with differential antibody staining. Once completed, staining information will be correlated with patient outcomes, treatment response, and other clinical and demographic parameters.

CONCLUSION

With immunotherapy becoming more prevalent in cancer treatment, correct patient stratification is of the utmost importance. It is therefore imperative to understand the impact of the tumor microenvironment and immune cells on sarcoma metastasis and disease progression.

CHARACTERIZING ORTHOPAEDIC ONCOLOGIC POLYTRAUMAS: A COMPARISON OF PATIENTS UNDERGOING OPERATIVE FIXATION OF MULTIPLE FRACTURES TO THOSE WITH SOLITARY FRACTURES

Kashyap J[1], Heim T[1,2], Goodman MA[2], McGough III RL[2], Lee S[2], Ercolano L[3], Lohse I[1,2], Weiss K[1,2]

[1]Musculoskeletal Oncology Laboratory, Department of Orthopaedic Surgery, University of Pittsburgh School of Medicine, Pittsburgh, Pa.
[2]Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.
[3]Department of Orthopaedic Surgery, Allegheny Health Network, Pittsburgh, Pa.

BACKGROUND

Orthopaedic oncologic polytraumas, multiple fractures secondary to metastatic malignancies, are understudied but increasingly prevalent due to growing long-term survival of patients with metastatic cancer. Existing studies offer contradictory results regarding the management of multiple fractures with staged versus simultaneous operative fixations. This study aims to evaluate the incidence of patients presenting with multiple fractures and compare their patient and disease characteristics, treatment algorithms, and outcomes to those of patients with solitary fractures.

METHODS

As part of a multicenter study, the researchers are conducting a retrospective review of patients in their institution's orthopaedic oncology practice. Patients aged 18–89 years who presented with one or multiple pathologic or impending long-bone fractures secondary to metastatic carcinoma, plasmacytoma/multiple myeloma, or lymphoma between January 1, 1998, and October 31, 2020, are included. Data on demographics, preoperative characteristics, fracture details, and postoperative status are being collected from patients' medical charts. Data will be summarized with descriptive statistics and chi-squared tests.

RESULTS

Initial data from 50 patients has been collected, including nine patients with multiple fractures. The most common primary tumors were lung ($n = 11$), breast ($n = 11$), and renal cell carcinoma ($n = 11$), with femur fractures ($n = 41$) being predominant. The mortality rate was 9of 9 among the polyostotic patients and 29 of 41 among the monostotic patients (relative risk = 1.41; 95% confidence interval, 1.16, 1.72). Average survival after operation was higher for polyostotic patients (85.11 weeks versus 41.79 weeks).

CONCLUSION

The results from this multicenter study involving 13 U.S. investigative sites will help predict which patient populations are more susceptible to oncologic polytraumas and what treatment algorithms are associated with reduced mortality and risk of complications.

THE TUMOR IMMUNE MICROENVIRONMENT OF DEDIFFERENTIATED SARCOMAS: DIGITAL SPATIAL PROFILING SHOWS IMMUNE TRANSCRIPTIONAL DIFFERENCES BETWEEN DEDIFFERENTIATED LIPOSARCOMA AND CHONDROSARCOMA

Schoedel K[1], Zilla M[1], Li W[2], Belayneh R[2], Duensing A[1], Lohse I[2], Chandran U[3], Wang J[3], Weiss K[2]

[1]Department of Pathology, University of Pittsburgh, Pittsburgh, Pa.
[2]Department of Orthopedics, University of Pittsburgh, Pittsburgh, Pa.
[3]Department of Biomedical Informatics, University of Pittsburgh, Pittsburgh, Pa.

BACKGROUND

Dedifferentiated sarcomas display the most aggressive behavior among mesenchymal malignancies. The tumor immune microenvironment of sarcomas is poorly understood, although B cells in tertiary lymphoid structures have been associated with improved survival in dedifferentiated liposarcoma (DDLPS). In this study, the researchers explore differences in immune cell subsets and immune-related RNA transcripts with respect to DDLPS and dedifferentiated chondrosarcomas (DDCS). The researchers hypothesized that differences in immune cell subsets and immune-related RNA transcripts would account for differences in patient outcome.

METHODS

The researchers obtained 28 cases of DDCS and 42 cases of DDLPS from Department of Pathology files.

Image analysis: Representative FFPE tissue blocks of the dedifferentiated components were selected, and immunohistochemical stains for CD4, CD8, and CD20 were applied to whole sections. Automated image analysis was performed to quantitate immune cell densities per mm^2 of tumor area.

Vectra Polaris: Tissue microarrays containing 14 DDCS (26 2 mm cores) and 19 DDLPS (37 2 mm cores) were created. A panel of antibodies was applied to highlight immune subsets (CD3, CD8, CD20, CD68, CD163, and CTLA4). Cell counts per core and antibody were collected for bioinformatics analysis using R package ggpubr v.0.4.0.

Digital spatial profiling (DSP): Tissue microarrays containing nine DDCS (27 regions of interest) and 13 DDLPS (36 regions of interest) underwent DSP by Nanostring GEOMX. Regions of interest included areas of tumor infiltrated by immune cells and non-immune areas. RNA-seq data collected were analyzed with R package GeomxTools v.2.0.0.

RESULTS

Image analysis and Vectra Polaris showed increased T cells in DDLPS as compared to DDCS: increased CD4 by image analysis ($p = 0.038$) and increased CD8 by Vectra Polaris ($p = 0.022$). B-cell populations were not statistically different by both methods and were low in both tumors.

DSP revealed increased immune-related RNA transcripts in DDLPS cases both in immune infiltrated and non-immune areas of the tumors. Immunoglobulins and some complement factors appeared to be increased in non-immune areas.

CONCLUSION

The tumor immune microenvironments of DDLPS and DDCS are different in that T-cell subsets (CD4 and CD8) appear to be increased in DDLPS, whereas CD20 populations are low in both tumors. Immune-related RNA transcripts revealed by DSP in DDLPS are more numerous and show higher expression than in DDCS, likely contributing to survival outcomes. Ultimately, understanding how to alter the DDCS immune environment so that it resembles that of DDLPS may improve survival in DDCS.

INTRAOPERATIVE EVALUATION OF BONE AND SOFT-TISSUE SARCOMA SURGICAL MARGINS WITH INDOCYANINE GREEN FLUORESCENCE IMAGING

Roth C[1], Gong MF[1], Li WT[1], Bhogal S[1], Heim T[1], SIlvaggio M[1], Malek M[2], Dhupar R[3], Lee SJ[1], McGough RL[1], Weiss KR[1]

1Department of Orthopaedic Surgery, UPMC, Pittsburgh, Pa.
2Department of Pediatric General and Thoracic Surgery, UPMC Children's Hospital of Pittsburgh, Pittsburgh, Pa.
3Department of Thoracic Surgery, UPMC, Pittsburgh, Pa.

INTRODUCTION

Sarcomas are rare malignant mesenchymal tumors with more than 50 different histological subtypes. Surgical resection is the cornerstone of management, with achievement of negative margins on final pathology associated with the highest survival benefit. Positive margins portend a high risk of local recurrence (LR) and overall poor prognosis. Indocyanine green (ICG) dye is a safe fluorophore dye which has been used in intraoperative margin assessment for resection of breast and gastrointestinal tumors. ICG use in sarcoma surgery has primarily been studied in preclinical mouse models and warrants further investigation. This study is an ongoing prospective, nonrandomized clinical study to assess how intraoperative ICG fluorescence imaging performs compared to final pathology in evaluating resection margins in patients with bone and soft-tissue sarcomas.

METHODS

Institutional Review Board approval was obtained, and patients with biopsy-confirmed bone or soft-tissue sarcoma were enrolled from UPMC Shadyside. Exclusion criteria included: age younger than 18 years, prior adverse reaction to iodine or fluorescein, and renal failure. On day of surgery, intravenous ICG was infused preoperatively three hours before surgery at a 2.0 mg/kg dosage. Drug administration time and dosage were selected based on reported ranges considered both safe and sufficient for visualization.[1] Following completion of tumor resection, the excised tumor and tumor bed were imaged intraoperatively with a SPY-PHI fluorescent camera (Stryker Co., Kalamazoo, Michigan). Based on previously published protocols from the breast cancer literature, areas within the tumor bed with a fluorescence intensity ≥ 1.5x the background intensity of healthy tissue were deemed positive ICG margins.[2] ICG margin results were compared with both final pathology and the operating surgeon's blinded clinical impression of margin status.

RESULTS

The study has enrolled 54 subjects with bone (n = 10) or soft-tissue (n = 44) sarcomas. ICG margins matched final pathology in 48% (21 of 54) of cases, with 93% sensitivity and 28% specificity. Comparatively, surgeon impression matched permanent pathology in 68% (36 of 54) of cases, with 20% sensitivity and 89% specificity. Of six patients who went on to develop local recurrence, both ICG and pathology determined positive margins in five of six. No significant differences were found in ICG infusion time, infusion to incision time, or dosage between cases when ICG correctly or incorrectly matched final pathology. The presence of preoperative radiation (15 of 54), preoperative chemotherapy (nine of 54), or recurrent sarcoma (six of 54) also did not significantly affect ICG margins compared to final pathology.

CONCLUSION

ICG fluorescence imaging shows potential utility as an intraoperative margin-assessment tool in bone and soft-tissue sarcoma surgical resection. It demonstrates high sensitivity, which may make it a useful tool in the hands of operating surgeons. Larger sample sizes are still needed to further delineate optimal ICG dosing, infusion timing, and effects of histological subtype/chemotherapy/radiation. Improving our understanding of the variables which must be optimized to use ICG fluorescent imaging accurately and effectively will ultimately determine how useful this technology will be in decreasing local recurrence in sarcoma.

REFERENCES

1. Brookes MJ et al. Intraoperative near-infrared fluorescence guided surgery using indocyanine green (ICG) for the resection of sarcomas may reduce the positive margin rate: an extended case series. *Cancers (Basel)*. 2021;13.
2. Pop F-C et al. Absence of residual fluorescence in the surgical bed at near-infrared fluorescence imaging predicts negative margins at final pathology in patients treated with breast-conserving surgery for breast cancer. *Eur J Surg Oncol*. 2021;47:269-75.

DISFULFIRAM AND ENZALUTAMIDE COMBINATION THERAPY TO TREAT METASTATIC OSTEOSARCOMA *IN VITRO*

Heim T, Lohse I, Weiss K

Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.

INTRODUCTION

Aldehyde dehydrogenases (ALDH) are overexpressed in many cancer types.[1] Previous studies have shown that metastatic osteosarcoma (OS) tissues and cell cultures have increased expression of ALDH1A1. Furthermore, *in vitro* and *in vivo* studies using the ALDH-inhibitor disulfiram have been promising.[2] However, combination therapy is the clinical standard to prevent treatment resistance and reduce effective doses, reducing the risks of toxicity and associated side effects.[3] Pathway analyses of sequencing data predicted androgen receptor (AR) to directly activate ALDH1A1 in OS lung metastases samples. Enzalutamide is an AR inhibitor currently used to treat prostate cancer.[4] This study investigated the effects of the combination of disulfiram and enzalutamide in metastatic OS cell lines *in vitro*.

METHODS

Primary OS SaOS-2 and its metastatic clone, SaOS-LM2, were treated with disulfiram and enzalutamide alone and in a combination matrix. For combination-matrix experiments, cell viability was measured after 72 hours of treatment. Single-treatment dose curves were created, and SynergyFinder 3.0 was used to evaluate the combination-matrix data. Promising combination-treatment regimens will be evaluated with growth-curve analysis and clonogenic survival assays.

RESULTS

Less than 50% cell viability was observed at 30 µM disulfiram and 300 µM enzalutamide for both cell lines in the study when treated separately. The combination had an average Bliss synergy score of –1.39 ± 4.2 (95% confidence interval [CI]) in SaOS-2 and an –1.19 ± 2.98 (95% CI) in SaOS-LM2. Highest levels of synergy with a score of 3.96 (± 4.2) were observed at 10 µM disulfiram and 100 µM enzalutamide in SaOS-2 cells. SaOS-LM2 displayed the highest level of synergy at concentrations of 0.1 µM disulfiram and 100 µM enzalutamide with a score of 2.42 (± 2.98). These scores indicate that enzalutamide and disulfiram have an overall additive effect. SynergyFinder results also revealed antagonistic effects of the combination treatment when treating SaOS-2 with doses of enzalutamide at 33 µM and lower, an effect that was not observed in SaOS-LM2 cells.

CONCLUSIONS

Disulfiram and enzalutamide have an additive effect when used in combination to treat OS *in vitro*. When used in combination, both drugs can be used at lower concentrations to achieve effective cell death. However, the effective dose of enzalutamide remains at least one order of magnitude greater than reported IC50s in cancers responsive to AR inhibition.[5] Furthermore, enzalutamide displayed antagonistic effects at these reported clinical doses when treating the primary OS cell line SaOS-2 in combination with disulfiram. Low-dose disulfiram has relatively low non-targeted toxicity and poses far fewer side effects than most chemotherapies used in the standard care of OS patients.[6] Because treatment of metastatic OS has been promising with clinically relevant doses, the authors are further investigating disulfiram with other chemotherapy agents.

REFERENCES

1. Zanoni M et al. *Front Med (Lausanne)*. 2022;1(9):795762.
2. Mandell J et al. *Sarcoma*. 2022;2022:7157507.
3. Harris M & Hawkins C. *Int J Mol Sci*. 2022;23(7):3817.
4. Heim T et al. *Oncogene*. 2024. doi: 10.1038/s41388-024-02957-x.
5. Purushottamachar P. *J Med Chem*. 2013;56(12):4880-98.
6. Lanz J et al. *Antibiotics (Basel)*. 2023;12(3):524.

ARTHRITIS AND ARTHROPLASTY DESIGN LAB

Ken Urish, MD, PhD, director
Beth Knapick, research specialist/ lab manager
Rekha Arya, postdoctoral fellow
Dongzhu Ma, scientist
Nadine Sadaka, research fellow
Jewelia Rempuszewski, research fellow
Andrew Frear, medical student
Sanathan Iyer, medical student
Victoria Wong, medical student
Richard Chao, medical student
Andrew Gordon, medical student
Christian Cisneros, medical student
Ye Seo Park, graduate student
Claudette Moul, undergraduate student
Niosha Parvizi, undergraduate student
Matthew Delach, undergraduate student
Shivani Patel, undergraduate student
Anthony Zygmunt, undergraduate student
Santiago Caceres, undergraduate student

Overview
The Arthritis and Arthroplasty Design (AAD) Lab was founded in 2016 with a mission to improve diagnosis and treatment of arthritis, focusing on joint arthroplasty. Our work is highly translational, with an emphasis on conducting basic science projects and clinical studies to improve the diagnosis, management, and treatment of arthritis. To accomplish this, the engineering and translational work in the laboratory focus on using bioreactor design, drug development, and molecular diagnostic and biomarker techniques. Retrospective, prospective, and large health population databases are used to quantify clinical outcomes. Clinical research topics include periprosthetic joint infection, taper corrosion in hip arthroplasty, and quantitative magnetic resonance imaging for early diagnosis of osteoarthritis and cartilage injury.

Year in Review
The establishment of the lab was supported by generous startup funds from the Department of Orthopaedic Surgery. Additional federal funding has since been obtained from the National Institutes of Health (NIH) and the Combating Antibiotic-Resistant Bacteria Biopharmaceutical Accelerator project (CARB-X), funded by the Biomedical Advanced Research and Development Authority, National Institute of Allergy and Infectious Diseases (NIAID), Bill and Melinda Gates Foundation). Other national funding sources include the Orthopaedic Research and Education Foundation and the Musculoskeletal Tissue Foundation. We are very excited about our funding with the NIH award from National Institute of Arthritis and Musculoskeletal and Skin Diseases and NIAID.

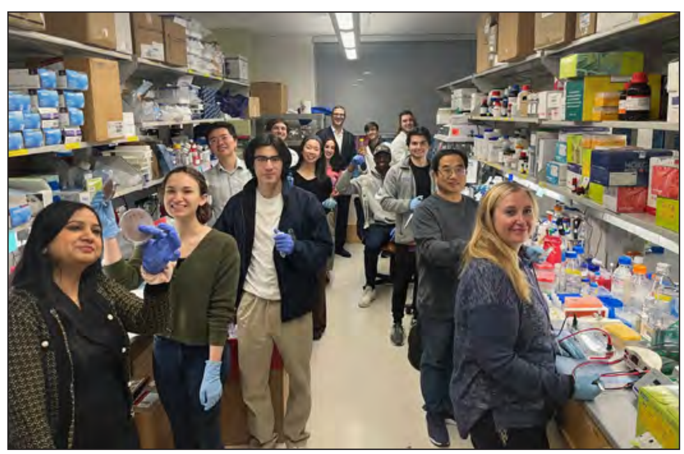
A key success of the group is its productive collaborations inside and outside the University. Projects are being completed with Hang Lin, PhD, and Peter Alexander, PhD. There are two prospective clinical studies being completed with the Biodynamics Laboratory under the leadership of its director, William Anderst, PhD. Here, changes in knee kinematics and clinical outcomes before and after surgery with robotic total knee arthroplasty and unicondylar knee arthroplasty will be completed. A series of multicenter clinical studies are underway with Neel Shah, MD, Department of Infectious Disease. Study design and statistical support are being completed by Dr. Scott Rothenberger, PhD, of the Clinical and Translational Science Institute. Finally, the laboratory is indebted to the continued support of its close collaborators and friends Kurt Weiss, MD, of the Cancer Stem Cell Laboratory. Strong collaborations with Carnegie Mellon University are essential for chemistry and engineering support.

The staff, medical students, undergraduates, and research fellows are spectacular in their dedication, effort, and ability to get the job done—all essential skills for being top-notch residents. The group will remain focused on attracting talented and energetic members whenever they are available and establishing continued productive collaborations in the upcoming year.

Rekha Arya, PhD, joined the group. Dr. Arya has worked for more than 14 years in areas related to quorum sensing, multi-omics in microbiology, microbial pathogenesis, and anti-virulence drug discovery; she has advanced knowledge in molecular characterization, cloning, bacterial cultures, cytotoxicity, and drug discovery.

Dongzhu Ma, MD, PhD, was welcomed back to the lab. Dr. Ma brings with him a wealth of experience and technical expertise. He is an expert with highly technical molecular techniques, including polymerase chain reaction and complex molecular biology assays.

This year has been very productive. There have been more than 20 publications, 13 Orthopaedic Research Society abstracts, and a series of major grants. This includes a major CARB-X grant supporting the development of a new class of antibiotics that has recently moved into U.S. Food and Drug Administration phase 1b studies (#NCT05137314). Other new areas of support include a Small Business Innovation Research grant, as well as a new R03 continuing our efforts in improving the diagnosis and treatment of osteoarthritis and outcomes after total knee arthroplasty. Finally, our group is very excited about its R01 support.



AAD Lab members from left to right: Rekha Arya, Jewelia Rempuszewski, Santiago Caceres, Richard Chao, Vicky Wong, Andrew Frear, Nadine Sadaka, Ken Urish, Matthew Delach, Anthony Zygmunt, Andrew Gordon, Christian Cisneros, Dongzhu Ma, and Beth Knapick

SUB-OPTIMAL DOSING OF VANCOMYCIN INCREASES RATES OF BIOFILM FORMATION AND SURGICAL INFECTION IN AN ANIMAL MODEL

Brothers KM, Parker DM, Ma D, Taguchi M, Thurlow LL, Urish KL

Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.

INTRODUCTION

Antibiotic stewardship is a cornerstone in the prevention of development of antibiotic-resistant organisms. This has great public health benefit, protecting the availability of effective antibiotics, but less obvious benefit at the individual level. At levels below the minimum inhibitory concentration (MIC), antibiotics have been observed to alter growth rates of many bacteria, including *Staphylococcus aureus*, the primary organism associated with orthopaedic infection. This is a particular concern with orthopaedic infection, as bone and joints are less permeable to antibiotics and have a notoriously lower level of bioavailability as compared to other tissue, leading to exposure to sub-MIC levels of antibiotics. Clinical studies have reported increased rates of surgical infection when vancomycin is used as compared to cefazolin.[1] The focus of this study was to determine the effect of sub-MIC levels of vancomycin on *S. aureus* growth, biofilm formation, and virulence. The authors hypothesized that sub-MIC levels of vancomycin could increase bacterial growth, biofilm formation, and rates of infection.

METHODS

S. aureus (MRSA USA300 JE2, MSSA Newman and SH1000) were used for all experiments. Bacteria were grown planktonically and were monitored with spectrophotometry. Quantitative agar culture was used to measure *S. aureus* biofilm biomass on titanium rods treated with sub-MIC vancomycin (0.00, 0.25, 0.50 µg/ml). A mouse abscess model was used to confirm phenotypes *in vivo*.

RESULTS

At 1/4 MIC, statistically significant increased rates of planktonic growth were observed in comparison to untreated controls (see Figure 1A). Treatment with 1/4 and 1/2 MIC vancomycin resulted in increased biofilm formation by approximately 150% ($p < 0.05$) and 244% ($p < 0.001$) in comparison to controls by 72 hours (day 3) of growth (see Figure 1B). Similar findings were observed in the Newman and SH1000 strain backgrounds. In a mouse abscess model, the biofilm mass (colony-forming unit) of the sub-MIC group was 7.5×10^6 and control was 5.8×10^5 at three days post-infection ($p < 0.01$). The infection rate was 44.38% (control) and 62.08% (sub-MIC) at three days post-infection ($p = 0.03$) (see Figure 1C).

DISCUSSION

Sub-MIC concentrations of vancomycin promoted *S. aureus* planktonic growth and biofilm formation, phenotypic measures of bacterial virulence. This phenotype induced by sub-MIC levels of vancomycin was observed to increase rates of infection and pathogenesis in the mouse animal model. The results suggest the importance of proper antibiotic selection, dosing, and indications. Further work is needed to confirm these results with clinical correlation.

SIGNIFICANCE

Risks of sub-MIC concentrations with vancomycin in orthopaedic procedures are greater, as there is decreased bioavailability in musculoskeletal tissue in comparison to other antibiotics. This highlights the importance of proper antibiotic stewardship and dosing of vancomycin for both surgical prophylaxis and treatment of orthopaedic infection. Proper antibiotic stewardship has the potential to improve individual outcomes for the patient by decreasing rates of surgical site infection.

ACKNOWLEDGMENTS

This research was supported by the Orthopaedic Research and Education Foundation, Musculoskeletal Tissue Foundation, and the National Institutes of Health (NIH/National Center for Advancing Translational Sciences KL2 TR000146, National Institute of Arthritis and Musculoskeletal and Skin Diseases K08AR071494).

REFERENCE

1. Wyles. *BJJ*. 2019.

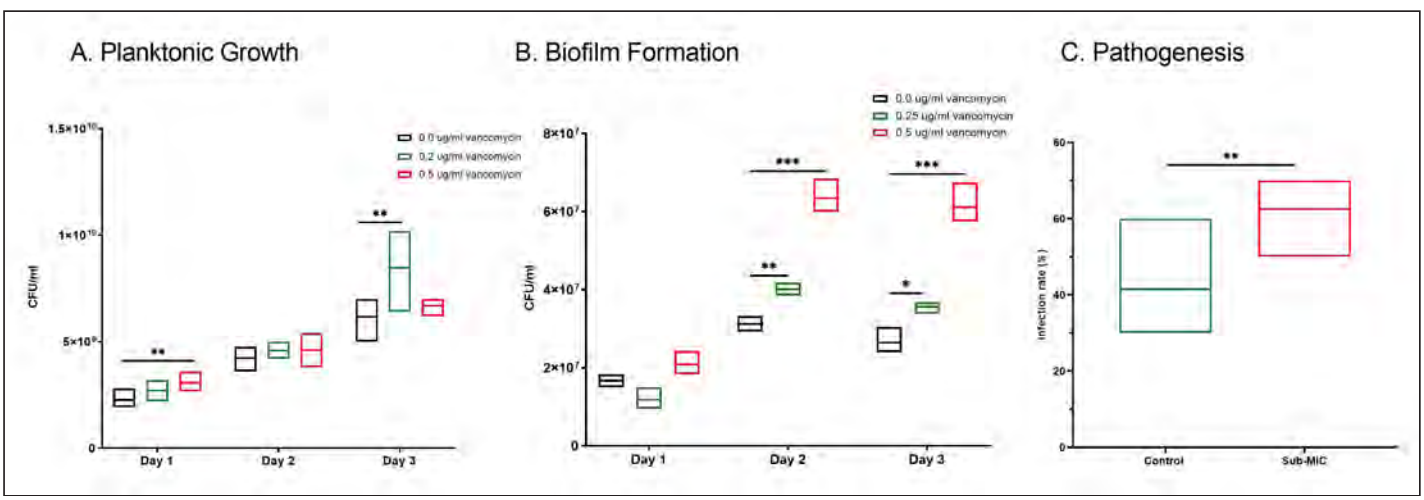


Figure 1. A. Sub-MIC vancomycin increased *S. aureus* planktonic growth in comparison to untreated controls.
B. Sub-MIC vancomycin increased *S. aureus* biofilm growth in comparison to untreated controls.
C. In a surgical infection model, mice inoculated at an ID50 with *S. aureus*, sub-therapeutic dosing resulted in increased infection rates.
***p < 0.05, **p < 0.01, ***p < 0.001**

PLG0206, AN ENGINEERED ANTIMICROBIAL PEPTIDE, HAS POTENT ACTIVITY AGAINST BIOFILM AND RESULTS IN DISEASE-FREE SURVIVAL IN A RABBIT MODEL OF *STAPHYLOCOCCUS AUREUS* PERIPROSTHETIC JOINT INFECTION

Brothers KM[1], Mandell JB[1,2], Taguchi M[1], Parker DM[1], Alexander PG[1], Dobbins D[4], Huang DB[4], Pachuda N[4], Urish KL[1,3]

[1]University of Pittsburgh, Department of Orthopaedic Surgery, Pittsburgh, Pa.
[2]University of Pittsburgh, Department of Infectious Diseases and Microbiology, Pittsburgh, Pa.
[3]University of Pittsburgh, Department of Bioengineering, Pittsburgh, Pa.
[4]Peptilogics, Pittsburgh, Pa.

INTRODUCTION

Periprosthetic joint infection (PJI) of total knee arthroplasties represents a major challenge to the field of orthopaedic surgery. These infections are commonly associated with antibiotic-tolerant *Staphylococcus aureus* biofilm. Cationic amphipathic peptides (CAPs) are antimicrobial peptides that serve as an alternative therapeutic strategy for treatment of recalcitrant bacterial biofilms. PLG0206 is a new class of broad-spectrum antimicrobials that has potent *in vitro* activity against biofilm, which led the authors to investigate local treatment of *S. aureus* biofilm as an adjuvant during a DAIR (debridement and antibiotics with implant retention) procedure.

METHODS

A rabbit PJI model was used, where a Kirschner wire tibial implant 20 mm long with a 3 mm articular hook was placed into the proximal tibia. After closure of the joint space, $2x10^6$ CFU/ml *S. aureus* (SH1000) was injected into the intra-articular space, and a mature biofilm was allowed to develop. At two days post infection, the joint space was reopened, irrigated, debrided, and treated with 0.5, 1, and 2 mg/ml PLG0206 for different time durations. For the survival study, at two days post-infection, rabbits were treated with 1 mg/ml PLG0206 for 15 minutes, and survival was monitored up to a period of 28 days. Animals were treated with cefazolin for a period of five days starting at two days post-infection and ending at seven days post-infection (see Figure 1B, vertical dashed line). When animals succumbed to infection, the metal implants and part of the proximal tibia were harvested. Implants were removed by sterile manipulation and colony-forming unit analysis.

RESULTS

Implants removed at two days post-infection and treated with 1 mg/ml and 2 mg/ml PLG0206 for 15 minutes had a significant reduction in bacterial biofilm burden, more than 100-fold (lower horizontal dashed line) (*$p < 0.05$) compared to incision-and-drainage-alone implants (see Figure 1A). An increase in biofilm bacterial burden was observed in implants treated at decreased times and peptide concentrations. I&D-alone rabbits all succumbed to infection within four days post-infection (see Figure 1B). Rabbits treated with PLG0206 only survived slightly longer but still displayed 0% survival by eight days post-infection. Cefazolin-treated rabbits (see Figure 1B, vertical dashed line) had 0% survival by 14 days post-infection. Rabbits that received combination treatment of systemic cefazolin and PLG0206 had 63% survival at 28 days post-infection ($p < 0.05$).

DISCUSSION

In the short-term *in vivo* experiments, PLG0206 significantly reduced bacterial biofilm burden in a rabbit PJI model. Increased dosing of PLG0206 had no greater impact on reduction of bacterial burden. Cefazolin-treated rabbits survived longer than both I&D-alone and PLG0206-treated animals. Combination therapy of PLG0206 with cefazolin was the most successful, with 63% rabbits surviving out to 28 days post-infection. These studies identify PLG0206 in combination with cefazolin as a promising new therapy for treatment of PJI.

ACKNOWLEDGMENTS

Combating Antibiotic-Resistant Bacteria Biopharmaceutical Accelerator project (CARB-X) funding for this research is supported by the Cooperative Agreement Number IDSEP160030 from Administration for Strategic Preparedness and Response /Biomedical Advanced Research and Development Authority and by an award from the Wellcome Trust. The contents are solely the responsibility of the authors and do not necessarily represent the official views of the U.S. Department of Health and Human Services Office of the Assistant Secretary for Preparedness and Response, or other CARB-X funders.

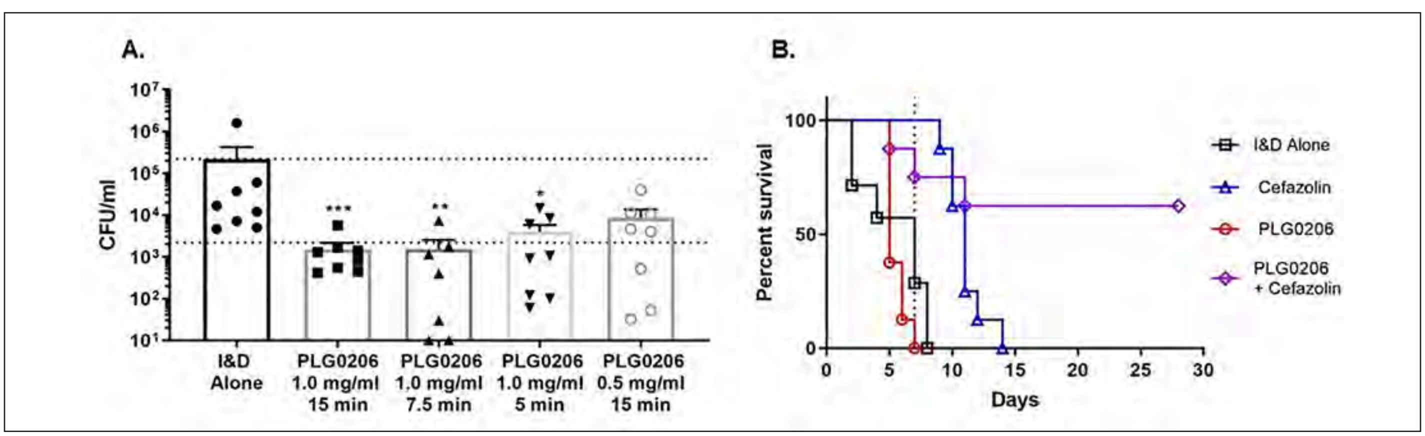


Figure 1. A. *In vivo* intra-articular treatment of PJI with PLG0206 for 15 minutes clears *S. aureus* biofilms. *$p < 0.05$ **$p < 0.01$ ***$p < 0.001$ B. Treatment with cefazolin systemically and PLG0206 intraoperatively results in increased survival.

IDENTIFYING OPTIMAL MONITORING PERIOD FOR TOTAL KNEE ARTHROPLASTY PERIPROSTHETIC JOINT INFECTION AFTER DEBRIDEMENT, ANTIBIOTICS, AND IMPLANT RETENTION

Chao R[1], Rothenberger S[1], Plates J[2], Klatt B[2], Shah NB[3], Urish KL[2]

[1]University of Pittsburgh School of Medicine, Pittsburgh, Pa.
[2]Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.
[3]Division of Infectious Diseases, University of Pittsburgh Medical Center, Pittsburgh, Pa.

INTRODUCTION

Periprosthetic joint infection (PJI) stands as the primary cause of total knee arthroplasty (TKA) failure. Debridement, antibiotics, and implant retention (DAIR) is a commonly employed intervention for TKA PJI. Identifying optimal monitoring periods after DAIR would be highly beneficial from an outpatient workflow perspective, and it could help in early detection of treatment failure as well as detecting adverse events among individuals who are on extended antibiotic therapy. It has been suggested that one year of monitoring is sufficient for accurate reporting for treatment failure of PJI of the hip or knee.[1] The optimal monitoring period for studying PJI is still not well established. This study aims to use breakpoint analysis to identify an optimal monitoring period for TKA PJIs.

METHODS

A prospective registry study involved 108 TKA PJI patients who underwent DAIR between 2005 and 2015 across 16 hospitals in a regional health system. Patients were followed up until December 31, 2022, to assess treatment failure rates. Breakpoint analysis was used to determine time points of significant decline in treatment failure rates, optimal monitoring periods, and differences in time to failure between acute PJI treated with acute antibiotics alone and those with extended oral antibiotics. Breakpoints are time points where there are statistically significant declines in TKA PJI failure rates.

RESULTS

The double breakpoint model identified significant changes in the failure rate at 0.92 years (95% confidence interval (CI): 0.90, 0.99) and 4.49 years (95% CI: 4.43, 4.49), the points in time by which 53.2% and 79.1% of all failures occurred, respectively. Estimated piecewise linear functions and breakpoints for the double breakpoint model are shown in Figure 1. Comparing the failure rate between 0–0.92 years and 0.92–4.49 years revealed a rate ratio of 14.12 (95% CI 9.67, 18.56; $p < 0.001$); in other words, the rate of change in the failure curve prior to 0.92 years was estimated to be 1,312% higher than the rate of change at 0.92–4.49 years. When comparing the rate of change in failure between 0.92–4.49 years and 4.49 years, the researchers obtained a rate ratio of 2.04 (95% CI: 0.99, 3.10; $p < 0.001$), indicating that the rate of change in failure was roughly half as large after 4.49 years compared to 0.92–4.49 years.

Stratified by antibiotic regimen, failure rates at one and five years were 62.5% and 85.0% for acute antibiotics alone and 42.3% and 73.1% for acute and extended antibiotics, respectively. No significant difference in time to failure was found between the two regimens.

DISCUSSION

This study fills a research gap on time to failure and monitoring periods for DAIR-treated PJI. Most failures occur by the one-year mark, and breakpoints at approximately one and five years indicate the critical monitoring period to be between one and five years. Continued evaluation and prospective studies are essential to validate these findings and guide clinical practice.

REFERENCE

1. Xu C et al. *Journal of Arthroplasty*. 2020;35(7):1906-11.

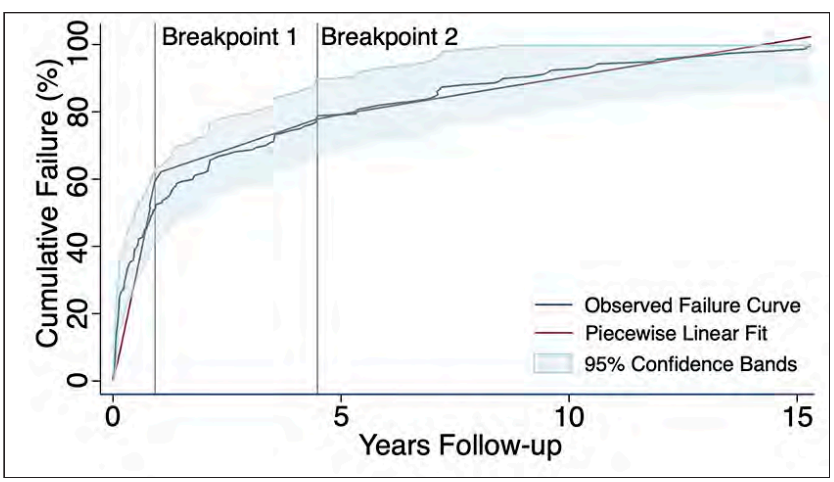


Figure 1. Double breakpoint model of cumulative PJI failures for all patients

PROSPECTIVE COHORT STUDY IDENTIFYING RISK FACTORS ASSOCIATED WITH TREATMENT FAILURE FOR ACUTE PERIPROSTHETIC JOINT INFECTIONS AFTER DEBRIDEMENT, ANTIBIOTICS, AND IMPLANT RETENTION

Chao R[1], Rothenberger S[1], Frear A[1], Hamlin B[2], Shah NB[3], Urish KL[2]

[1]University of Pittsburgh School of Medicine, Pittsburgh, Pa.
[2]Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.
[3]Division of Infectious Diseases, University of Pittsburgh Medical Center, Pittsburgh, Pa.

INTRODUCTION

Periprosthetic joint infections (PJIs) are common and serious complications after total knee arthroplasty (TKA). The preferred intervention—debridement, antibiotics, and implant retention (DAIR)—has fair success rates, but multiple retrospective studies have reported failure rates of 33% to 64%. The role of extended oral antibiotics in PJI with retained infected hardware is uncertain, with conflicting retrospective findings on prevention and survival benefits.[1] No prospective studies have addressed this gap.

This study aims to prospectively investigate the impact of prolonged oral antibiotics on preventing treatment failure in PJI. Objectives include comparing treatment failure rates in DAIR patients with and without extended oral antibiotics, identifying predictive risk factors for PJI treatment failures, and evaluating adverse events associated with extended oral antibiotic use.

METHODS

The researchers performed a prospective, multicenter cohort study including 74 TKA PJI patients undergoing DAIR between 2016 and 2021 across 16 hospitals within a regional health system. Descriptive statistics quantified patient characteristics and adverse events (AEs) by antibiotic duration. Fisher exact test compared AE rates between primary antibiotic and chronic therapy patients. Cox proportional hazards models assessed survival probability relative to antibiotic duration (continuous and categorical). Time-to-event analyses estimated mortality probability. Multivariable Cox models, incorporating patient and clinical characteristics, determined predictors of survival probability, employing forward selection (0 < 0.05 for variable entry). Time on antibiotics (continuous or categorical) was retained in every model.

RESULTS

Of the 74 patients in the study, 39 received acute antibiotics and 35 received acute and extended oral antibiotics. The average body mass index was 33.3 kg/m^2, and 41.9% were female. Multivariable analysis showed extended antibiotic use and gender as predictors of treatment success. Men had double the hazard for failure compared to females. Kaplan-Meier curves indicated no significant difference in infection-free survival, but hazard ratios demonstrated a significant difference favoring extended oral antibiotics. No statistically significant difference in AEs were found between patients on acute antibiotics alone and those on acute and extended oral antibiotics, suggesting safe administration of extended oral antibiotics.

DISCUSSION

The effectiveness of extended oral antibiotics remains controversial, with retrospective studies showing conflicting results. This prospective study suggests a statistically significant decrease in PJI treatment failure with extended oral antibiotic therapy. Females had a significantly lower hazard ratio for treatment failure, indicating male sex as a potential risk factor for PJIs. Despite the extended oral antibiotics group being older, there was decreased treatment failure, supporting the effectiveness of extended oral antibiotics. A limitation for the study was that it was not randomized, and choice of antibiotics was surgeon dependent.

This prospective study provides evidence that extended oral antibiotics may decrease PJI treatment failure. Gender and age were identified as potential predictive factors. Continued evaluation through larger prospective studies is necessary to support these findings.

REFERENCE

1. Shah NB et al. *Clinical Infectious Diseases.* 2020;70(4):559-65.

Predicting Factors	Unadjusted HR (95% CI)	Unadjusted P Value	Adjusted HR	Adjusted P Value
Abx Duration		0.043		0.017
Primary Alone	(reference level)		(reference level)	
Primary+ Chronic	0.53 (0.28, 0.98)		0.46 (0.24, 0.87)	
Age	0.98 (0.96, 1.01)	0.219	---	---
BMI	0.99 (0.95, 1.03)	0.596	---	---
Sex		0.091		0.036
Male	(reference level)		(reference level)	
Female	0.58 (0.30, 1.11)		0.49 (0.25, 0.95)	
CCMI	0.92 (0.79, 1.08)	0.281	---	---
DM	0.77 (0.34, 1.75)	0.538	---	---
RA	1.27 (0.50, 3.25)	0.616	---	---
ASA Score		0.199	---	---
1-2	(reference level)			
3	1.65 (0.68, 4.00)			
4	3.40 (0.93, 12.42)			
Host Score		0.588	---	---
A	(reference level)			
B	0.68 (0.31, 1.47)			
C	0.78 (0.10, 6.27)			
Time Symptomatic			---	---
<1 week	(reference)	0.861		
2-4 weeks	1.08 (0.45, 2.59)			
>4 weeks	NA (nobody >4 weeks)			
Primary Organism		0.262	---	---
Culture Negative	(reference)			
Staph Aureus	1.45 (0.68, 3.21)			
Other	0.80 (0.36, 1.78)			

Table 1. Multivariable analysis of predictors of treatment success

ANALYZING HOW TIMING OF DEBRIDEMENT, ANTIBIOTICS, AND IMPLANT RETENTION IN TOTAL KNEE ARTHROPLASTY PERIPROSTHETIC JOINT INFECTION AFFECTS RATES OF REOPERATION

Frear A[1], Sadhwani S[2], Kamson A[2], Cisneros C[1], Chao R[1], Smith C[3], Wilson A[1], Shah N[4], Klatt B[3], Urish K[3]

[1]University of Pittsburgh School of Medicine, Pittsburgh, Pa.
[2]Department of Orthopaedic Surgery, UPMC Central PA, Harrisburg, Pa.
[3]Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.
[4]Division of Infectious Diseases, UPMC, Pittsburgh, Pa.

INTRODUCTION

In total knee arthroplasty (TKA) periprosthetic joint infection (PJI), debridement, antibiotics, and implant retention (DAIR) has a high failure rate. The objective of the current study was to evaluate differences in DAIR outcomes performed at postoperative versus intermediate versus hematogenous time points from index TKA.

METHODS

The researchers performed a retrospective review of 67 patients ages 18 to 80 years who were diagnosed with PJI after TKA and underwent DAIR from 2018 to 2020. Categorization was based on timing of DAIR relative to index arthroplasty, with zero to six weeks termed postoperative (n = 26), six weeks to one year termed intermediate (n = 11), and more than one year termed hematogenous (n = 30). Exclusion criteria consisted of operations between index procedure and DAIR, trauma to joint, chronic antibiotic use, positive blood cultures, diabetes with A1C > 9, body mass index > 50, current substance abuse, alcoholism, smoking, and immunosuppressant use. The primary outcome was failure rate based on infection recurrence, defined as any type of reoperation. Manipulations under anesthesia were not deemed DAIR failure.

RESULTS

The overall failure rate was 44% at two-year follow-up (19% at three months; 27%, at six months, and 45% at one year) following DAIR. At three months, 22 postoperative, eight intermediate, and 26 hematogenous group patients remained failure free (86% versus 73% versus 85%, p = 0.56). At six months, 24 postoperative, seven intermediate, and 19 hematogenous group patients remained failure free (80% versus 64% versus 73%, p = 0.55). At one year, 17 postoperative, five intermediate, and 22 hematogenous group patients remained failure free (65% versus 45% versus 66%, p = 0.25). The majority of DAIR failures occurred within one year of operation (see Figure 1).

CONCLUSION

The overall failure rate following DAIR for acute TKA PJI is high. No significant difference was observed in DAIR failure rates between any PJI group, although there was a trend toward intermediate PJI DAIR having a higher failure rate than postoperative or hematogenous PJI DAIR. Additional power is necessary to further assess timing of DAIR and its effects on reoperation rates.

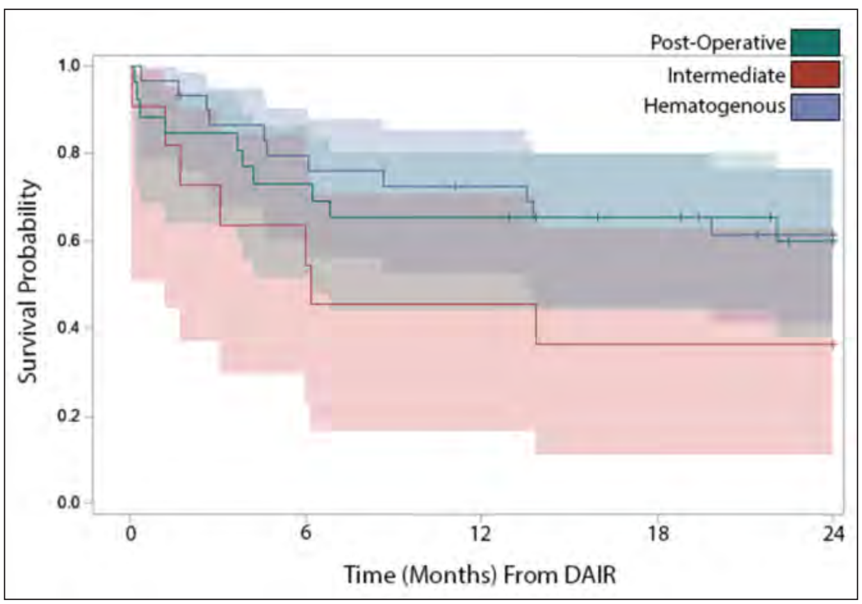


Figure 1. Debridement, antibiotics, and implant retention (DAIR) failure as time of DAIR from index TKA. Kaplan-Meier survival analysis with 95% confidence interval shading. Wide overlap of shading denotes non-significance at all observed time points. No significance was found among the three groups.

EXPRESSION OF METHICILLIN RESISTANCE IN *STAPHYLOCOCCUS AUREUS* IS MEDIA DEPENDENT

Gish CG, Cappellini AJ, Mandell JB, Metwali OA, Koch JA, Brothers KM, Urish KL

Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.

INTRODUCTION

Methicillin-resistant *Staphylococcus aureus* (MRSA) infections are an increasing issue in the orthopaedic field, with an increase from 2% to 50% of all *S. aureus* infections classified as MRSA from 1974 to present.[1,2] *S. aureus mecA* is the source of methicillin resistance. The *mecA* gene is responsible for resistance to beta-lactam antibiotics, such as penicillin, amoxicillin, and cefazolin.[3] The purpose of this study was to test conditions that lower methicillin resistance. The authors hypothesized that culturing MRSA in different culture conditions would result in altered cefazolin resistance.

METHODS

MRSA USA300 JE2, MSSA SH1000, and nine MRSA clinical isolates were tested. To determine minimum inhibitory concentration (MIC) of planktonic bacterial strains, the researchers inoculated each strain in Mueller Hinton Broth (MHB), Tryptic Soy Broth (TSB), Fetal Bovine Serum (FBS), and 10% FBS + Dulbecco's Modified Eagle Medium (10% FBS + DMEM) overnight at 37^{o} C. Strains were normalized to 0.5 x 10^{6} colony-forming units (CFUs)/ml in each media condition, plated in 96-well plates with serial dilutions of vancomycin and cefazolin ranging from 0–500 µg/ml and incubated at 37^{o} C for 24 hours. For mouse survival experiments, an overnight culture of MRSA USA300 JE2 was diluted to 1.0 x 10^{10} CFU/ml. To create an infection model, 100 µl was administered by intraperitoneal injection into C57BL/6J mice. Cefazolin and vancomycin were administered immediately after infection, and mice were monitored for three days post-infection.

RESULTS

In MHB, the MICs were 1–2 µg/ml for vancomycin (see Figure 1A) and 125–500 µg/ml for cefazolin (see Figure 1B). In TSB, the MICs were 0.5–4 µg/ml for vancomycin (see Figure 1A) and 4–500 µg/ml for cefazolin (see Figure 1B). In FBS, the MICs were 2–8 µg/ml for vancomycin (see Figure 1A) and 0.5–4 µg/ml for cefazolin (see Figure 1B). In 10% FBS + DMEM, the MICs were 8–32 µg/ml for vancomycin (see Figure 1A) and 0.5–2 µg/ml for cefazolin (see Figure 1B). When resuspended in MHB (see Figure 1C), only 20% of mice survived JE2 infection with cefazolin treatment. However, when JE2 was resuspended in FBS prior to infection (see Figure 1D), cefazolin treatment resulted in 100% survival.

DISCUSSION

Varying resistance to cefazolin was observed in different media conditions. Surprisingly, vancomycin MIC significantly increased ($p < 0.05$, see Figure 1A) as media approached physiological conditions. There was a significant increase ($p < 0.05$, see Figure 1B) in the efficacy of cefazolin as media was changed from standard culture media to more physiologically relevant media. In MHB, the media used in clinical microbiology labs to determine antibiotic resistance, MRSA isolates demonstrated the expected phenotype of resistance to cefazolin. This phenotype was reversed when these same strains were cultured in serum, and MRSA isolates became completely sensitive to cefazolin. These results suggest that a component of serum alters *mecA* gene expression. To test this phenotype *in vivo*, the researchers used a mouse infection model. Mice inoculated with JE2 resuspended in FBS rather than MHB had a higher survival rate when treated with cefazolin ($p < 0.001$, see Figure 1C-D), suggesting that cefazolin had increased activity against MRSA. This supports clinical studies demonstrating improved efficacy when MRSA infections are treated with dual therapy of vancomycin and cefazolin as compared to vancomycin alone.[4-5]

ACKNOWLEDGMENTS

This research was supported by the Orthopaedic Research and Education Foundation, Musculoskeletal Tissue Foundation, and National Institute of Arthritis and Musculoskeletal and Skin Diseases (K08AR071494).

REFERENCES

1. Lakhundi S et al. *American Society for Microbiology*. 2018.
2. Panlilio AL et al. *Infection Control & Hospital Epidemiology*. 1992.
3. Pastagia M et al. *Emerging Infectious Diseases*. 2012.
4. Tong S et al. *Journal of the American Medical Association*. 2020.
5. Geriak M et al. *American Society for Microbiology*. 2019.

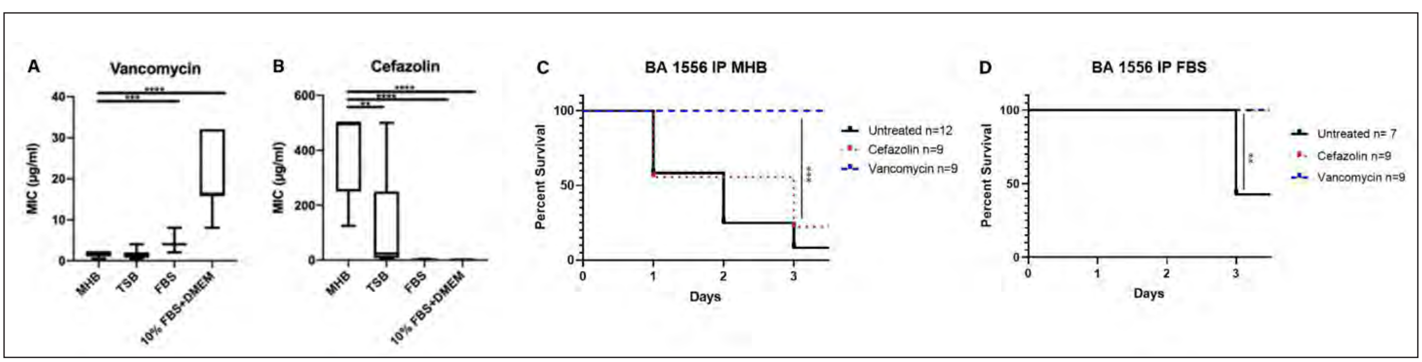


Figure 1. MICs of planktonically grown MRSA for vancomycin (A) and cefazolin (B) in varying media conditions. **$p < 0.01$ ***$p < 0.001$ ****$p < 0.0001$ Kaplan Meier plot of C57BL/6J mice infected with MRSA BAA-1556 USA 30 JE2 resuspended in MHB (C) or FBS (D). Immediately after infection, mice were given no treatment, vancomycin, or cefazolin and survival monitored for up to three days.

THE JOINT MICROENVIRONMENT DECREASES MRSA RESISTANCE TO CEFAZOLIN

Gish CG[1], Parker DM[1], Brothers KM[1], Urish KL[1,2]

[1]Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.
[2]Department of Bioengineering, University of Pittsburgh, Pittsburgh, Pa.

INTRODUCTION

Methicillin-resistant *Staphylococcus aureus* (MRSA) remains a significant contributor to periprosthetic joint infection (PJI) following knee and hip arthroplasties.[1] MRSA is clinically identified through CLSI antibiotic susceptibility testing in standard laboratory medium Mueller-Hinton Broth (MHB). However, recent studies have shown that antibiotic susceptibility can change based on the type of media used for testing.[2] In light of this, the authors questioned whether MRSA susceptibility to first-generation cephalosporins could be altered in media replicating the joint microenvironment. They hypothesized that MRSA would be susceptible to cefazolin in pseudo synovial fluid (pSF) rather than the standard laboratory media MHB.

METHODS

The researchers prepared pSF by combining 3 mg/ml hyaluronic acid (HA), 9 mg/ml fibrinogen (Fg), and 10 mg/ml albumin (Alb) in Dulbecco's Modified Eagle Medium supplemented with 5% non-essential amino acids (DMEM).[3] Each component was also tested individually at the stated concentration in DMEM. The minimum inhibitory concentration (MIC) of MRSA strain BAA-1556 USA 300 JE2 was assessed using the broth microdilution method according to Clinical and Laboratory Standards Institute protocol.[4] In brief, USA 300 JE2 was inoculated into 5 ml of tryptic soy broth (TSB) overnight at 37° C. Bacteria were normalized with a 0.5 McFarland standard to reach a final concentration of 1 x 10^6 colony-forming units/ml. Cefazolin was tested at concentrations ranging from 0.016 µg/ml to 64 µg/ml. The MIC was determined after 24 hours of incubation at 37° C using PrestoBlue™ (Gibco) viability reagent according to the manufacturer's instructions. All experiments were performed in triplicate.

RESULTS

The average cefazolin MIC (see Figure 1A) was 1.5 µg/ml in DMEM, 1.7 µg/ml in HA, 0.042 µg/ml in Fg, 4.0 µg/ml in Alb, and 0.042 µg/ml in pSF. All MHB MICs were greater than or equal to 64 µg/ml. Both the 0.5 µg/ml and 10 µg/ml doses of cefazolin eradicated all bacteria in Fg and pSF (see Figure 1B), whereas only the 10 µg/ml dose achieved a three-log reduction in the other pSF media components.

DISCUSSION

Growing MRSA in media replicating the host joint microenvironment significantly reduced its cefazolin MIC compared to MHB ($p < 0.0001$, see Figure 1A). Fibrinogen is an acute-phase protein that is crucial for bacterial aggregation in synovial fluid.[3] In addition, fibrinogen appears to contribute to cefazolin susceptibility, as it was the only one of the three pSF components to significantly lower the MIC in comparison to DMEM ($p = 0.01$, see Figure 1A). Furthermore, no statistical difference was observed between Fg and pSF bacterial reduction at both doses of cefazolin tested. MRSA bacteremia has a mortality rate nearly twice that of methicillin-sensitive *S. aureus* bacteremia.[5] Investigating MRSA's changing susceptibility to first-generation cephalosporins may lead to new treatment strategies.

ACKNOWLEDGMENTS

This research was supported by the Orthopaedic Research and Education Foundation, Musculoskeletal Tissue Foundation, and National Institute of Arthritis and Musculoskeletal and Skin Diseases (NIAMS K08AR071494).

REFERENCES

1. Tsai Y et al. *Journal of Orthopaedic Surgery (Hong Kong)*. 2019.
2. Ersoy S et al. *EbioMedicine*, 2017.
3. Knot S et al. *Frontiers in Microbiology*. 2021.
4. Clinical and Laboratory Standards Institute. *Methods for Dilution Antimicrobial Susceptibility Tests for Bacteria That Grow Aerobically* (11th ed.), CLSI standard M07. Wayne, Pennsylvania: Clinical and Laboratory Standards Institute; 2018.
5. Whitby M et al. *Medical Journal of Australia*. 2001.

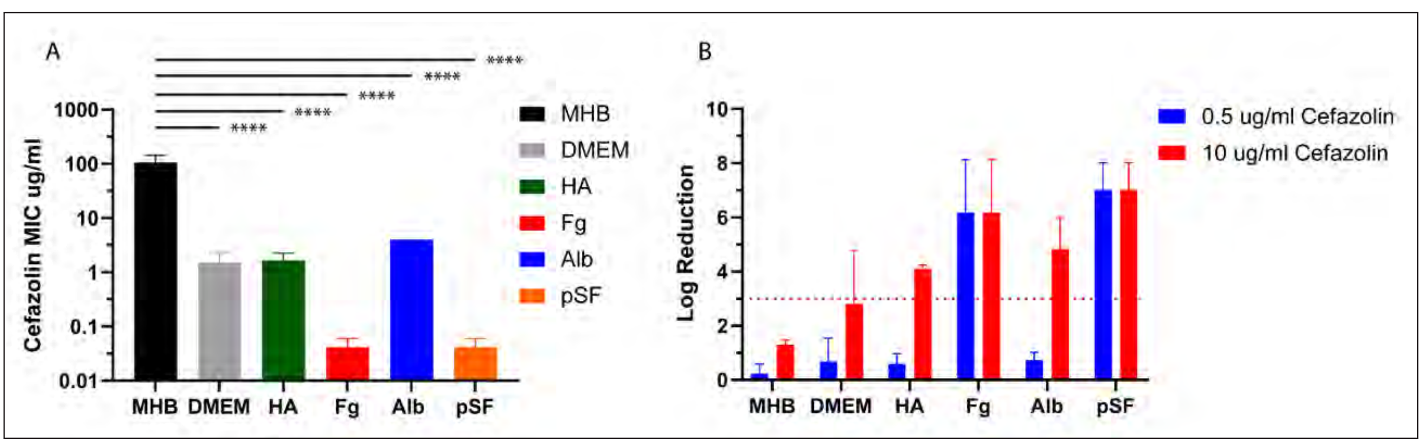


Figure 1. A) MIC for BAA-1556 USA 300 JE2 grown in different media types ****p<0.0001. B) Bacterial reduction after 24 hours of cefazolin treatment. Dashed red line denotes a 3-log reduction. MHB=Mueller Hinton Broth, DMEM=Dulbecco's Modified Eagles Medium, HA=Hyaluronic acid, Fg=Fibrinogen, Alb=Albumin, and pSF=Pseudo synovial fluid.

METHICILLIN-RESISTANT *STAPHYLOCOCCUS AUREUS MAZEF* EXPRESSION PROMOTES INFECTIONS BY INFLUENCING CELLULAR GROWTH AND ANTIBIOTIC SUSCEPTIBILITY

Mandell JB[1], Gish CG[1], Parker DM[1], Brothers KM[1], Urish KL[1,2,3]

[1]Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.
[2]Bone and Joint Center, UPMC Magee-Womens Hospital, University of Pittsburgh Medical Center, Pittsburgh, Pa.
[3]Department of Bioengineering, Clinical and Translational Science University of Pittsburgh, Pittsburgh, Pa.

INTRODUCTION

Staphylococcus aureus infections are a major concern in orthopaedic surgery, accounting for 50% of all *S. aureus* infections. *S. aureus* biofilms can be highly tolerant and difficult to eliminate. An altered bacterial metabolism is needed for antibiotic survival and growth of biofilms, which is accomplished by multiple stress-response signaling systems, including toxin-antitoxin (TA) systems. The most well-known and widely studied chromosomal TA system in *S. aureus* is the MazEF system. The MazF toxin has been shown to act as an endoribonuclease cleaving specific sequences in transcripts of many bacterial metabolic processes, including protein synthesis, cell-wall production, cell division, and virulence factors. As environmental stress regulation has been shown to influence antibiotic sensitivity in *S. aureus*, the researchers utilized a JE2 *mazF* transposon mutant in MRSA strain JE2 to further understand how this TA system is involved in antibiotic resistance and pathogenesis *in vivo*.

METHODS

Twelve-week-old C57BL/6J female mice (Jackson Laboratory) were used (n = 5). *S. aureus* strains were grown overnight in tryptic soy broth before being resuspended to a concentration of 1×10^8 CFU/mL in PBS. Then, 100 µl bacterial suspension was administered via retro-orbital injection, and mice were monitored for seven days. Mice were euthanized at the end of the experiment (seven days post-infection) or after losing 20% of their pre-infection weight as per Institutional Animal Care and Use Committee guidelines. After euthanasia, mouse blood via cardiac puncture, lungs, spleen, liver, and kidney were obtained to determine colony-forming units (CFUs) at these sites. All organs were individually homogenized and serial diluted before the researchers performed CFU analysis on blood agar plates.

RESULTS

Wild-type (WT)-challenged mice displayed 80% mortality in the untreated and cefazolin-treated groups, whereas the vancomycin group displayed 0% mortality. At the time of euthanasia, animal tissue (liver, kidney, spleen, and lung) was harvested and processed to obtain metastatic abscess burden resulting from sepsis. In WT-challenged mice, the vancomycin-treated group displayed significantly reduced abscess burden in the liver, kidney, and spleen compared to the untreated group ($*p < 0.05$). Cefazolin-treated mice displayed equivalent burden compared with untreated mice. *mazF::tn*-challenged mice displayed 80% mortality in the untreated group, whereas the vancomycin and cefazolin groups displayed 0% mortality. For *mazF::tn*-challenged mice, metastatic abscess burden in the liver, kidney, and spleen of vancomycin- and cefazolin-treated groups displayed significantly reduced burden compared to the untreated group ($*p < 0.05$).

DISCUSSION

The mechanism behind *S. aureus* biofilm antibiotic tolerance and its ability to establish a chronic infection remains unknown. This study demonstrates that the TA system *mazEF* acts to inhibit biofilm formation and promote biofilm antibiotic tolerance, which allows *S. aureus* to transition from an acute to a chronic infection which is less virulent but cannot be eradicated with antibiotics.

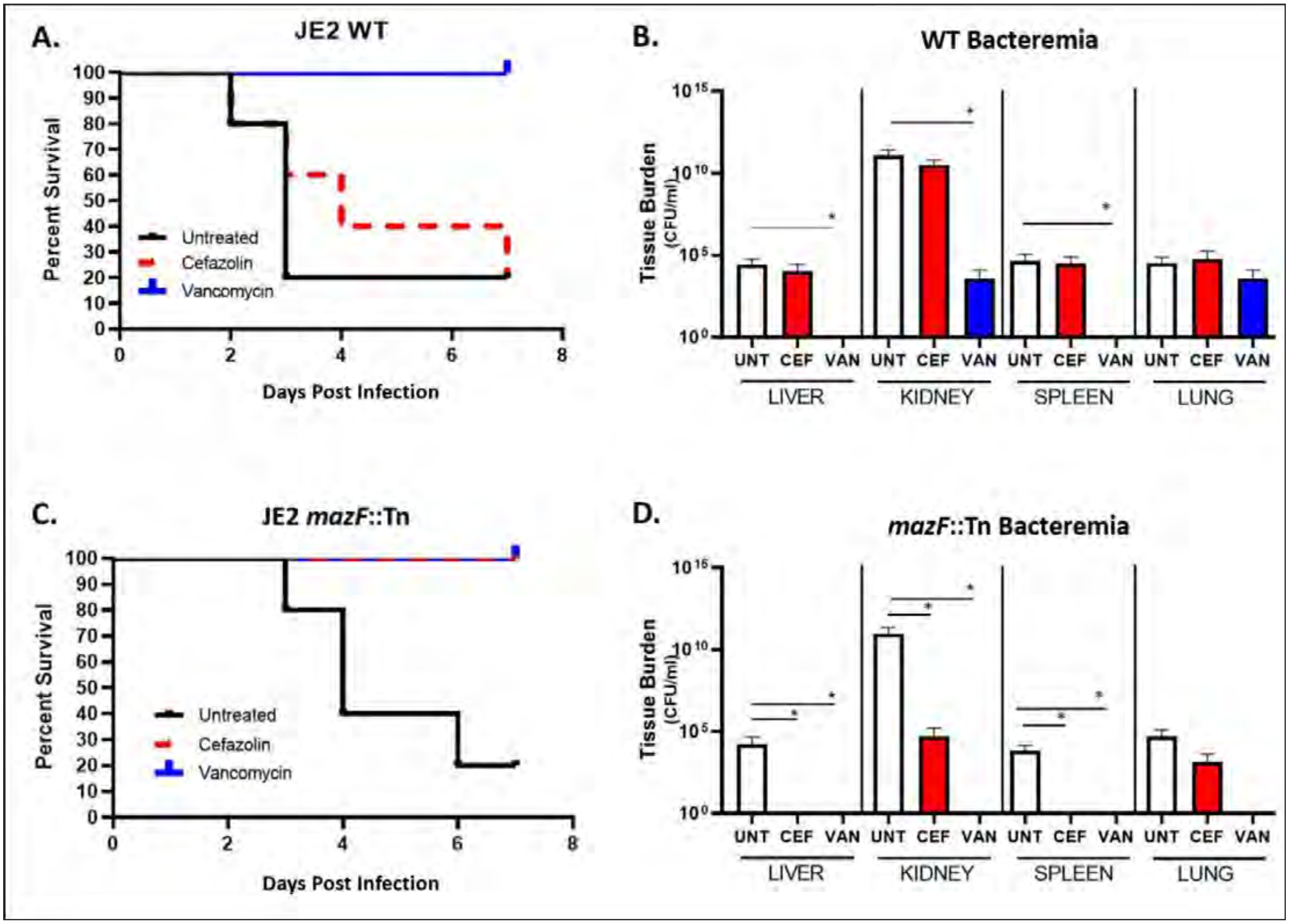


Figure 1. In JE2 WT sepsis, untreated and cefazolin-treated groups displayed similar mortality (~ 20%) compared with the vancomycin-treated group (A). At time of euthanasia, intraperitoneal organs were collected and processed to determine metastatic abscess formation. In JE2 WT sepsis, there were significant reductions in organ abscess burden in the vancomycin-treated group compared to the untreated group (B). In *mazF::tn* sepsis, the cefazolin- and vancomycin-treated groups displayed similar mortality (~ 100%) compared with the untreated group (C). The cefazolin- and vancomycin-treated groups displayed significantly reduced metastatic abscess burden compared to the untreated group (*p < 0.05) (D).

HYDROGEN PEROXIDE, POVIDONE-IODINE AND CHLORHEXIDINE FAIL TO ERADICATE *STAPHYLOCOCCUS AUREUS* BIOFILM FROM INFECTED IMPLANT MATERIALS

Parker DM, Koch JA, Gish CG, Brothers KM, Li WT, Urish KL

Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.

INTRODUCTION

Periprosthetic joint infection (PJI) is a major complication in joint replacement surgery. Treatment involves removal of the infected implant, irrigation and debridement of the surgical site, and revision arthroplasty. Antiseptics are added to help with the effectiveness when treating PJIs; however, evidence has demonstrated that oxidative stress can reduce *Staphylococcus aureus* metabolic activity and increase antibiotic tolerance in established biofilms.[1] The objectives of this study were to determine whether antiseptics help eliminate an established biofilm and to determine whether antiseptics in combination with cefazolin display synergy in reducing biofilm burden.

METHODS

S. aureus (SH1000) was grown on 1 cm titanium rods for 48 hours in tryptic soy broth (TSB) with a media change after 24 hours. Rods were then treated for 24 hours with different irrigant solutions: chlorhexidine (CHX) 0.05% concentration, povidone-iodine (PI) 0.3% concentration, and hydrogen peroxide (H_2O_2) 1.5% concentration. After exposure time was complete, the solution was diluted 1:100 in phosphate-buffered saline to terminate the reaction. The sonicate was serially diluted and plated onto blood agar plates for bacterial burden analysis (colony-forming units/mL). To test synergy, the same biofilm protocol above was used; however, wires were treated with the antiseptics listed above for 2.5 minutes and then placed into 2.5 µg/mL cefazolin/TSB dilution for 24 hours.

RESULTS

Bactericidal was defined as a three-log reduction in bacterial burden. PI, H_2O_2, and CHX were not observed to have bactericidal properties against SH100o biofilm. PI, H_2O_2, and CHX decreased bacterial burden by 2.2, 2.2, and 1.6 log, respectively ($p < 0.0001$) (see Figure 1A). When cefazolin was added to PI, H_2O_2, and CHX, biofilm burden was reduced by 4.6, 4.9, and 4.5 log ($p < 0.0001$), respectively, in comparison to the untreated group. Compared to cefazolin treatment alone, the combination of cefazolin with PI, H_2O_2, or CHX resulted in a 0.40, 0.70, and 0.20 log reduction, respectively (see Figure 1B), which was not statistically significant ($p > 0.99$).

DISCUSSION

There is currently a lack of clinical evidence demonstrating bactericidal efficacy of antiseptics in treating PJI. The use of antiseptics to treat PJI is largely based on results from clinical studies that demonstrated irrigation solutions to prevent PJI cases. In this study, PI, H_2O_2, and CHX were not bactericidal to *S. aureus* but did decrease biofilm burden. This demonstrates the challenge in treating infections associated with biofilms and the need for independent irrigation solutions, specifically those that have the potential to be bactericidal against an established biofilm. There was no correlative synergy between cefazolin and PI, H_2O_2, or CHX. No statistical differences were demonstrated between cefazolin combined with antiseptics and cefazolin alone regarding biofilm antimicrobial efficacy. This reinforces evidence that PI, H_2O_2, and CHX combined with cefazolin may induce antibiotic tolerance.

REFERENCE

1. Rowe. *Nature Microbiology*. 2019.

ACKNOWLEDGMENTS

Research was supported by the Orthopaedic Research and Education Foundation,
Musculoskeletal Tissue Foundation, and National Institutes of Health (NIH/National Center for Advancing Translational Sciences KL2 TR000146).

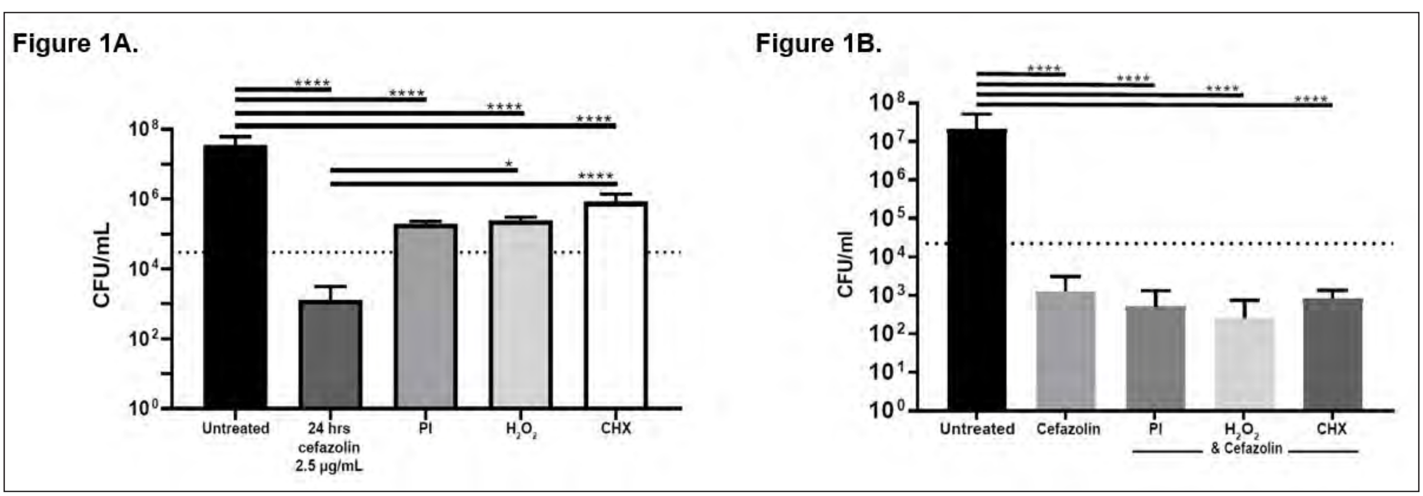


Figure 1. Povidone-iodine at 0.3%; hydrogen peroxide at 1.5%; chlorhexidine at 0.05%; cefazolin = 2.5 µg/mL; Bactericidal = three-log reduction. A. Antiseptics are not bactericidal against *Staphylococcus aureus* biofilm. The amount of *S. aureus* biofilm after treatment was quantified and compared B. Antiseptics in combination with cefazolin reduces biofilm but does not display synergy. The amount of *S. aureus* present after treatment with cefazolin in combination with antiseptics was quantified and compared.

ASSESSING THE POTENTIAL OF PHAGE THERAPY AGAINST MDR *PSEUDOMONAS AERUGINOSA* USING A *C. ELEGANS* INFECTION MODEL

Rekha A, Sadaka N, Rempuszewski J, Frear A, Urish K

Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.

INTRODUCTION

Prosthetic joint infection (PJI) poses a significant challenge in orthopaedic care, often resulting in prolonged suffering and complications. PJI is the most severe arthroplasty complication and the largest reason for failure, at approximately 25% of all revisions. It is a devastating diagnosis, often requiring multiple surgical procedures over several years, with a high mortality rate of 25%. Multidrug-resistant (MDR) *Pseudomonas aeruginosa* is a particularly challenging adversary, as conventional antibiotic treatments are often ineffective. There is an urgent need to identify alternative therapies that can overcome the limitations of conventional antimicrobial-based treatment strategies. The authors' work has demonstrated the efficacy of bacteriophages to treat infection and increase the survival of *Caenorhabditis elegans*, which allows a more reliable evaluation of the clinical therapeutic potential of lytic phages.

METHODS

P. aeruginosa was grown overnight, was washed with phosphate-buffered saline, and maintained the 1 x 10^6 colony-forming units (CFU)/mL for infection. The efficacy of phage therapy was studied with a 1:100 multiplicity of infection (MOI). The 96-well plate with phage-treated and no-phage groups were incubated at 20° C, and survival was monitored every 24 hours for seven days.

RESULTS

The *C. elegans* were infected with clinical samples of Pseudomonas *aeruginosa* followed by phase treatment. The researchers employed a 1:100 MOI, which corresponded to a concentration of 10^5 CFU/mL:10^7 plaque-forming units (PFU)/mL. They assessed phage activity in *C. elegans* survival by examining prophylactic phage therapy and post-infection phage therapy as shown in Figure 1A. *C. elegans* infected with *P. aeruginosa* strain 1, and subsequently treated with phages, demonstrated a substantial enhancement in survival rates 66 ± 3% and 86 ± 7%, respectively, compared to the untreated group, which exhibited a mere 13 ± 5% survival rate after seven days of infection (see Figure 1B). Next, *C. elegans* infected with *P. aeruginosa* strain 2 and treated with phages displayed a significant increase in survival rates. The survival rates for phages were 73 ± 2% and 80 ± 3%, respectively, in contrast to the untreated group, which only showed a 6.6 ± 5% survival rate (see Figure 1C).

DISCUSSION

We have demonstrated the efficacy of bacteriophages approved by the U.S. Food and Drug Administration (FDA) in increasing the survival of *C. elegans* infected with MDR *P. aeruginosa*. The bacteriophages were found to be effective in eliminating the bacterial load, increasing the life span of *C. elegans*. However, the higher concentration of bacteria–phage ratio (1:100 or 10^5 CFU/mL:10^7 PFU/mL) showed up to 66 ± 3 and 86 ± 7% nematode survival when treated with phage 1 and phage 2, respectively. To the best of the authors' knowledge, this is the first study to report the successful use of *C. elegans* to test the efficacy of FDA-approved bacteriophages in a liquid assay format.

REFERENCES

1. Bozic KJ et al. *Journal of Bone & Joint Surgery*. 2012;94(9):794-800.
2. Shah NB et al. *Clinical Infectious Diseases*. 2020;70(4):559-65.
3. Perez-Jorge C et al. *Expert Opinion on Pharmacotherapy*. 2016;17(9):1233-46.
4. Brives C & Pourraz JJPC. *Palgrave Communications*. 2020;6(1):1-11.
5. York AJNRM. *Nature Reviews Microbiology*. 2022;20(12):703.

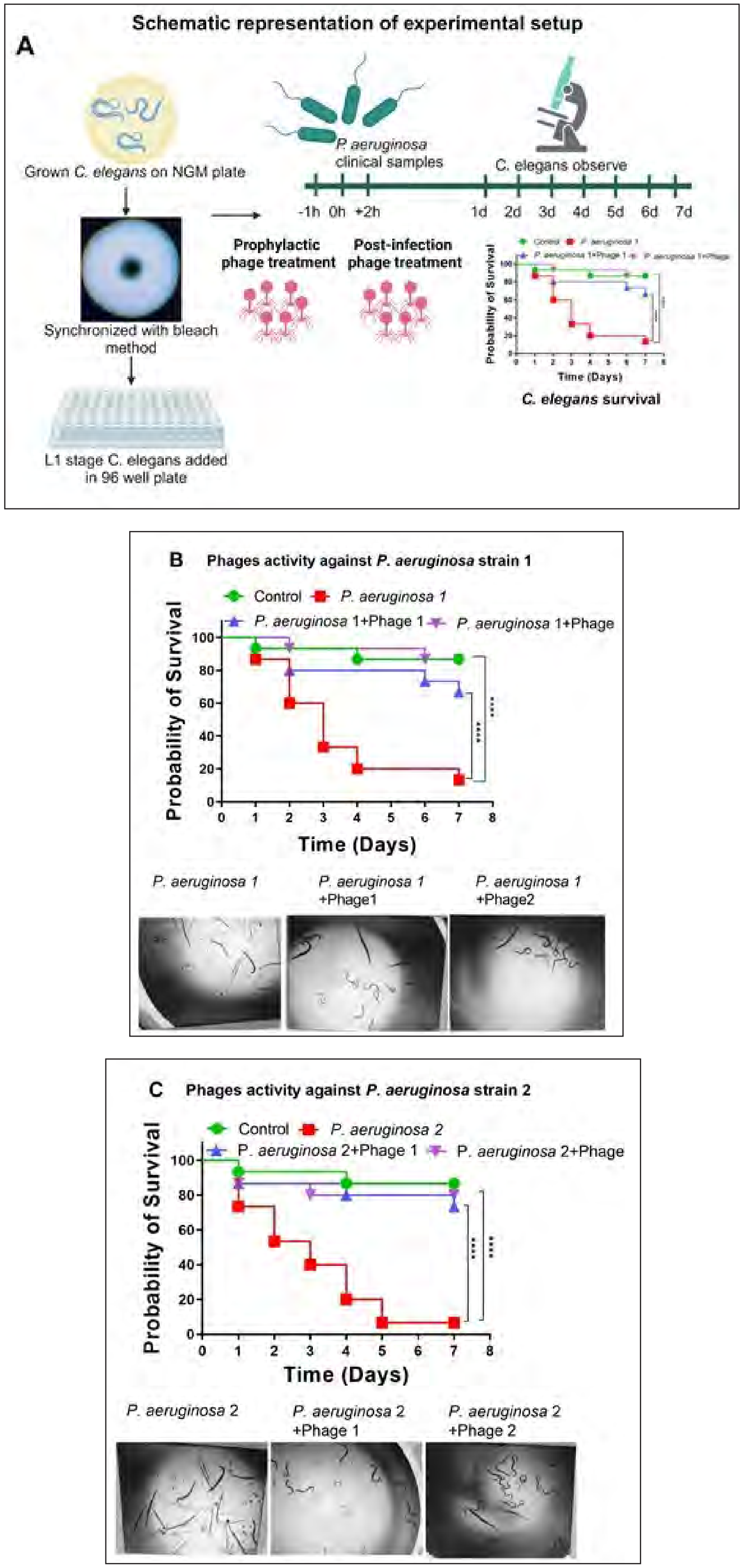


Figure 1. Phage therapy in *Caenorhabditis elegans* infected with patient isolates. Patient isolates were tested for their virulence in a *C. elegans* infection model. The control group consisted of *C. elegans* fed with *Escherichia coli OP50*, and patient isolates were used. The untreated strain was used as a reference strain. Fifteen nematodes were used in each group. A. Schematic representation of experimental design. B, C. Representative survival curve of *C. elegans* infected by *Pseudomonas aeruginosa* strains 1, 2 and treated with phages.

DIFFERENCES BETWEEN *STAPHYLOCOCCUS AUREUS* ACUTE AND CHRONIC INFECTION IN A MOUSE PERIPROSTHETIC JOINT INFECTION MODEL

Taguchi M[1,2], Brothers KM[1], Kihara S[3], Mandell JB[1], Mittwede PN[1], Narra SP[4], Fu FH[5], Urish KL[1]

[1]Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.
[2]Department of Orthopaedic Surgery, Tokyo Women's Medical University, Medical Center East, Tokyo, Japan
[3]Department of Orthopaedic Surgery, Konan Medical Center, Kobe, Japan
[4]Department of Mechanical Engineering, Carnegie Mellon University, Pittsburgh, Pa.
[5]Department of Orthopaedic Surgery, UPMC Freddie Fu Sports Medicine Center, University of Pittsburgh, Pittsburgh, Pa.

INTRODUCTION
Total knee arthroplasty (TKA) is the most common major surgical procedure in the United States, and its largest reason for failure is periprosthetic joint infection (PJI).[1] PJI is a devastating diagnosis with limited treatment options and can require repeated surgical intervention. Failure rates have been reported to be as high as 60% and often result in complete removal of arthroplasty implant materials. There is little understanding of the difference between acute and chronic PJI from the perspective of bacteria pathogenesis. The objective of this study was to determine spatial and temporal differences between acute and chronic PJI.

METHODS
A mouse PJI model was used, where a 3D printed titanium tibial implant (see Figure 1A) was placed in the proximal tibia with polymethylmethacrylate (see Figure 1B). *Staphylococcus aureus* (SH1000) was injected into the intra-articular space immediately after surgery at a density of 1 x 10^6 colony-forming units. Antibiotic treatment with cefazolin (50 mg/kg, three times a day) was initiated at several time points. Migration of bacteria as a function of time was determined using an agar culture assay. Biofilm mass was determined by quantitative culture from the implant and proximal tibia.

RESULTS
First, the researchers characterized the distribution of *S. aureus* on the surface of the titanium implant. At one hour after infection, bacterial colonies were identified only on the articular surface of the implant. Thereafter, bacteria were observed to progressively migrate toward the distal metaphysis. The total bacterial burden peaked by three days after infection before rapidly decreasing afterward.

Because biofilm antibiotic tolerance plays a role in PJI, the researchers next wanted to determine the time frame in which this tolerance occurs *in vivo*. When cefazolin treatment was started on day 1, 50% of infections were cleared and implants were culture-negative after seven days. However, cefazolin was unable to clear *S. aureus* infection when antibiotics were withheld for two days. The overall bacterial burden increased on both implant and surrounding metaphyseal bone. After day 3, there was evidence that a chronic infection had developed, where there was little change in the distribution or burden of bacteria. The transition from an infection with acute to more chronic characteristics began on day 3 after infection and continued over a one-week time period.

DISCUSSION
These findings indicate that there is evidence of an earlier transition from acute to chronic infection occurring within the first week post-infection. Bacterial migration, bacterial burden, and biofilm were all pronounced within the first 72 hours. These findings suggest that the current timeline for the development of chronic infection may result in delayed or potentially inappropriate interventions.

REFERENCES
1. Urish KL et al. A multicenter study of irrigation and debridement in total knee arthroplasty periprosthetic joint infection: treatment failure is high. *J Arthroplasty*. 2018;33(4):1154-9.
2. Li C et al. Management of periprosthetic joint infection. *Hip Pelvis*. 2018;30(3):138-46.

ACKNOWLEDGMENTS
This research was supported by the Orthopaedic Research and Education Foundation, Musculoskeletal Tissue Foundation, and National Institute of Health (NIH/ National Center for Advancing Translational Sciences KL2 TR000146).

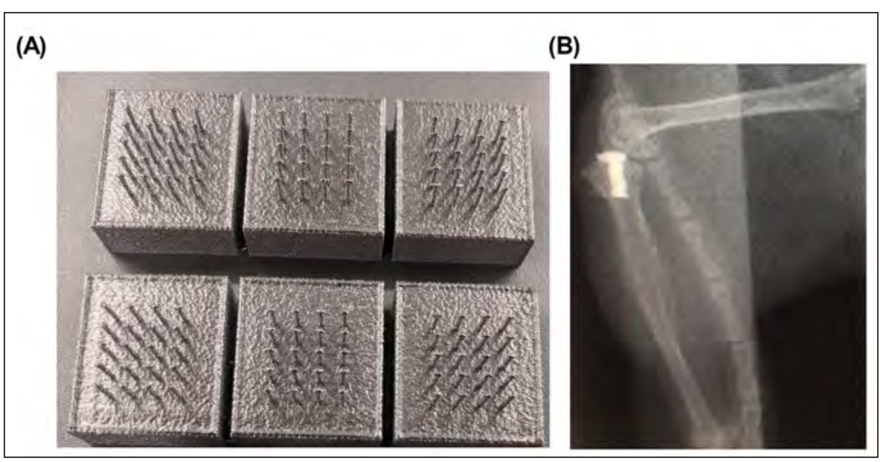


Figure 1. (A) Image of 3D-printed titanium alloy implants and (B) X-ray verification of 3D-printed tibial titanium alloy placement into the tibial canal

ISOLATION OF NOVEL *STAPHYLOCOCCUS* BACTERIOPHAGES FROM WASTEWATER INFLOW FOR USE IN ORTHOPAEDIC TREATMENT

Zygmunt A, Delach M, Patel S, Knapick B, Ma D, Sadaka N, Rempuszewski JJ, Arya R, Urish KL

Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.

INTRODUCTION

Methicillin-resistant *Staphylococcus aureus* (MRSA) infection is a leading cause of hospital-acquired infections. Due to the high burden of these microbes on the healthcare system each year, more emphasis has been placed on the development of alternative non-antibiotic therapies, such as bacteriophage therapy. Isolation of novel bacteriophages for use in bacteriophage therapy is crucial in building a large and diverse library for clinical use. Municipal wastewater has been identified as a potential source for novel MRSA-targeting phages. Thus, this study aimed to test concentrated wastewater samples against clinical isolates of MRSA for use as a possible source of novel bacteriophages for clinical use.

METHODS

Raw wastewater inflow was collected from Pine Creek Wastewater Treatment Plant and McCandless Township Sanitary Authority in Pittsburgh, Pennsylvania. Each sample was first pelleted to remove any larger contaminants and then filtered through a vacuum filter system. Each of these samples were then concentrated with a centrifugal filter column and then again filtered through a 0.22 µM filter. These concentrated samples were then tested for phage activity against 10 different clinical isolates of *S. aureus*, each with different multi-locus sequence typing (MLST) profiles. Eight of the selected samples were MRSA strains, and two of them were methicillin-sensitive *S. aureus*. Two lab standard strains of *S. aureus*, JE2 and SH1000, were also tested alongside the clinical isolates. Selected clinical samples were isolated from prosthetic joint infections of the knee, hip, and elbow or from infection of the nares.

RESULTS

Phage activity was detected from the Pine Creek wastewater sample on two of the clinically isolated strains of *S. aureus* denoted 16 and 210, respectively. Each plaque on the two plates was selected and expanded to assess for ability to infect continuously. Three different putative phages were isolated from this procedure. Two of the phages were isolated off of patient strain 210, and the researchers denoted these 210:V and 210:XIV, respectively. The last phage was isolated off of isolate strain 16, referred to as 16:I. 210:V and 210:XIV had a similar plaque morphology: small, round, and clear, suggestive of lytic activity. 16:I, on the other hand, was turbid and large and presented with a halo-like morphology, indicative of lysogenic activity.

DISCUSSION

This methodology proved to be successful in isolating phages that are capable of propagation on strains of *S. aureus* isolated from patient infections. Subsequent steps include sequencing of these three phages to determine whether they are unique, followed by testing of these phages *in vivo* to evaluate their efficacy as potential therapeutics against MRSA infections.

REFERENCES

1. Siddiqui AH et al. *StatPearls Publishing.* 2023.
2. Nasser A et al. *Osong Public Health Res Perspect.* 2019;10(1):20-4.
3. Plumet L et al. A review of animal models, treatments, and clinical trials. *Front Cell Infect Microbiol.* 2022.
4. Scheper H et al. *Front Microbiol.* 2021.

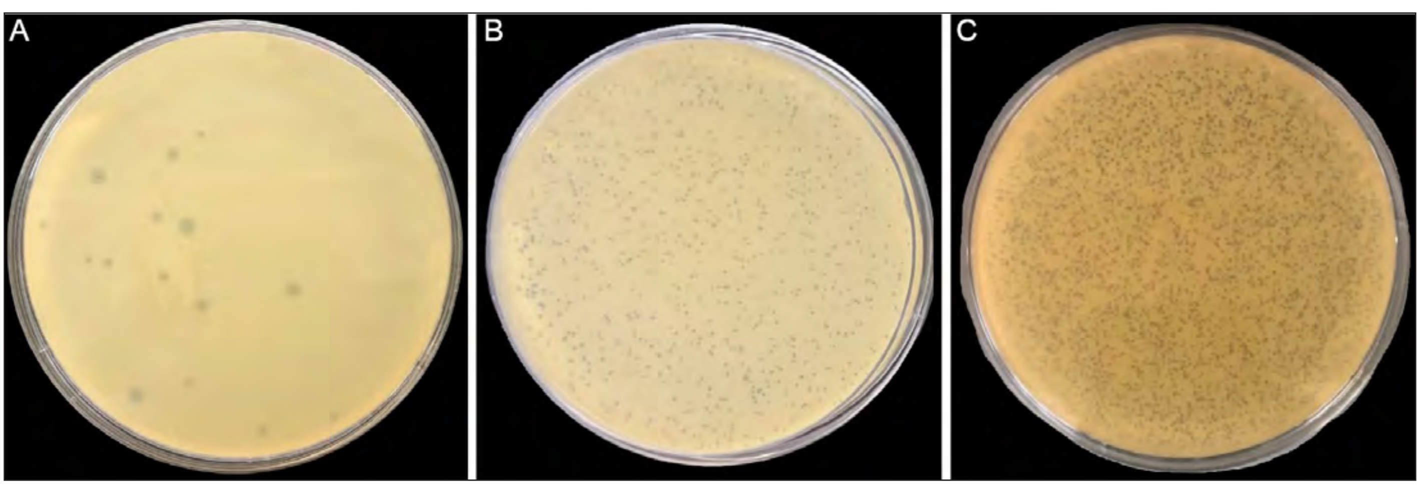


Figure 1. Representative images of each purified phage isolated from wastewater inflow testing on clinical samples. All isolates grown on TSB and added to TSA Top Agar before incubation overnight at 37°C. a) Plaques of 16:1 on a lawn of clinical isolate 16, displaying a halo-like morphology. b) Plaques of 210:V on a lawn of clinical isolate 210, displaying a lytic morphology. c) Plaques of 210:XIV on a lawn of clinical isolate 210, displaying a lytic morphology.

SHOULDER AND ELBOW MECHANICAL RESEARCH LABORATORY

Christopher C. Schmidt, MD, director

The Shoulder and Elbow Mechanical Research Laboratory is guided by Christopher C. Schmidt, MD, and co-supervised by Patrick J. Smolinski, PhD, and Mark C. Miller, PhD.

The laboratory published a landmark paper, "Relative Contributions of the Supraspinatus Cord and Strap Tendons to Shoulder Abduction and Translation," in the *Journal of Shoulder and Elbow Surgery* this year, showing that abduction force from a simulated supraspinatus (SS) cord tear can recover with full-load transfer to an intact SS strap tendon, and vice versa. This mechanical finding helps to explain the efficacy of nonoperative management of small (< 10 mm) rotator cuff tears.

The lab is proud to announce that our students Austin Cook and Justin Buce successfully defended their master's theses and matriculated from the graduate program at the Department of Mechanical and Materials Science in the Swanson School of Engineering at the University of Pittsburgh. They studied pathoanatomic distal biceps tears and load transfer of the rotator cuff tendons. Mr. Cook is working as an engineer, improving the designs of shoulder arthroplasties, and Mr. Buce as an industrial robotics integrator. We applaud their intellect and hard work.

We are also pleased to inform that former lab manager Sean Cook is currently in his second semester of medical school at the University of Illinois College of Medicine.

Omar Rodriguez-Alejandro, MD, 2022–2023 fellow, finished the mechanical study titled "Relative Contributions of the Supraspinatus Cord and Strap Tendons to Shoulder Abduction and Translation." He also completed a mechanical study comparing the coracohumeral ligament (CHL) supraspinatus (SS) cord tendon's effect on shoulder abduction force. Dr. Rodriguez-Alejandro discovered that the SS cord and not the CHL is the key structure responsible for transmission of anterior shoulder abduction force. This work indicates that repairing the SS cord could be an essential step in improving clinical strength and preventing SS muscle fatty infiltration. His work was presented at the annual meeting of the Orthopaedic Research Society in February 2024 and has been submitted for publication.

We welcomed two incoming engineering students to our lab, Gabe Stay, BS, and Josh Frantz, BS. Both will be working in the lab, completing their graduate degrees in mechanical engineering. They will focus on the anatomy and mechanics of the anterosuperior rotator cuff tendons.

Current Laboratory Personnel

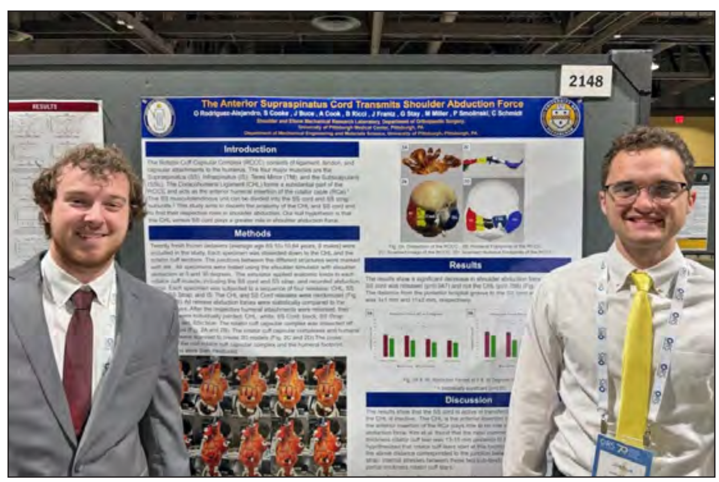
Engineering graduate students:
- Gabe Stay, BS (mechanical engineering)
- Josh Frantz, BS (mechanical engineering)

Laboratory manager:
- Bethany Ricci, BS

Current orthopaedic fellow:
- Justin Badon, MD

Physician collaborators:
- Loukia Papatheodorou, MD
- Omar Rodriguez-Alejandro, MD

From left to right: Sean Cooke, Josh Dworkin, Justin Buce, and Austin Cook enjoy the view of the Three Rivers from top of Mt. Washington.



Gabe Stay and Josh Frantz present at the 2024 annual meeting of the Orthopaedic Research Society.

Publications

Schmidt CC, Rodriguez-Alejandro O, Cooke SP, Dworkin JD, Cook AJ, Buce JG, Stefko JM, Cline NS, Smolinski PJ, Miller MC. Relative contributions of the supraspinatus cord and strap tendons to shoulder abduction and translation. *Journal of Shoulder and Elbow Surgery*. 2024;33(1):172-80. doi: 10.1016/j.jse.2023.07.003.

Dworkin JD, Schmidt CC, Cooke SP, Bruce JG, Cook AJ, Miller MC, Smolinski PJ. The pathoanatomy of atraumatic partial distal biceps tears: a cadaveric study. *Journal of Shoulder and Elbow Surgery International*. 2023;7:506-10.

Presentations

Rodriguez-Alejandro OE, Cooke SP, Buce JG, Cook AJ, Ricci BR, Frantz J, Stay G, Smolinski PJ, Miller MC. The anterior supraspinatus cord transmits shoulder abduction force, not the rotator cable [paper 2148]. Annual meeting of the Orthopaedic Research Society; February 2–6, 2024; Long Beach, California.

Schmidt CC, Rodriguez-Alejandro OE, Cooke SP, Dworkin JD, Cook AJ, Buce JG, Smolinski PJ, Miller MC. Supraspinatus cord and strap tears can be treated conservatively: a biomechanical study [podium paper 058]. Annual meeting of the American Academy of Orthopaedic Surgeons; March 7–11, 2023; Las Vegas, Nevada.

Justin Buce, Austin Cook, and Sean Cooke with others at their graduation dinner
From left to right: Dean Sotereanos, Rachael Cobo, Maureen Linkosky, Justin Buce, John Linkosky, Loukia Papatheodorou, Camille Buonocore, Christopher Schmidt, Angela Connelly, Ashley Bufano, Austin Cook, Omar Rodriguez-Alejandro, Viviana Rodriguez-Alejandro, Sean Cooke, Sara Pearlman, Kevin Cooke Sr., and Kevin Cooke Jr.

From left to right: Mark Miller, Evan Washington, Gabe Stay, Justin Badon, Josh Frantz, Angela Connelly, Patrick Smolinski, Christopher Schmidt, Bethany Ricci, and Rachael Cobo enjoy a night at Topgolf.

Bottom row, from left to right: Rachael Cobo, Bethany Ricci, Eileen Colliton, and Brian Foster; top row, from left to right: Jeff Chen, Erika Chen, Maureen Linkosky, Loukia Papatheodorou, Donna Sotereanos, Dean Sotereanos, Angela Connelly, Justin Badon, Hannah Badon, Christopher Schmidt, Camille Buonocore, Gabe Stay, and Josh Frantz celebrate with the team for the holidays.

THE ANTERIOR SUPRASPINATUS CORD TRANSMITS SHOULDER ABDUCTION FORCE

Rodriguez-Alejandro OE, Schmidt CC, Ricci BG, Cooke SP, Buce JG, Cook AJ, Stay GJ, Frantz JS, Dworkin JD, Miller MC, Smolinski PJ

Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.

INTRODUCTION

The rotator cuff capsular complex (RCCC) consists of ligament, tendon, and capsular attachments to the humerus. The coracohumeral ligament (CHL) forms a substantial part of the RCCC and acts as the anterior humeral insertion of the rotator cable (RCa).[1] The supraspinatus (SS) musculotendinous unit can be divided into the SS cord and SS strap units, respectively.[2] This study sought to define the contributions of the SS cord and CHL on shoulder abduction force.

METHODS

Twenty fresh-frozen cadaveric specimens (average age = 69 ± 11 years, nine males) were dissected down to the CHL and rotator cuff tendons. All specimens were tested in a shoulder simulator with physiological load vectors applied to the upper (127 N) and lower (108 N) subscapularis, SS cord (56 N), SS strap (24 N), infraspinatus (90 N), and teres minor (97 N).[3] After testing of the native condition, each specimen was subjected to a release of the CHL and SS cord. The order of these releases was randomized (see Figure 1A and 1B). Abduction force was measured by a six-degree-of-freedom load cell, and testing was completed at both 0° and 30° of shoulder abduction.

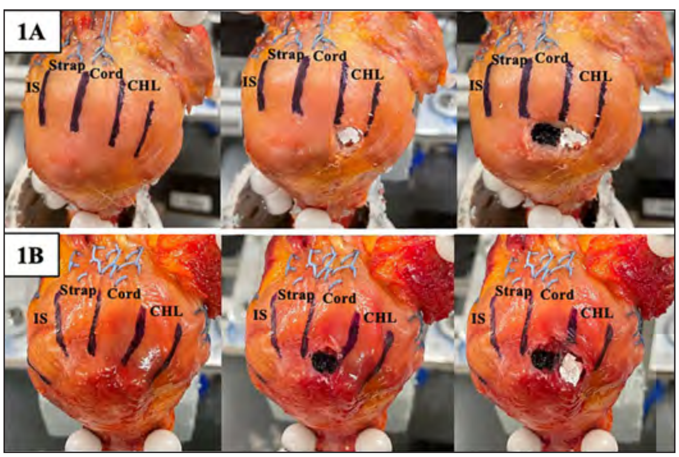


Figure 1. A: Coracohumeral ligament first release sequence; B: Supraspinatus cord first release sequence

RESULTS

The shoulder abduction force results comparing the CHL and SS cord release groups to the native cases are shown in Table 1. An SS cord first release significantly decreased shoulder abduction force by 10% at 0° and 22% at 30° ($p = 0.047$). A CHL first release decreased shoulder abduction force by 3% at 0° and 7% at 0°. However, this decline was not significant ($p \geq 0.356$). The decline in abduction force after the CHL and SS cord were both released was significant for all cases ($p \leq 0.045$).

DISCUSSION

The SS cord and not the CHL is the key structure in transmitting anterior shoulder abduction force. The SS cord played a significant role in shoulder abduction force transmission, whereas the CHL, acting as the anterior insertion of the RCa, did not. Repair priority should be given to the SS cord as opposed to the anterior insertion of the RCa to maximize shoulder abduction strength.

REFERENCES

1. Burkhart S et al. *Arthroscopy*. 1993;9(6):611-6.
2. Roh M et al. *JSES*. 2000;9(5):436-40.
3. Schmidt C et al. *JBJS*. 2022;104(14):1292-300.

Abduction Angle	Released Structure	Abduction Force [N]	Percentage of Native Force	p-value (vs Native)
CHL First Group				
0°	CHL	5.9 (1.7)	97%	p=0.610
	CHL + SS cord	4.9 (2.0)	80%	p=0.022
30°	CHL	6.7 (3.1)	93%	p=0.356
	CHL+ SS cord	5.9 (2.5)	82%	p=0.045
SS cord First Group				
0°	SS cord	4.5 (1.4)	90%	p=0.047
	SS cord + CHL	4.1 (1.5)	82%	p=0.013
30°	SS cord	4.6 (2.0)	78%	p=0.047
	SS cord + CHL	4.3 (1.8)	73%	p=0.012
CHL = Coracohumeral ligament, SS = Supraspinatus				

Table 1. Abduction forces of the coracohumeral ligament and supraspinatus cord releases compared to native

ROTATOR CUFF STRAIN IN THE ANTERIOR AND POSTERIOR SUPRASPINATUS

Schmidt CC, Badon JT, Ricci BG, Frantz JS, Stay GJ, Smolinski PJ, Miller MC

Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.

INTRODUCTION

The ability of the rotator cable (RCa) to stress shield the crescent area (CA) has been previously studied through a method known as digital image correlation (DIC).[1] In this method, strain values were recorded in both the RCa and CA on a single line bisecting the supraspinatus (SS). The SS musculotendinous unit can be divided into the SS cord and SS strap, and it is possible that strain variations exist between the two subunits. This study aimed to develop a method for recording strain of the SS cord and SS strap in the RCa and CA using DIC (Correlated Solutions, Inc).

METHODS

One cadaveric shoulder specimen was dissected down to the CHL and rotator cuff tendons. The musculotendinous units covering the humeral head were stained with oil-based black ink and speckled with white nail polish (see Figure 1). The specimen was mounted in a custom-built shoulder simulator with DIC cameras mounted above the humeral head (see Figure 2). Mechanical testing consisted of five loading conditions. Native was defined by the physiological load of each muscle: SS cord: 56 N, SS strap: 24 N, teres minor: 97 N, infraspinatus: 90 N, upper subscapularis: 127 N, and lower subscapularis: 108 N. Four other loading conditions followed. The first condition increased the load on the SS cord by 50% while keeping the other rotator cuff tendons as physiological loads. This load condition was repeated for the second test, but instead decreased the load on the SS cord by 50%. These patterns of load variation were repeated for the SS strap while all remaining tendons were held at physiological loads. Testing occurred at both 0° and 30° of shoulder abduction. A bursal-sided identification method to locate the RCa and CA was utilized.[2] The first principal strain and direction were calculated at all four locations using the DIC software (Vic-3D). The researchers kept locations constant by positioning each marker on a line bisecting the SS cord or SS strap.

RESULTS

The resulting strain values and direction were in line with previously published values.[1]

DISCUSSION

A DIC method using two bisecting lines on the SS cord and SS strap allows for specific strain measurements around each SS subunit. Further testing is required for comparisons of strain values and direction among the four locations. This study helped to establish a specific method of measuring strain that can be employed in future studies.

REFERENCES

1. Schmidt CC et al. *JBJS*. 2022;104(14):1292-300.
2. Zink TR et al. *JSES*. 2021;30(7S):S57-65.

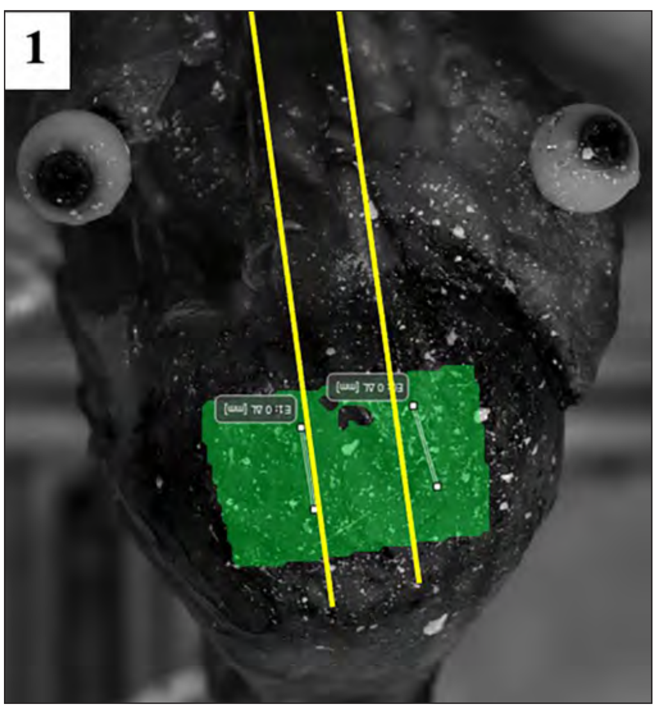


Figure 1. A photograph of the specimen during digital image correlation post-processing. The yellow lines represent the two bisecting lines of the supraspinatus (SS) cord and SS strap. The tracking map was later extended to include the rotator cable (RCa) and crescent area (CA) portions along the yellow bisecting lines (not pictured). The principal strain in the RCa and CA was measured on each bisecting line.

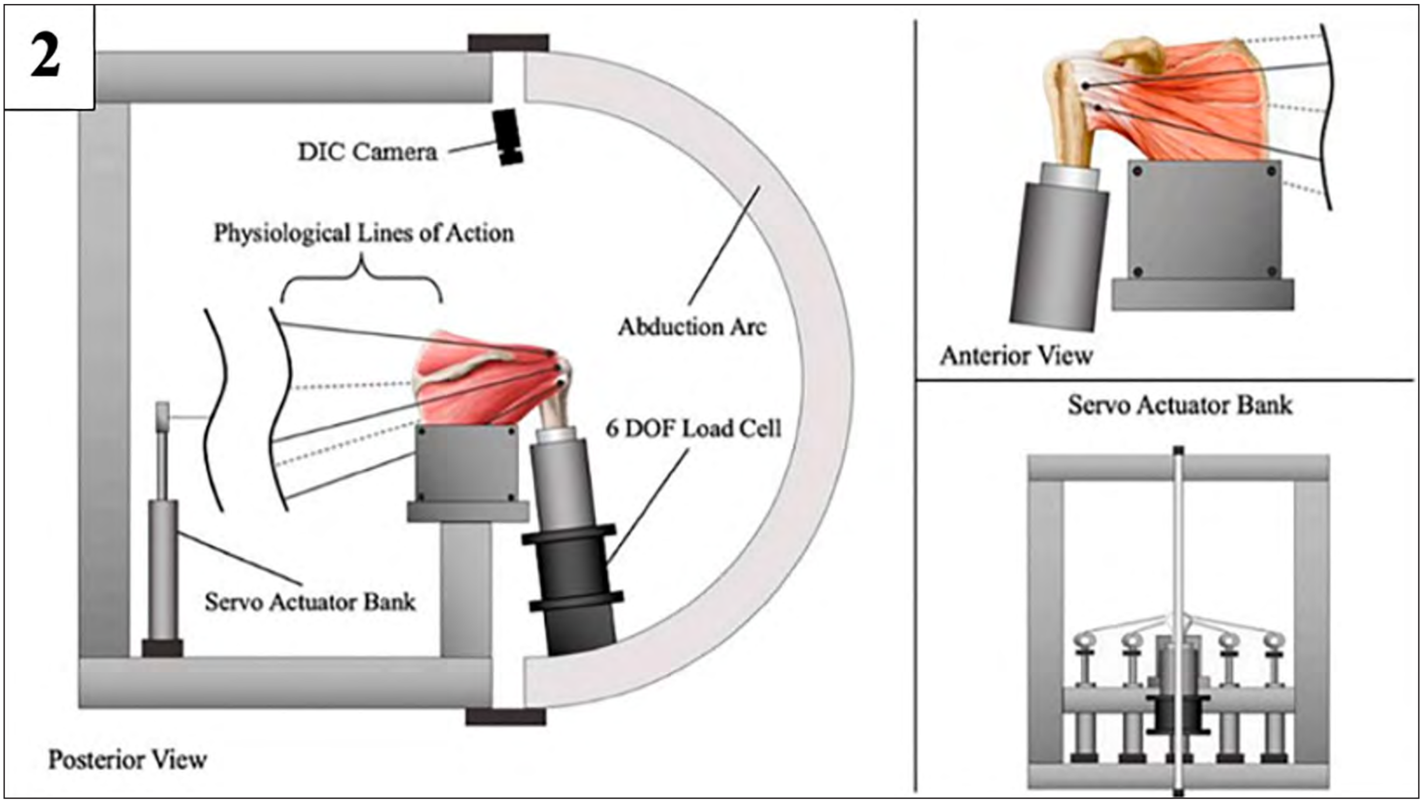


Figure 2. A schematic of the shoulder simulator

SHOULDER ABDUCTION FORCE LOSS AFTER ROTATOR CUFF TEAR PROGRESSION

Schmidt CC, Rodriguez-Alejandro OE, Ricci BG, Cooke SP, Buce JG, Cook AJ, Stay GJ, Frantz JS, Miller MC, Smolinski PJ

Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.

INTRODUCTION

It has been shown that tear propagation to the infraspinatus (IS) muscle is the critical stage for significant changes in humeral head kinematics.[1] However, the effects of posterior tear propagation on shoulder abduction force transmission remain unclear. The purpose of this study was to examine changes in shoulder abduction force after posterior tear propagation through supraspinatus (SS) strap and IS tendon releases.

METHODS

Twenty fresh-frozen cadaveric specimens (average age = 69.10 ± 10.64 years) were tested in a shoulder simulator with physiological load vectors applied to the upper (127 N) and lower (108 N) subscapularis, SS cord (56 N), SS strap (24 N), infraspinatus (90 N), and teres minor (97 N) tendons. The coracohumeral ligament (CHL) and SS cord were released from their footprints to create an initial anterior tear. Each specimen was then subjected to SS strap release, followed by IS release (see Figure 1A and 1B). Testing was completed at both 0° and 30° of shoulder abduction, and a 6-degree-of-freedom load cell measured shoulder abduction force at the unconstrained distal humerus.

RESULTS

Abduction forces and comparisons between release cases are shown in Table 1. An SS strap release led to no significant change in abduction force when compared to the previous anterior release ($p \geq 0.264$). However, an additional IS release led to a significant decline in abduction force when compared to the SS strap release ($p < 0.001$).

DISCUSSION

The current study found that tear propagation to the IS did result in a significant decline in shoulder abduction force when compared to SS strap release. SS strap release did not significantly decrease abduction force following the anterior releases. Tear propagation to the IS, as opposed to the SS strap, may be a stronger predictor of shoulder abduction force declines following an anterior tear. A mechanical case can be made to further investigate how different stages of posterior tear propagation can affect shoulder abduction force.

REFERENCE

1. Oh JH et al. *JBJS*. 2011;93(22):2100-9.

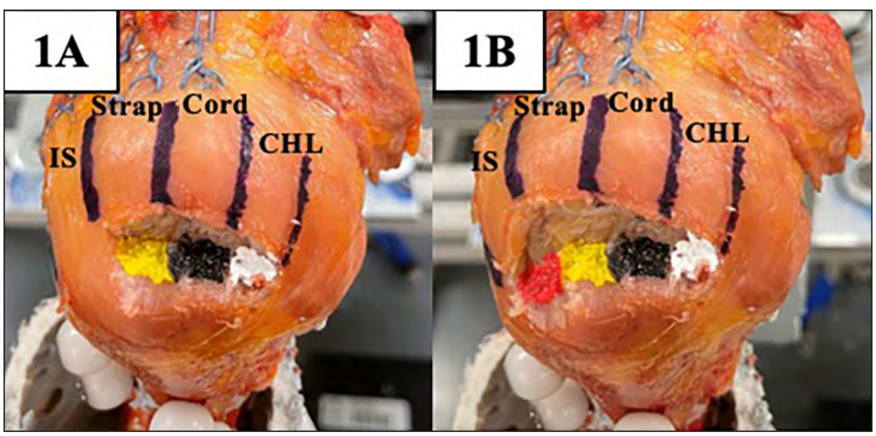


Figure 1. A: Supraspinatus (SS) strap release following anterior release (i.e., release of the coracohumeral ligament and SS cord); B: Infraspinatus release off the footprint

Abduction Angle	Released Structure	Abduction Force [N]	Percentage of Native Force	p-value (vs prior released structure)
0°	SS strap	4.3 (1.3)	77%	p>0.999
	SS strap + IS	3.7 (1.3)	66%	p<0.001
30°	SS strap	4.8 (2.3)	73%	p=0.264
	SS strap + IS	3.3 (1.9)	51%	p<0.001

Table 1. Abduction force of the SS strap and infraspinatus releases compared to native and previous releases

JOINT TISSUE BIOLOGY, PATHOLOGY, AND ENGINEERING LABORATORY

Hang Lin, PhD, director

LAB MEMBERS

Haruyo Yagi, PhD, research scientist
Jiangyinzi Shang, PhD, postdoctoral associate
Shotaro Kamijo, PhD, visiting scholar
Meagan Makarcyzk, graduate student
Sophie Hines, BS, graduate student
Lauren Simonian, medical student
Marfred M. Umanes, medical student
Xenab Ahmadpoor, MS, research assistant
Jessie Sun, MS, research assistant
Yiqian Zhang, BS, visiting scholar
Yanfan Lu, BS, visiting scholar
Katelyn Lipa, undergraduate student
Justin Zbikowski, undergraduate student
Alyssa Aguglia, undergraduate student
Celeste Lintz, undergraduate student
Suyash Sinkar, undergraduate student
Olivia Bartholomew, undergraduate student

OVERVIEW

The mission of the Joint Tissue Biology, Pathology, and Engineering Laboratory (JTBE) is to foster innovative and interdisciplinary research utilizing principles of life sciences and engineering to develop tools and techniques for studying the development, function, pathogenesis, and regeneration of musculoskeletal tissues. Through the use of different platforms, including traditional tissue cultures, animal models, and emerging organ-on-a-chip systems, the lab aims to develop efficacious and safe therapies to treat various joint diseases, particularly osteoarthritis. We also train the next generation of researchers to enhance their surroundings by engaging in integrity, excellence, and teamwork.

YEAR IN REVIEW

In 2023, the lab continued to be supported by external funding from the National Institutes of Health (NIH), Department of Defense, and Pennsylvania Department of Health. We were also awarded a new NIH R21 grant to use a novel compound to enhance reparative outcomes after microfracture. The team published eight peer-reviewed articles last year, and two of them were published in journals with an impact factor higher than 10.

With support from the department leadership, the JTBE seminar series, cohosted by Hang Lin, PhD, and Peter Alexander, PhD, continued to invite external experts to share their work and get to know Pitt's orthopaedic research capacity. Moreover, a special trainee session occurs after the presentation, which provides invaluable opportunities for trainees to interact with outstanding researchers from other institutions.

AN INNERVATED SYNOVIUM-CARTILAGE CHIP FOR MODELING KNEE JOINT INFLAMMATION AND ASSOCIATED PAIN

Makarczyk M[1,2], Preissegger M[3], Zhong[1], Hines S[1,2], Aguglia A[1,2], Zbikowski J[1,2], Padget A[1], Gao Q[4], Cho S[1], Tuan R[1], Weber D[5], Bunnell B[6], Goodman S[4], Gold M[3], Lin H[1,2]

[1]Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.
[2]Department of Bioengineering, University of Pittsburgh, Pittsburgh, Pa.
[3]Department of Neurobiology, University of Pittsburgh, Pittsburgh, Pa.
[4]Department of Orthopaedic Surgery, Stanford University, Palo Alto, Calif.
[5]Department of Biomedical Engineering, Carnegie Mellon University, Pittsburgh, Pa.
[6]Department of Microbiology, Immunology, and Genetics; University of North Texas Health Science Center; Forth Worth, Texas

INTRODUCTION

The leading symptom of osteoarthritis (OA) is pain, the primary reason most patients seek medical care. There are no consistently effective approaches for the management of OA pain that are devoid of deleterious side effects.[1] In OA, the cartilage begins to degrade, and degradation products can then affect the synovial tissue which encompasses the cartilage. Synovial inflammation is considered to be a primary contributor to pain during early OA progression.[2] The objective of this study was to use a cartilage-synovial tissue chip, the NeuSynCar model, to investigate the interaction of cartilage degradation products and an innervated synovial-like tissue to assess pain during OA. The authors hypothesized that degradation products from engineered cartilage tissue would promote synovial inflammation and subsequently activate pain signaling in human neurons.

METHODS

Fibroblasts derived from human bone marrow–derived mesenchymal stem cells and M0 macrophages were encapsulated in 10% methacrylated gelatin (GelMA) to form a synovial-like tissue (SYN). Human primary chondrocytes were encapsulated in 15% GelMA to form the cartilage construct (CAR). Rat dorsal root ganglion (rDRG) neurites (NEU) were seeded adjacent to the SYN in a two-chamber microfluidic chip allowing for the innervation of the SYN. Medium from CAR was provided to the SYN for tissue crosstalk. The CAR was treated with interleukin (IL)-1β (10 ng/mL) for three days to induce OA-like inflammation. SYN constructs were treated with conditioned medium from inflamed CAR for two days to demonstrate the effect of soluble cartilage factors. Neurons were transfected with GCaMP, and rDRGs were assessed with live imaging to investigate their response to the conditioned medium in the synovial-like chamber. Student t-tests and two-way analyses of variance were used to assess statistical significance.

RESULTS

CAR constructs treated with IL-1β showed robust inflammation and degradation. LUMINEX assay showed a significant increase of matrix metalloproteinases and proinflammatory cytokines in CAR conditioned medium and an increase in CCL-2 and CXCL-1 in the SYN constructs after treatment with CAR conditioned medium. Treatment of the SYN with CAR conditioned medium demonstrated an M1 polarizing effect compared to the healthy control. Interestingly, fluorescence imaging of rodent and human DRG neurites showed activation when treated with inflamed CAR medium, suggesting the generation of pain activity (see Figure 1).

DISCUSSION

The authors aim to study the mechanisms of cartilage-synovial crosstalk and pain activation during OA. Currently, they are establishing a prolonged real-time imaging apparatus to assess pain activation over a number of days. The final objective of this study is to use the system as a platform for personalized pain medicine.

REFERENCES

1. Riewruja K et al. 2022. *Osteoarthr Cartil Open*.
2. Terkawi MA et al. 2022. *Biomedicines*.

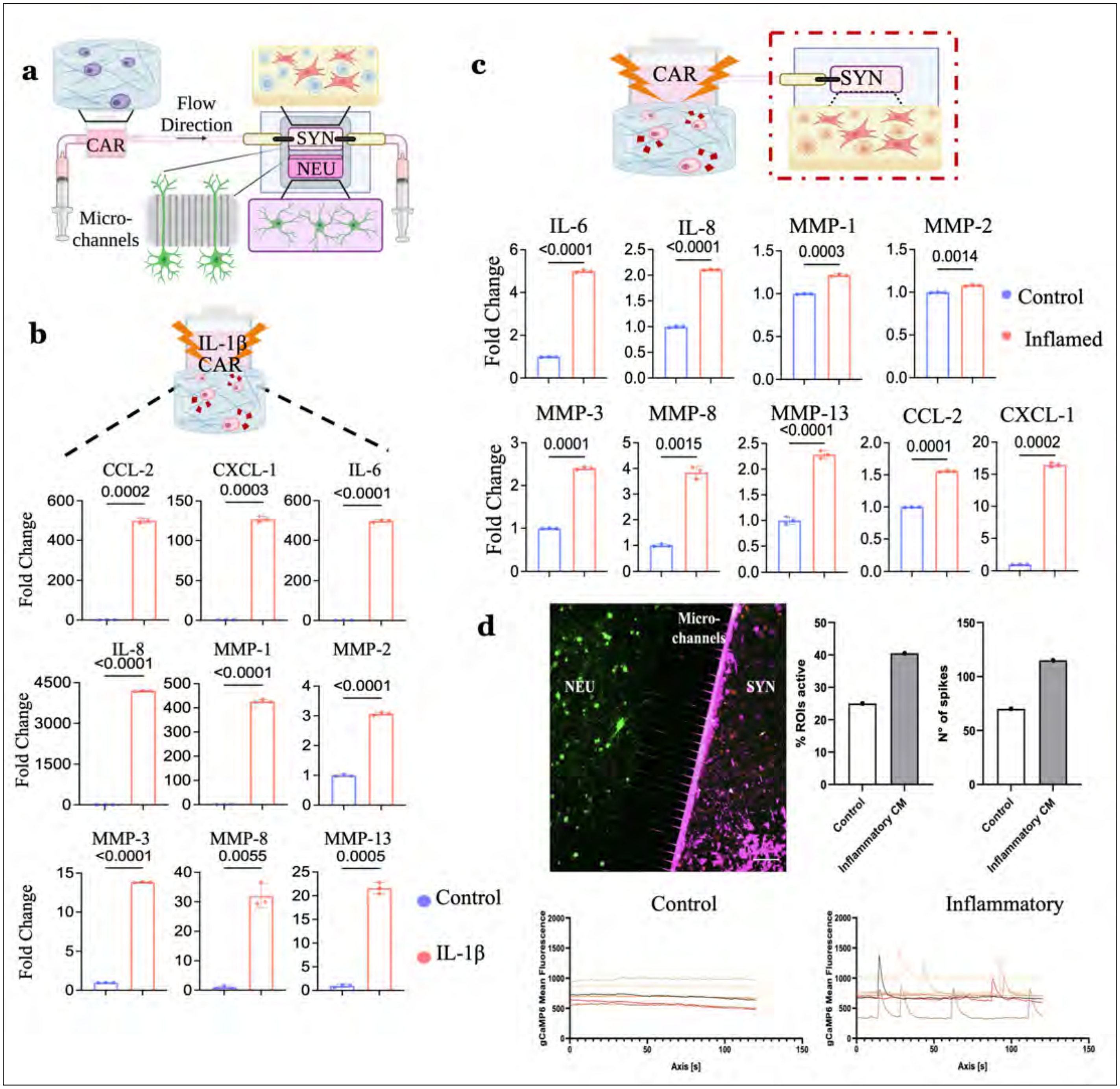


Figure 1. a) NeuSynCar model schematic, b) LUMINEX data from cartilage (CAR) bioreactor (n = 3), c) LUMINEX data of synovial-like (SYN) tissue following treatment with CAR conditioned medium (n = 3), d) GCaMP fluorescence imaging and intensity quantifications. rDRG neurites (green) are innervating SYN tissue with fibroblasts (pink) and macrophages (red).

AGING-ASSOCIATED INCREASE OF GATA BINDING PROTEIN 4 LEVELS IN CHONDROCYTES IMPAIRS THEIR REGENERATIVE CAPACITY

Makarczyk M[1,2], Zhang Y[1], Aguglia A[1,2], Hines S[1,2], Lin H[1,2]

[1]Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.
[2]Department of Bioengineering, University of Pittsburgh, Pittsburgh, Pa.

INTRODUCTION

Aging is the biggest risk factor for osteoarthritis (OA),[1] and most cases occur in adults older than 45.[2] Investigating the mechanisms of healthy aging and molecules involved in age-related pathogenesis might elucidate the mechanisms of age-associated OA onset and progression. In this study, the authors aimed to compare the transcriptome of young (< 45 years) and old (> 70 years) human chondrocytes from healthy donors to define the key molecules that mediate chondrocyte aging.

METHODS

Based on age-related details, young and old human chondrocytes isolated from healthy donors were individually plated and collected for RNA sequencing analysis. Cartilage samples were stained for GATA binding protein 4 (GATA4). Young chondrocytes were cultured in monolayer and transfected with the lentiviral vector containing *GATA4* gene or the control lentivirus for 10h, which were constructed by VectorBuilder (ID: NM_0013089093). Transfected chondrocytes were collected and formed into pellets at a cell seeding density of 3 x 10^5. Pellets were treated with chondrogenic medium containing transforming growth factor-β3; medium was changed daily for seven days. After transfection, western blot, quantitative polymerase chain reaction, and immunohistochemistry were used to verify the stable expression of GATA4 in cells.

RESULTS

IPA Upstream Regulator Analysis was used to predict the key factors in young and old cells (see Figure 1). Interestingly, GATA4 was predicted to be one key regulator of chondrocyte aging. GATA4 IHC staining depicted that aged individuals have higher GATA4 compared to young individuals, confirming that old chondrocytes express more GATA4 than young cells. The lentiviral vector upregulation of GATA4 significantly impaired cartilage formation, indicated by the activation of catabolic pathways. Safranin O staining and Collagen Type II IHC showed less staining of ECM components in the GATA4 KI groups (see Figure 2).

DISCUSSION

The authors have identified an aging-associated increase of GATA4 in chondrocytes, which impaired cartilage formation potential. Interestingly, GATA4 has been shown to be involved in the activation of inflammatory pathway nuclear factor-κB (NF- κB).[3] Further analysis needs to be verified using western blot to ascertain the activation of the NF- κB pathway during GATA-4 induction.

REFERENCES

1. Rahmati M et al. *Ageing Res Rev.* 2017;40:20-30.
2. Makarczyk MJ et al. *Tissue Eng Part C Methods.* 2021;27:124-38.
3. Shi W et al. *Front Med.* 2021;8.

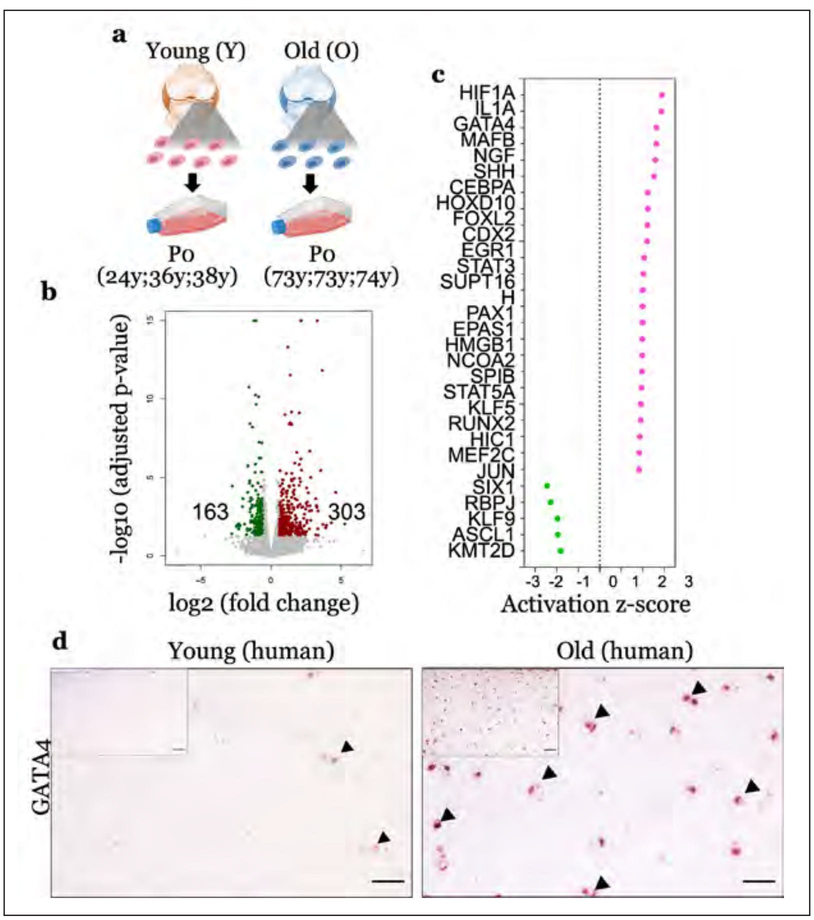


Figure 1. a) Schematic of healthy chondrocytes isolated from young (< 45 years) and old (> 45 years) donors, b) volcano plot demonstrating 303 upregulated and 163 downregulated genes, c) activation z score of genes in aged (pink) versus young (green) chondrocytes, d.) IHC of GATA4 staining in human cartilage samples
Scale bar = 50 µm

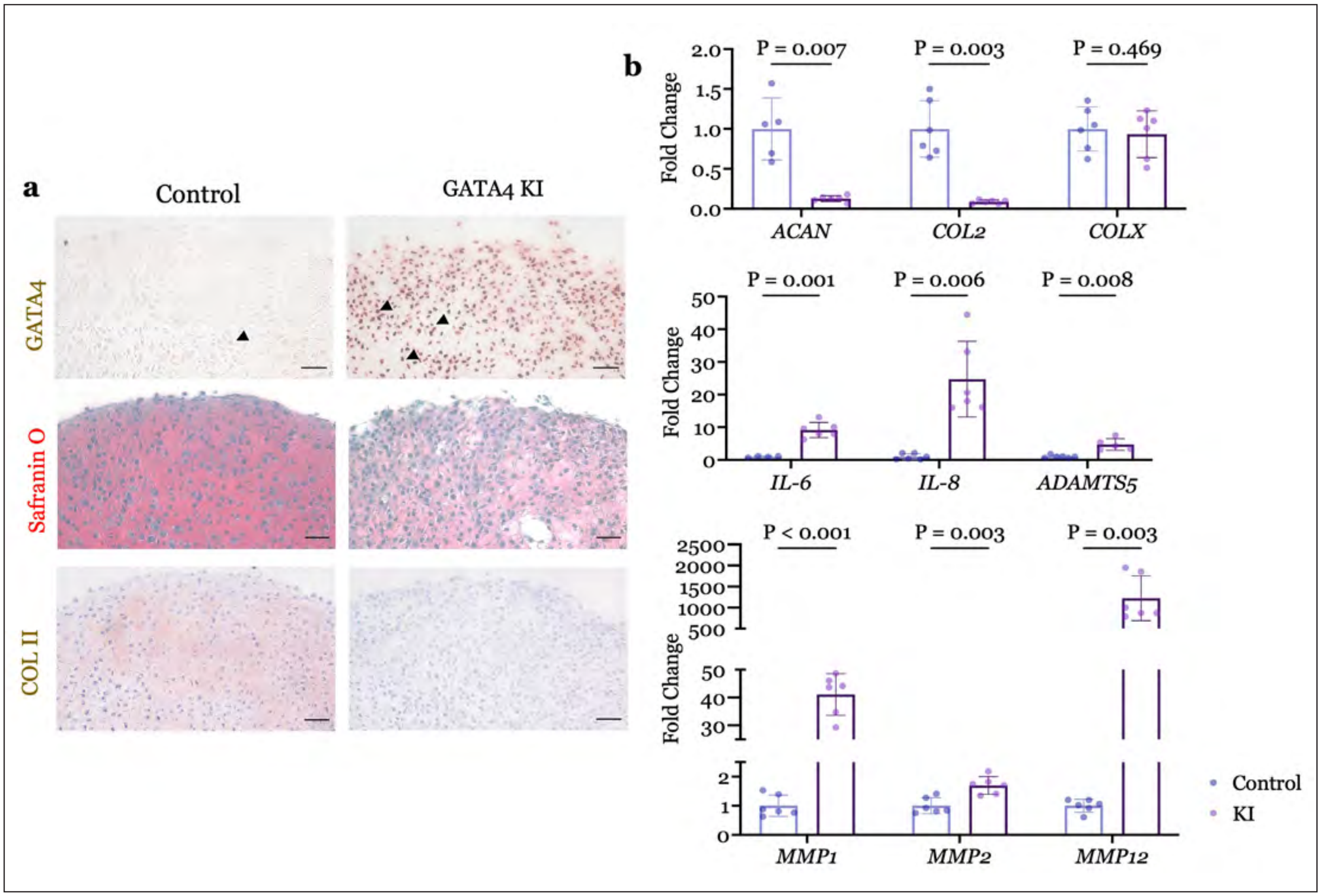


Figure 2. Assessing the influence of GATA-4 overexpression during chondrogenesis: a) IHC analysis of GATA4, Collagen II, and Safranin O staining (scale bar = 50 µm), b) reverse transcription quantitative polymerase chain reaction results from GATA4 knock-in

POTENTIAL OF FORSKOLIN IN ENHANCING MICROFRACTURE-BASED CARTILAGE REGENERATION

Simonian LE, Lintz C, Lin H

Department of Orthopaedic Surgery, University of Pittsburgh School of Medicine, Pittsburgh, Pa.

INTRODUCTION

The microfracture procedure is an arthroscopic surgery for repairing osteochondral defects in the knees.[1] Unfortunately, there are inherent problems with this procedure. The new cartilage that is formed to repair the osteochondral defect is fibrocartilage, which tends to fail within about three to five years after the surgery.[2]

In order to reduce the amount of fibrocartilage produced, the authors have studied fibrosis that occurs during new cartilage formation. Yes-associated protein/transcriptional coactivator with PDZ binding motif (YAP/TAZ) expression in the Hippo pathway may be a therapeutic target. Previous studies have demonstrated that inhibition of YAP/TAZ reduces fibrosis.[3] There are specific drug candidates that have YAP/TAZ inhibiting potential, such as forskolin. Forskolin can act as an indirect YAP inhibitor. It does so by increasing cAMP, which activates upstream large tumor suppressor 1/2 (Lats1/2) kinase activity, which subsequently increases phosphorylated YAP. Once YAP is phosphorylated, it will not translocate to the nucleus and be expressed, thereby reducing fibrosis proliferation.[4,5]

The authors used an *in vitro* chondrogenesis model to test the influence of YAP inhibitors, specifically forskolin in this study, on new cartilage formation. They hypothesized that administration of forskolin or other YAP inhibitors would reduce fibrosis and increase hyaline cartilage formation.

METHODS

Human mesenchymal stem cells (MSCs) were isolated from bone marrow samples, then pooled and expanded in growth media. Then 1×10^6 P6 MSCs were subsequently encased into a 44 µL fibrin scaffold and differentiated into chondrocytes within the scaffold over the course of 28 days in chondrogenic media. At zero, seven, or 14 days of chondrogenesis, forskolin was introduced into the culture with concentrations of 1 µM or 10 µM. Treated chondrocytes were analyzed by reverse transcription quantitative polymerase chain reaction (RT-qPCR) and one-way analysis of variance test with Tukey's post-hoc test, western blot, and histology.

RESULTS

In all three tested time points, forskolin at both doses could suppress the expression of representative markers of fibrosis, including type 1 collagen (*COL1*) and type 3 collagen (*COL3*), in MSC-derived cartilage (Figure 1A and 1B). A significant difference was only observed at 10 µM for *COL1* ($p < 0.0001$) at all time points. To further validate the findings from RT-qPCR, western blot was performed to examine the protein levels of *COL1*. At 10 µM, forskolin significantly reduced *COL1* levels (Figure 1C). The highest degree of *COL1* suppression was observed when forskolin was introduced at day 7 of chondrogenesis.

DISCUSSION

The results indicate that the administration of forskolin reduces *COL1* and *COL3*. It is also apparent that 10 µM of forskolin was a sufficient dose to reduce fibrosis markers at multiple time points. There was also no apparent impairment in chondrogenesis based on Safranin O staining. This indicates that targeting the YAP/TAZ pathway is a potential therapeutic option. Of note, forskolin is a relatively nonspecific inhibitor of this pathway, so the authors seek to further test this utilizing other, more specific YAP inhibitors. In the future, they will test the potential of introducing forskolin and other YAP inhibitors to enhance microfracture-based cartilage regeneration *in vivo*.

REFERENCES

1. Steadman JR et al. *Cartilage*. 2010.
2. Mithoefer K et al. *AJSM*. 2009.
3. Mia MM & Singh MK. *Cells*. 2022.
4. Haak AJ et al. *Science Translational Medicine*. 2019.
5. Yu FX et al. *Cell*. 2012.

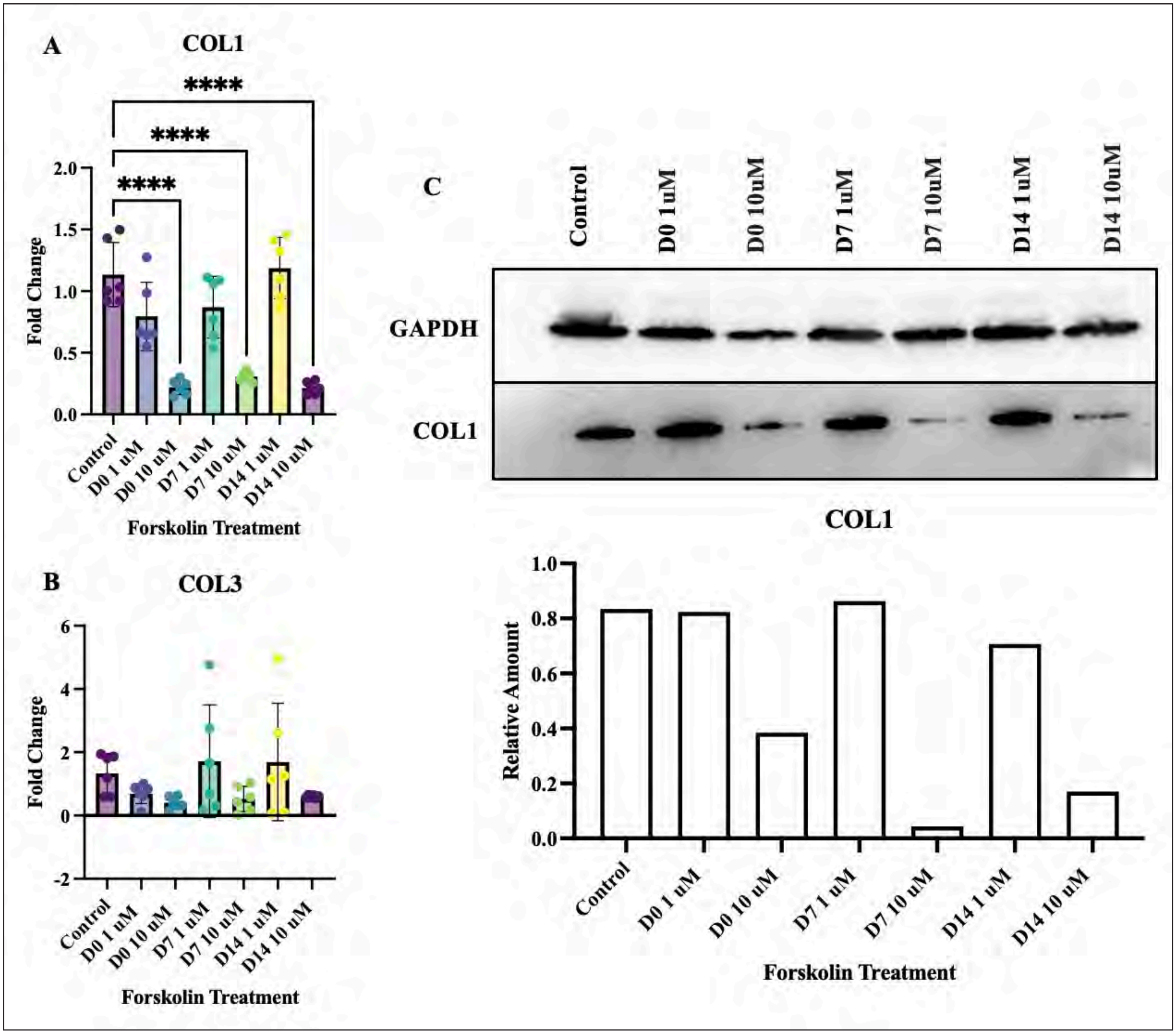


Figure 1. ***COL1*** **(A) and** ***COL3*** **(B) gene expression in mesenchymal stem cell–derived cartilage after being treated with 1 µM or 10 µM of forskolin at day 0, day 7, or day 14 of chondrogenesis, (C)** ***COL1*** **protein levels after treatment**
****** $p < 0.0001$**

ASSESSING THE CONTRIBUTION OF ESTROGEN RECEPTOR-A LOSS TO CARTILAGE DEGRADATION IN OSTEOARTHRITIS

Yangfan Lu Y[1,2], Jessie Sun J[1], Hang Lin H[1]

[1]Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.
[2]Department of Orthopaedics, Xiangya Hospital, Central South University, Changsha, Hunan, China

INTRODUCTION

Knee osteoarthritis (KOA) is a common joint disease, and cartilage degradation represents a central pathological change. Currently, the prevalence of KOA among people older than 60 years in the United States is more than 37%, and among people older than 40 years in China the rate is as high as 15.6%. Patients with long-term KOA also suffer from sleep disorders, depression, and even disability. At present, non-steroidal anti-inflammatory drugs (NSAIDs), intra-articular injections, artificial joint-replacement surgery, and other methods are used as the main means to alleviate or treat KOA, but none of them can effectively delay or reverse the occurrence and development of KOA and associated cartilage degeneration.

Previous studies in the authors' lab demonstrated that levels of estrogen receptor-α (ERα) decreased with OA pathogenesis, which is sex- and ligand-independent. Moreover, when expression levels of ESR1, the gene encoding ERα, were suppressed, mechanical loading enhanced hypertrophic and osteogenic transition *in vitro*. The authors also found out the critical role of ERα in maintaining the health of chondrocytes by inhibiting DNA damage and senescence. However, as of now, the influence of ERα on cartilage degradation and OA pathogenesis has not been examined in animal models.

METHODS

Destabilization of the medial meniscus (DMM) surgery was performed to induce OA in mice. With approval from the Institutional Animal Care and Use Committee, the researchers performed DMM surgery in 12-week-old ERα global knockout mice (Esr1-/-) and wild-type (WT) mice. After surgery, mice were housed for 12 weeks. The knee joints were fixed and embedded. All samples were sectioned at a thickness of 6 μm. Safranin O/Fast green staining and immunohistochemical staining were performed. Cartilage damage was measured with the Osteoarthritis Research Society International (OARSI) score. To exclude systemic influence due to the global loss of ERα, the researchers are also working on the generation of transgenic mice with cartilage-specific depletion of ERα. Mouse genotyping was conducted with the mice tail DNA.

RESULTS

DMM mice exhibited significant cartilage erosion and loss of both proteoglycans and cellularity in the articular cartilage when compared with sham-surgery mice. The generation of OA phenotype was further confirmed by a significantly higher OARSI score. Interestingly, Esr1-/- mice undergoing DMM showed a higher OARSI score than WT control. Moreover, levels of matrix metallopeptidase 13 (MMP13) and osteocalcin (OCN) were increased, whereas collagen type II (COL2) and SRY-box transcription factor 9 (SOX9) were significantly decreased in Esr1-/- DMM mice compared with WT DMM mice.

The results demonstrated that global loss of ERα and DMM synergistically increase the hypertrophic and ossific transition of chondrocytes and accelerate OA progression. To exclude the systemic influence due to global ERα loss, transgenic mice with cartilage-specific depletion of ERα are also generated. Genotyping data confirmed the successful generation of ERacKO and LT mice. Importantly, the IHC results indicated the ablation of ERa in articular chondrocytes of ERacKO mice.

DISCUSSION

Through the ongoing study, the researchers will finally determine whether cartilage-specific deletion of ERα will result in cartilage degradation, as they observed in Esr1-/- mice. In order to verify whether the presence of estrogen will affect the effect of ERα knockout on the OA phenotype, they will conduct a new study by including additional female mice undergoing ovariectomy to remove the influence of endogenous estrogen. Lastly, they will conduct a mechanistic study to define the pathways mediating ERα and pathological changes in chondrocytes.

REFERENCES

1. Wang N & Lin H. Novel role of estrogen receptor-α on regulating chondrocyte phenotype and response to mechanical loading. *Osteoarthritis Cartilage*. 2022;30(2):302-14.
2. Zhang X & Lin H. In vitro study to identify ligand-independent function of estrogen receptor-α in suppressing DNA damage-induced chondrocyte senescence. *FASEB J*. 2023;37(2):e22746.

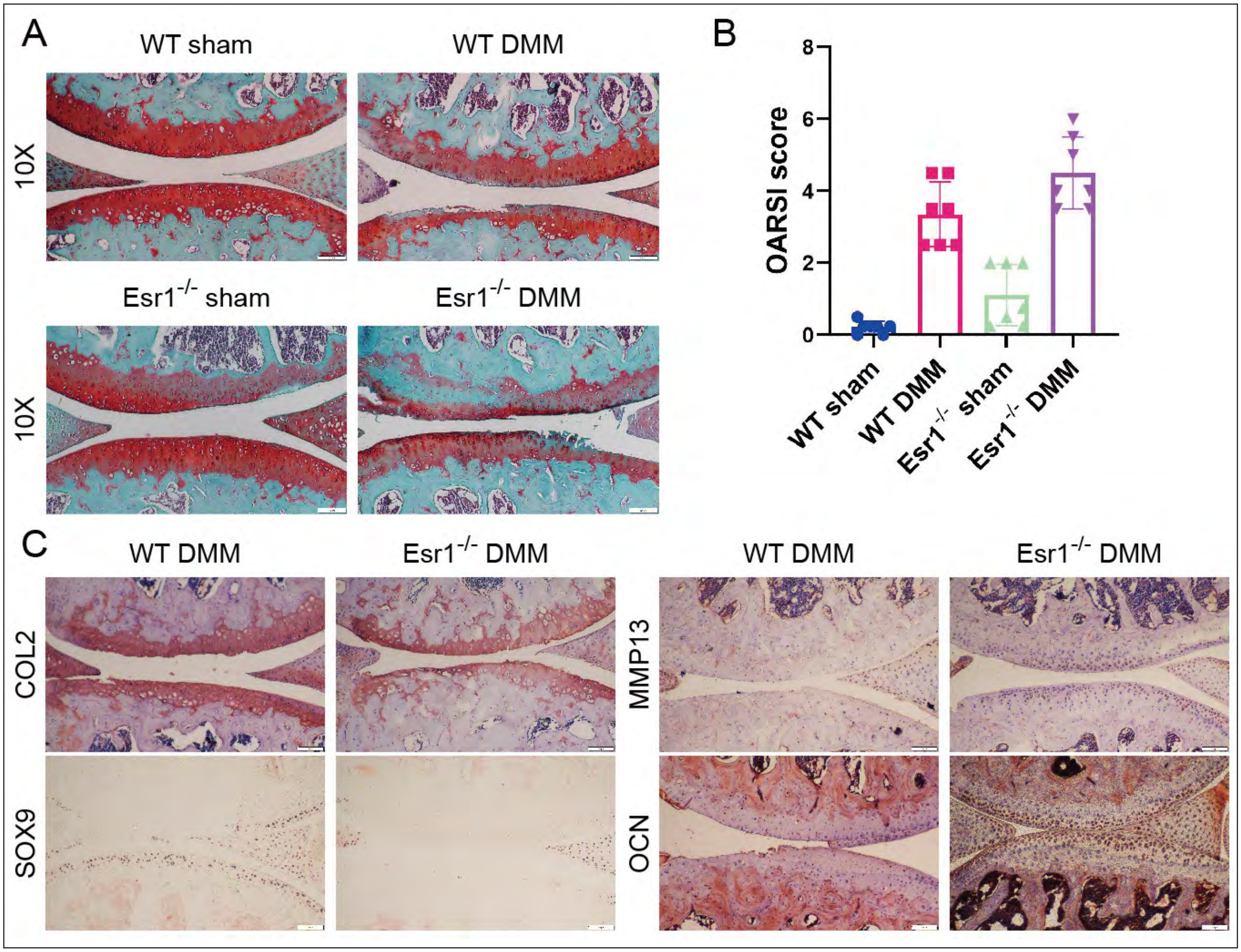


Figure 1. (A) Representative images from Safranin O/Fast green staining. Wild-type (WT) and ERα global knock out (Esr1-/-) mice were used. Scale bar = 100 µm. (B) The researchers analyzed the severity of osteoarthritis-like phenotype 12 weeks after surgery by grading histological sections using the Osteoarthritis Research Society International score system. (C) Representative images of immunohistochemical staining for COL2, SOX9, MMP13, and OCN in knee joint of mice (scale bar = 100 µm)

SURREALITY LAB

Edward Andrews, MD, codirector
Jacob Biehl, PhD, codirector

Lab Leadership
Stephen Canton, MD, deputy director
Andrew Legarreta, MD, director of artificial intelligence (AI)
Nicolás Kass, BS, innovations and research fellow
Nikhil Sharma, BS, innovations and research fellow
Michael Kann, BE, innovations and research fellow
Shovan Bhatia, BE, innovations and research fellow

Clinical Team
Samuel Adida, Regan Shanahan, Akshay Sankar, Jhair Colan, Fritz Steuer, Anthony Tang, Sumaarg Pandya, Lucy Cheng, Brandon Aguilar, Mohamed Jawad-Makki, Amogh Vellore

Technical Team
Rishi Basdeo, Elliot Finney, Griffin Hurt, Talha Khan, Brayden Nguyen

OVERVIEW

The Surreality Lab represents a trailblazing collaboration between the disciplines of medicine and computer science, driven by a shared commitment to revolutionize the landscape of surgical care. Founded within the Department of Neurosurgery at the University of Pittsburgh Medical Center and the University of Pittsburgh's School of Computing and Information, the lab serves as the nucleus of cutting-edge research and development in three pivotal technological realms: spatial computing (SC), AI/machine learning (AI/ML), and robotics.

The lab's inception stems from a recognition of the exponential potential of these technologies in addressing critical challenges within health care. Although SC is still in its infancy within medical applications, the technology presents boundless opportunities to enhance surgical precision, medical education, and patient care. Simultaneously, AI/ML and robotics are reshaping the practice of medicine, optimizing treatment strategies, streamlining workflows, and predicting outcomes with unprecedented accuracy.

At the Surreality Lab, a multidisciplinary team of medical professionals, computer scientists, engineers, and innovators collaborate tirelessly to push the boundaries of what's achievable in surgical care. Given the widespread potential of these technologies, the team works across a diverse range of subspecialties, including neurosurgery, orthopaedic surgery, plastic surgery, otorhinolaryngology, and urology, among others.

Our ethos centers on fostering a thriving ecosystem of innovation, where novel ideas germinate, evolve, and culminate into tangible solutions that impact patient care. We champion a symbiotic approach in which our technical and clinical teams work together to transform visionary concepts into real-world applications, with discovery in the realms of both computing and medicine. We support project teams with funding, resources, mentorship, and guidance through the intricate paths of ideation, investigation, analysis, publication, commercialization, and beyond.

Join us in our mission to redefine surgical care through technological innovation, and along the way define the next generation of collaborative, interdisciplinary researchers.

YEAR IN REVIEW

In 2023, the Surreality Lab was supported by funding from four separate grants, including the Pittsburgh Foundation Copeland Grant, Beckwith Institute Clinical Transformation Grant, UPMC Mercy Medical Executive Committee Grant, and NSF Graduate Research Fellowship Program. The lab also maintained strategic partnerships with industry leaders, such as Medivis and HaptX, as well as academic institutions, such as Carnegie Mellon University. Our research team published three peer-reviewed articles, and one won best journal paper at the International Symposium on Mixed and Augmented Reality. Additionally, lab members presented seven oral podium and poster presentations at several academic conferences across the disciplines of orthopaedic surgery, neurosurgery, plastic surgery, otorhinolaryngology, urology, computer science, and virtual reality, winning five awards for best abstract and best presentation.

FEASIBILITY AND USABILITY OF AUGMENTED REALITY TECHNOLOGY IN THE ORTHOPAEDIC OPERATING ROOM

Canton SP[1], Austin CN[2], Steuer F[2], Dadi S[3], Sharma N[2], Kass NM[2], Fogg D[4], Clayton E[5], Cunningham O[2], Scott D[5], LaBaze D[5], Andrews EG[6], Biehl JT[7], Hogan MV[5]

[1]Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.
[2]University of Pittsburgh School of Medicine, Pittsburgh, Pa.
[3]Rowan-Virtua School of Osteopathic Medicine, Stratford, N.J.
[4]Texas Tech University Health Sciences Center El Paso, El Paso, Texas
[5]Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, Pa.
[6]Department of Neurological Surgery, University of Pittsburgh Medical Center, Pittsburgh, Pa.
[7]School of Computing and Information, University of Pittsburgh, Pittsburgh, Pa.

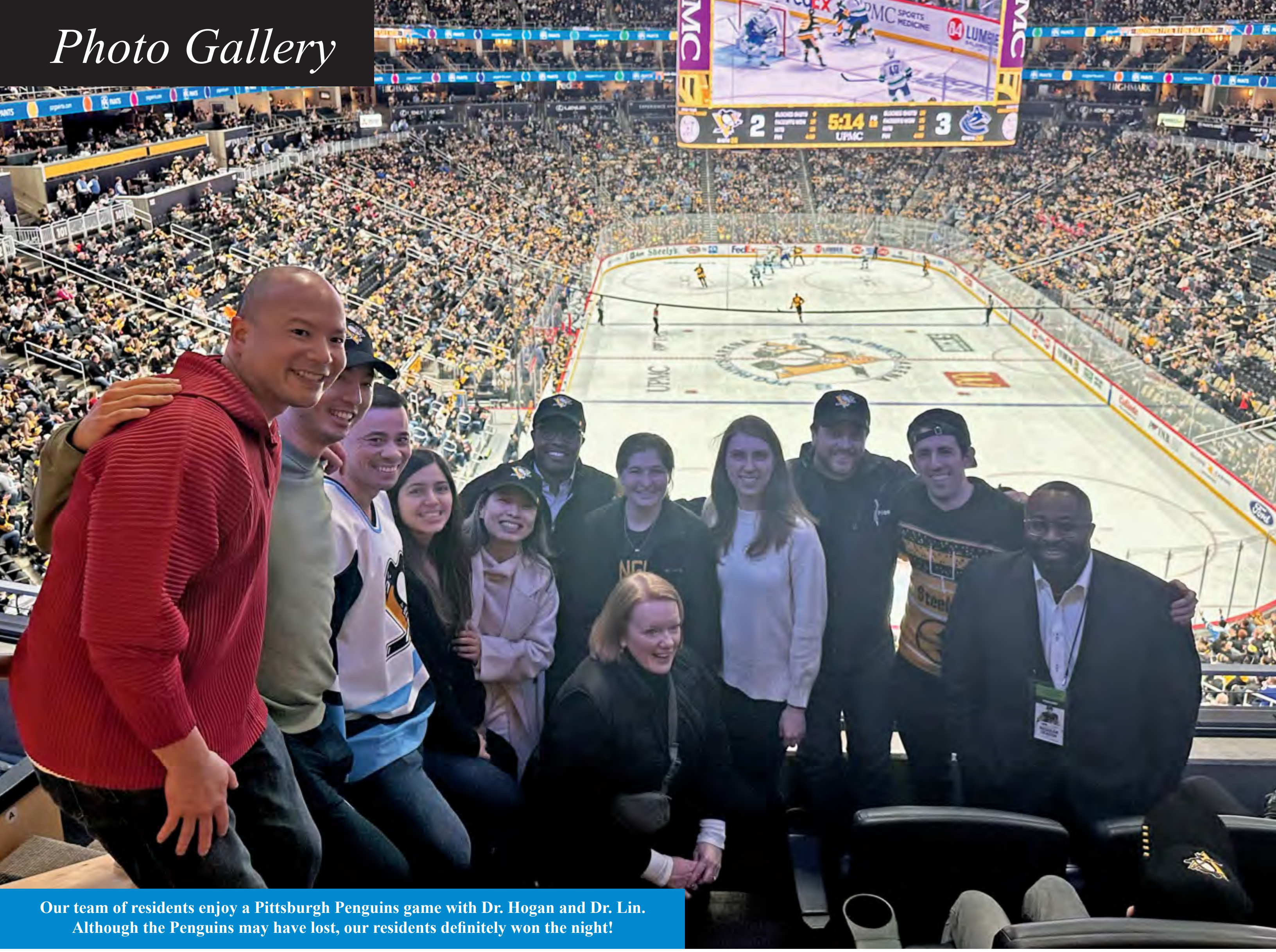
INTRODUCTION

Augmented reality (AR) has gained popularity in various sectors, including gaming, entertainment, and health care. The desire for improved surgical navigation within orthopaedic surgery has led to the evaluation of the feasibility and usability of AR in the operating room (OR). However, the safe and effective use of AR technology in the OR necessitates a proper understanding of its capabilities and limitations. This review aims to describe the fundamental elements of AR, highlight limitations for use within the field of orthopaedic surgery, and discuss potential areas for development.

FINDINGS

To date, studies have demonstrated evidence that AR technology can be used to enhance navigation and performance in orthopaedic procedures. General hardware and software limitations of the technology include the registration process, ergonomics, and battery life. Other limitations are related to human-response factors, such as inattentional blindness, which may lead to the inability to see complications within the surgical field. Furthermore, the prolonged use of AR can cause eye strain and headache due to phenomena such as the vergence-convergence conflict. AR technology may prove to be a better alternative to current orthopaedic surgery navigation systems. However, the current limitations should be mitigated to further improve the feasibility and usability of AR in the OR setting. It is important for both non-clinicians and clinicians to work in conjunction to guide the development of future iterations of AR technology and its implementation into the OR workflow.

Photo Gallery



Our team of residents enjoy a Pittsburgh Penguins game with Dr. Hogan and Dr. Lin. Although the Penguins may have lost, our residents definitely won the night!

Hanging with Hogan

Foot and ankle all-stars: Dr. Hogan with superchief Dr. Rebekah Belayneh and alumna Dr. Lorraine Boakye at the AOFAS meeting in Big Sky, Montana

Dr. Hogan with staff from St. Francis University during his invited speech to commemorate their Martin Luther King Jr. convocation

Dr. Hogan and alumna Dr. Boakye catch up at the recent AAOS meeting.

Dr. Hogan hosts the residents and his research fellow at a Pitt basketball game.

Ortho resident from Temple Kamali Thompson, MD, MBA, former Pitt Ortho resident Dr. Vonda Wright, and Dr. Hogan on stage at AAOS

Dr. Hogan at the Penguins game during Black History Month after being named a Penguins Community Impact Champion

Dr. Hogan and Dr. Lin pose with residents Dukens LaBaze, Joshua Adjei, and Stephen Canton on Pitt Ortho interview night.

Pitt Ortho shows their school spirit at Pitt basketball home game.

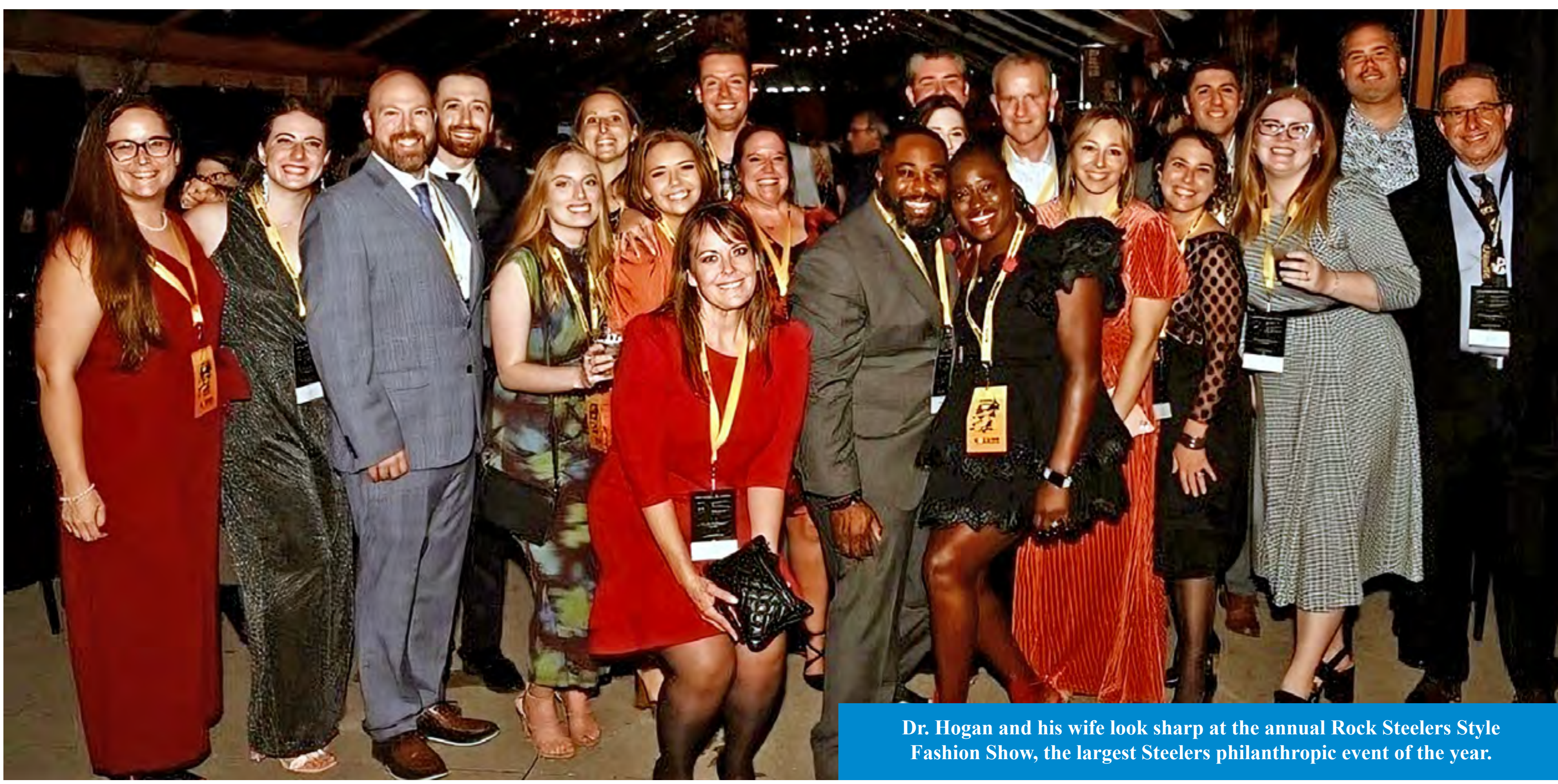
Dr. Hogan hosts residents Dukens LaBaze, Devon Scott, and his research fellow at a Steelers Game.

Our fearless leaders at the Pitt Ortho tailgate

Dr. Hogan welcomes new foot and ankle faculty member Dr. Lauren Lewis, MD, MPH, during her first week. Welcome to Pitt Ortho, Dr. Lewis!

Current ortho research residents Cortez Brown and Chris Como and medical student Kim Hua with Dr. Hogan at ORS

Dr. Hogan with Pittsburgh Pirates great Andrew McCutchen



Dr. Hogan and his wife look sharp at the annual Rock Steelers Style Fashion Show, the largest Steelers philanthropic event of the year.

Dr. Hogan and his family at the Arthritis Foundation's Bone Bash

ORS leadership dinner meeting

Multiple generations of Pitt Ortho greatness!
Dr. Hogan with Dr. Lin's daughter Gabby
at the Acrisure Stadium Welcome Picnic

White Coat Ceremony

Pitt Med Class of 2027 shows off their new white coats at the White Coat Ceremony, where they were led in the Hippocratic Oath by a recording of Freddie Fu.

Fun Stuff

Residents Susanne Boden and Matt Gong refuel at The Porch, a local restaurant in Oakland, after a busy day at Presby.

Residents Rob Tisherman, Alexandra Gabrielli, Rick Wawrose, and Maggie Hankins show that time-honored Pitt Ortho supportive culture at the annual chief roast.

Residents Alan Wilson and Cortez Brown respect the past and embrace the future with resident Dukens LaBaze at the annual chief roast.

A fitting send-off for former POJ Editor-in-Chief Rick Wawrose at the annual chief roast

Celebrating the holidays at the LaBaze household with residents Anthony Oyekan, Joshua Adjei, and Rebekah Belayneh

Esteemed Pitt Ortho alumni (and multiple current faculty) Adam Olsen, Joseph DeGroot, Malcolm Dombrowski, Lee Sasala, Justin Arner, and Juan Giugale catch a well-deserved hang at a local bar.

Pitt Ortho residents and significant others celebrate Chinese New Year at Hunan Bar.

Residents Kevin Byrne, Ehab Nazzal, and Bill Li knock down some pins at Arsenal Bowl.

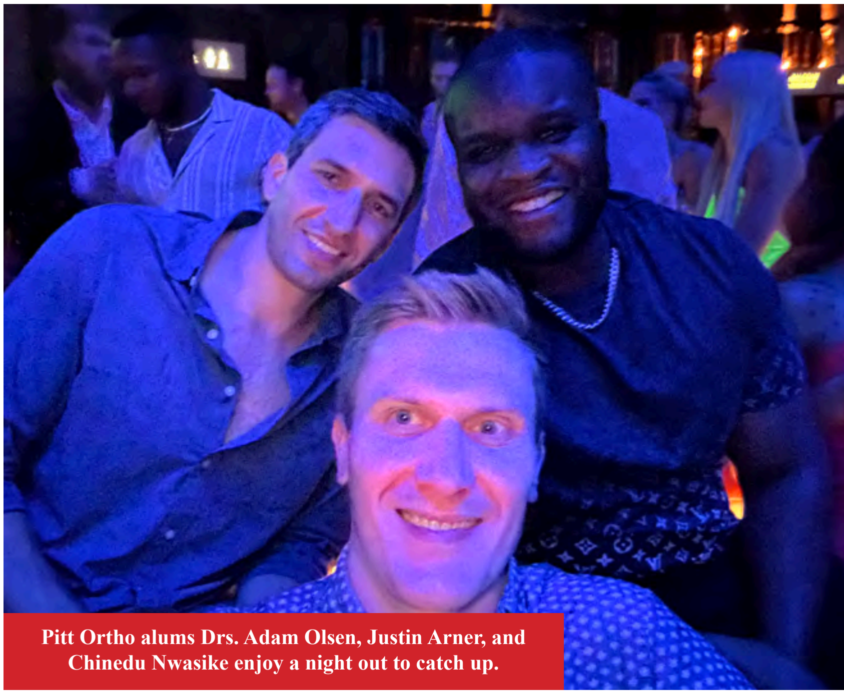
A night out with residents Gabrielle Fatora, Bill Li, and Morgan Kohls


The ortho residents find time between fixing fractures to celebrate the true meaning of Christmas at Stephen Chen's annual holiday party. Horns up!


Alan Wilson and Stephen Chen reminisce at the annual chief roast event.


The illustrious ortho oncology lab duo of Dr. Weiss and Bill Li man the cannon during some sight-seeing at Castillo San Felipe del Morro in Puerto Rico.


Residents Devon Scott, Stephen Canton, and Anthony Oyekan enjoy time by the pool.


Pitt Ortho alums Drs. Adam Olsen, Justin Arner, and Chinedu Nwasike enjoy a night out to catch up.

Dr. Kaufmann hosts his annual Pitt football tailgate, one of the best events of the year! H2P!

Pitt Ortho at the Penguins game


Residents Jay Dalton, Mike Fox, and Gabrielle Fatora at a Steelers game

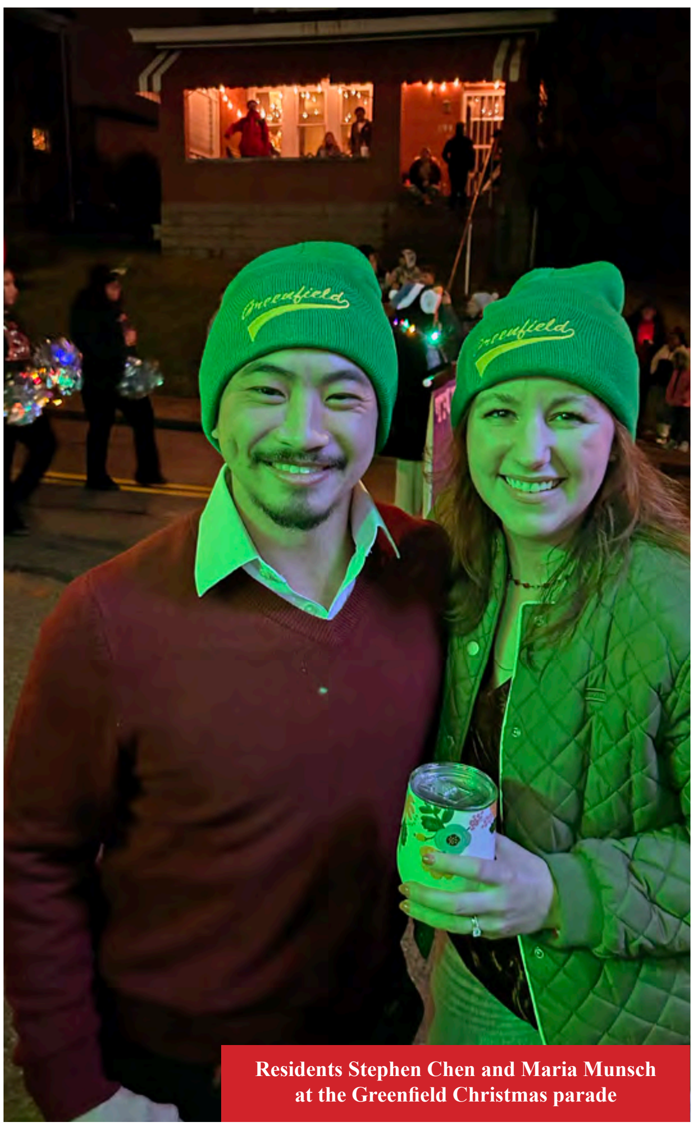

Dr. McClincy (former POJ editor!) representing the Dartmouth Big Green at the Steel City Big Pour Event

Dr. Goitz with hand/upper-extremity fellow Nicole Shaw and resident Maria Munsch at the UPMC holiday skating rink

Bill Li and Stephen Bayer catch some rays on a day off at the pool in Pittsburgh.

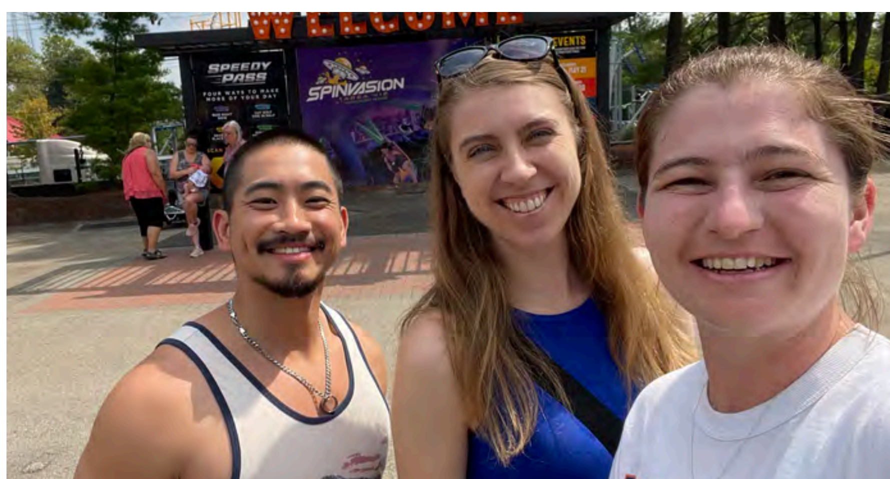

Residents Jay Dalton and Mike Fox take St. Louis native Chris Forbringer to his first Steelers game.

Pitt Ortho intern camaraderie at its finest



Residents Stephen Chen and Maria Munsch at the Greenfield Christmas parade

Residents Jay Dalton and Mike Fox prove that pop punk is alive and well with Ruby Hollinger in the Steel City at the Hot Mulligan show.



Residents Stephen Chen, Gabrielle Fatora, and Susanne Boden at Kennywood

Our intern Zino Kuhn guides his co-interns Jasmine Wang and Maddie Weiner through a little OR practice at their combined birthday party.

Mike Fox and Jay Dalton see Mayday Parade/All Time Low at Stage AE in the 'Burgh.

Residents Jay Dalton and Mike Fox reliving their glory days at When We Were Young Festival in Las Vegas, Nevada

Residents Jay Dalton and Brandon Couch at Urban Tap. Horns up!

Pitt Ortho rocking out to Blink-182 (with Tom!) at PPG Paints Arena

Celebrating the squad one last time at chief roast

The original entering class of 2019 watches some holiday football at the Chens' house.

Residents Stephen Chen and Jay Dalton tune up at Dr. Joon Lee's annual spine lab and guitar rock fest.

Pitt Ortho Journal Club

Residents Douglass Tucker, Rahul Ramanathan, and Zino Kuhn on a night out in the ‘Burgh

Residents Rebekah Belayneh, Guttu Maskalo, Bill Li, and Xi Chen hanging out

Trauma attending Dr. Moloney (former POJ editor!) hosts the Women in Ortho mentorship dinner.

Pittsburgh bar crawl with residents Rebekah Belayneh, Stephen Canton, and Emily Lau

Pittsburgh bar crawl with residents Rebekah Belayneh, Stephen Canton, and Emily Lau

Dr. Goitz hitts the links with resident Susanne Boden and hand/upper-extremity fellow Alejandro Morales-Restrepo.

Brandon Couch enjoys some wings to kick off the football season at the Chens' house.

A night out with the Pitt Ortho residents and their significant others

Spine wine meeting at Shady Grove

Dr. Baratz gives some sage four-wheeler advice to resident Morgan Kohls.

Residents and members of the Ferguson Lab lineage Stephen Chen and Chris Como discuss important matters at Gallery Baker Square.

Residents and significant others enjoy the winter magic at the UPMC downtown ice skating rink.

Pitt Ortho celebrating Morgan Kohls' birthday at Industry Public House

Clockwise from left, current resident Rebekah Belayneh, former Pitt hand/upper-extremity fellow Shea Ray, and former resident Lorraine Boakye grabbing some refreshments in Greenville, SC

Lins and Pins event happy hour social with resident Mike Fox, Elizur CEO Jim Grant, and Dr. Lin's research and clinical team

A night out with Dr. Lin, wife Karen Lin, and Dr. Lin's clinical team and their spouses at Meat and Potatoes

Zino Kuhn and Gabe Brandner relax after a long week as ortho interns.

Hitting the slopes with the Lins

Residents Bill Li, Brandon Couch, Stephen Chen, Chris Como, and Emily Lau at the rodeo

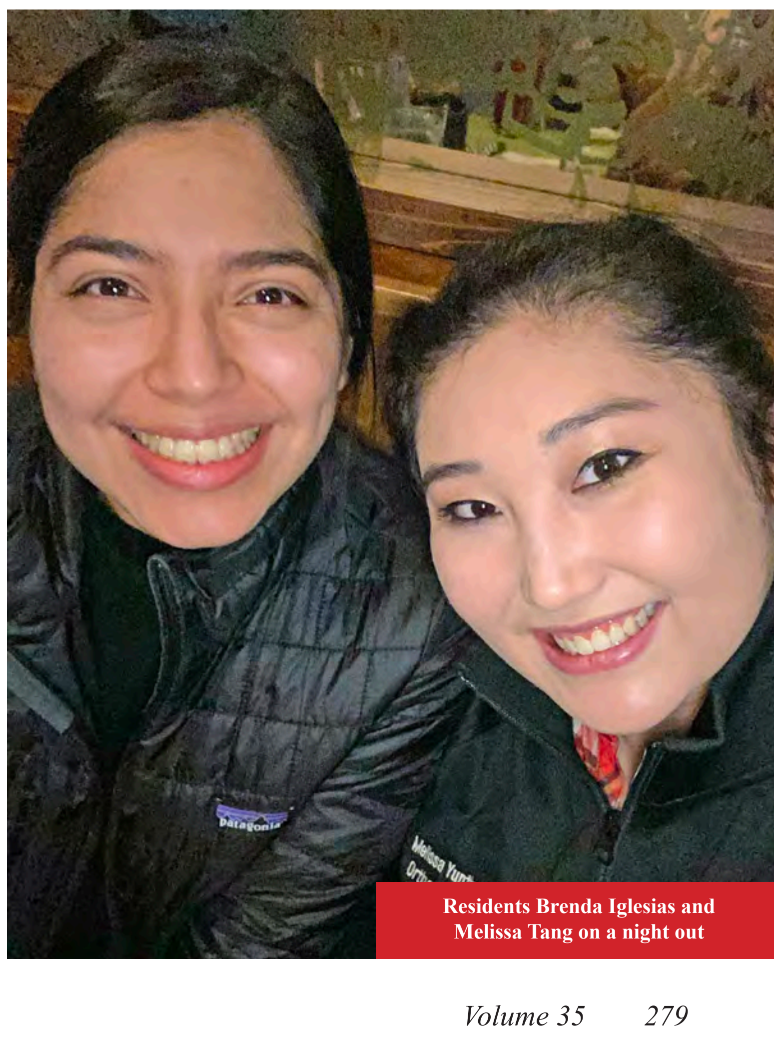
Dr. Lin's clinical team, Danielle and Michelle, at the Christmas Dinner at Meat and Potatoes

Residents Brenda Iglesias, Rebekah Belayneh, and Xi Chen at the Penguins game with new headgear from Dr. Hogan. Go Pens!

Pitt Ortho Olympics with residents Maria Munsch, Nya Wagala, Stephen Chen, and Gabrielle Fatora

Women in Ortho meeting at Topgolf with Drs. Lauren Lewis, Deniz Olgun, Gele Moloney, and Dr. D'Auria

Dr. Lin and his research fellows Sophia McMahon, Gillian Kane, Ajinkya Rai, and Matt Como



Residents Brenda Iglesias and Melissa Tang on a night out


Residents get together for a photo.


UPMC resident alumni Dr. Justin Arner, Dr. Dan Leigey, and Dr. Mike McClincy and their spouses

A very Yinzer Christmas with resident Jay Dalton


Superchief Brandon Couch and new trauma faculty Dr. Tyler Peterson discuss some heady trauma topics over brews.

Pitt Ortho in attendance for the Eras Tour with Taylor Swift

Residents Rebekah Belayneh, Jasmine Wang, Cheeney Nwosu, and Xi Chen get some reps in during summer anatomy education.

Dr. Kurt Weiss, MD, moderating at Cancer Biology Program Scientific Retreat

Hard at Work

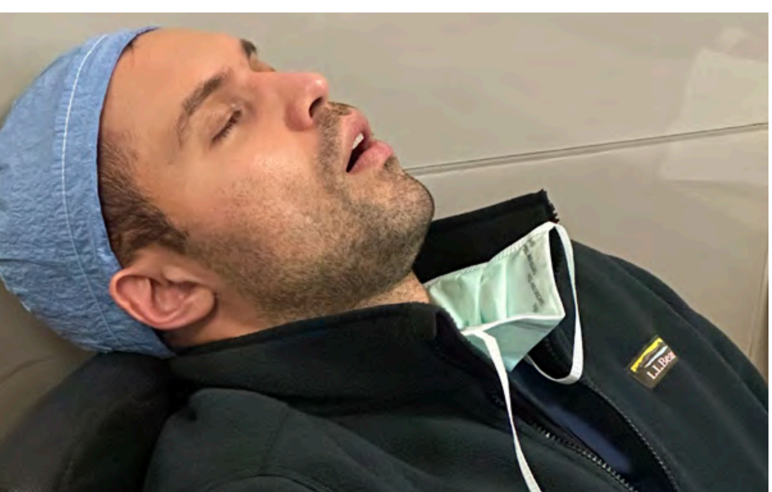
The interns get a taste of virtual reality with Dr. Gruen during Wednesday education.

Hanging out with Dr. Gruen during intern education

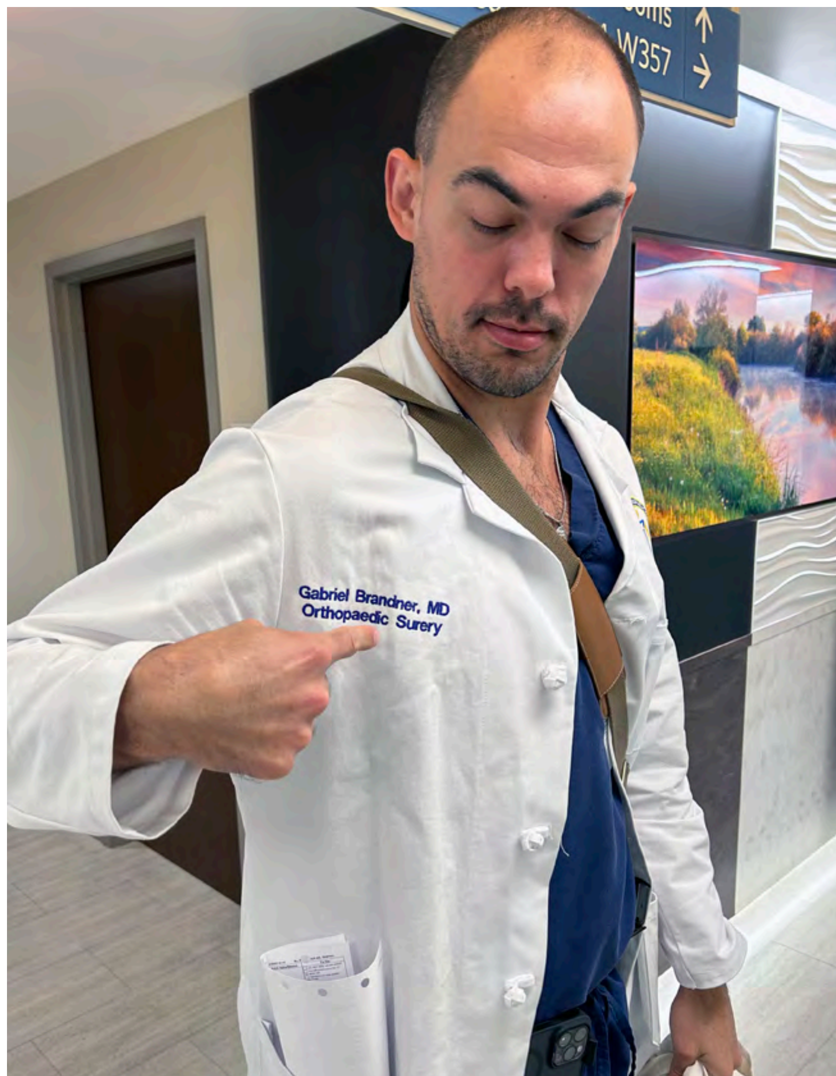
Ortho residents take a much-needed break with a traditional team breakfast while on service at UPMC Children's Hospital of Pittsburgh.

Jasmine Wang, Cheeney Nwosu, and Xi Chen showing some team bonding in anatomy lab

Dr. Hogan imparts his surgical wisdom onto the residents.



Ehab Nazzal taking a moment to appreciate the 2 a.m. lull on night float



Gabriel Brandner shows off his newly embroidered white coat at UPMC Shadyside.

Xi Chen and Morgan Kohls after a successful reduction in the ED

Guttu Maskalo can’t wait for the next surgical case.

Nick Drain looks for a quick spin before he goes into surgery.

Bill Li always prepared to operate

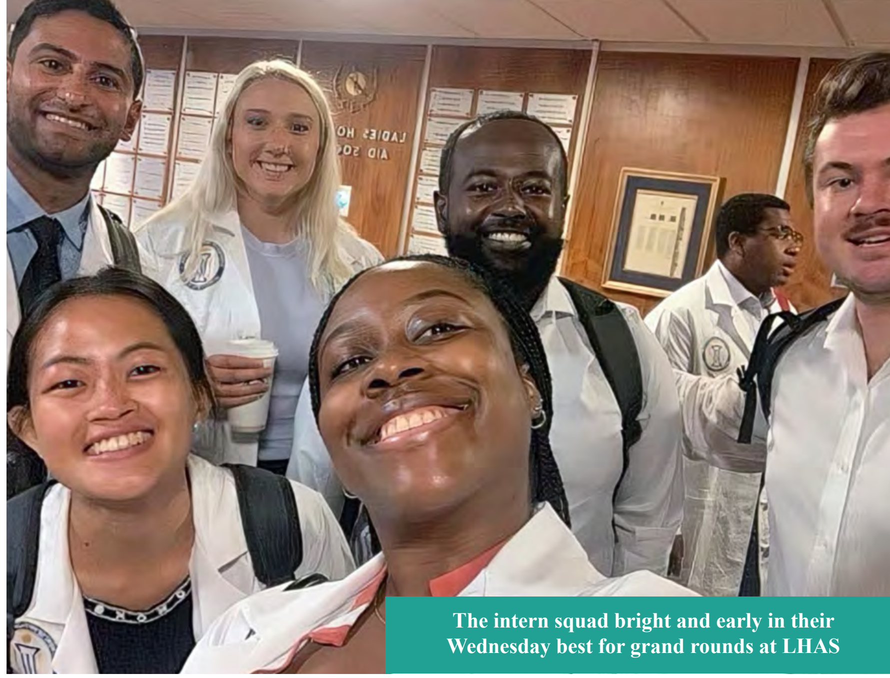
Bill Li shows that "if you love what you do, you'll never work a day in your life."

Xi Chen and Morgan Kohls doing standard ortho case prep

Kevin Byrne assists Dr. Siska on a fracture case.

Dr. Peterson imparts some ortho trauma knowledge with Stephen Canton in the anatomy lab.

Xi Chen and Bill Li patiently wait to run the list with Dr. Siska between cases.



The intern squad bright and early in their Wednesday best for grand rounds at LHAS

Rebekah Belayneh snaps a selfie after a successful case.

"… Is it ok if our resident tries to get the a-line?"

"… Just a few more minutes for that a-line …"

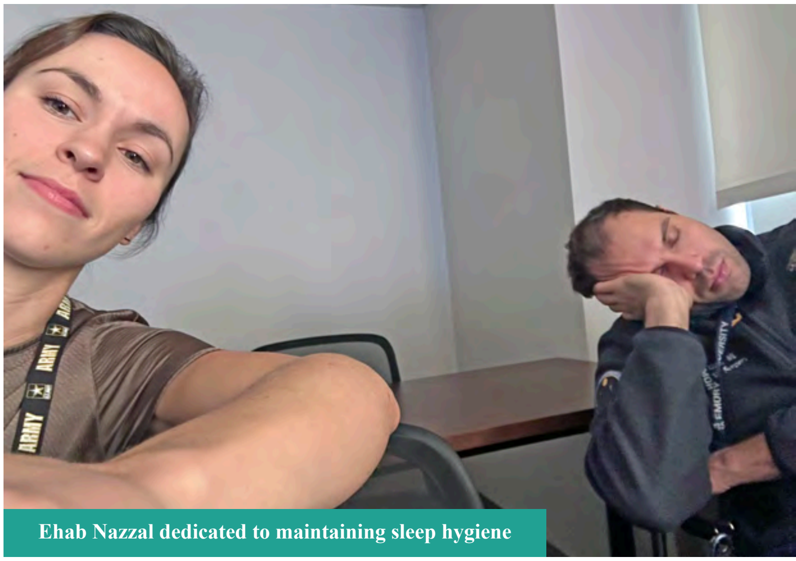
Joshua Adjei and Rebekah Belayneh with some UPMC swag bucket hats

Jay Dalton and Stephen Chen after a day fixing some bones over the weekend at UPMC Presbyterian

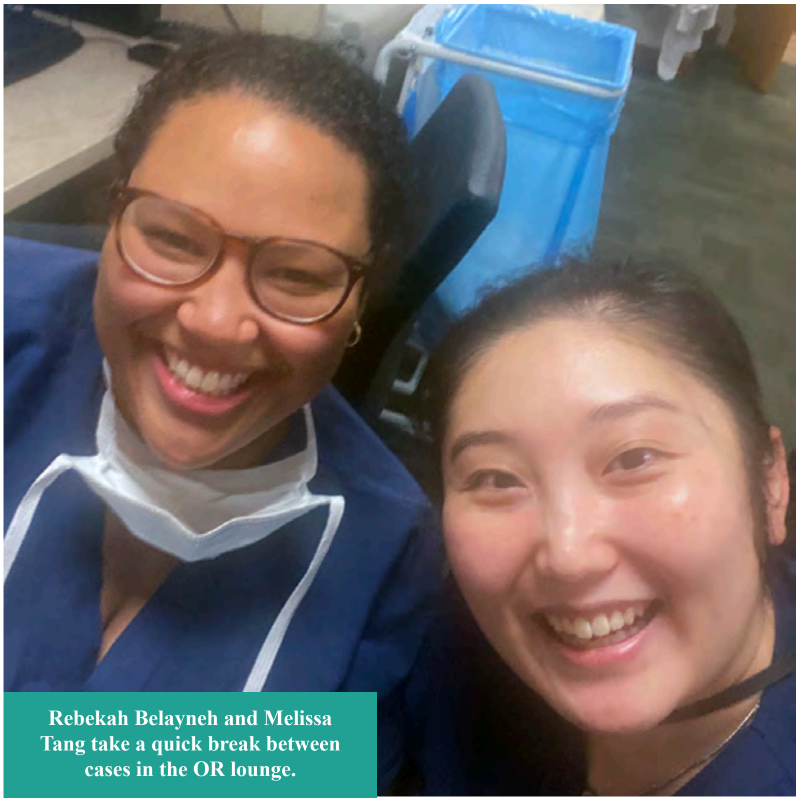
Cheeney Nwosu, Gabriel Brander, and Rebekah Belayneh spend some time in the UPMC Presbyterian ortho lounge between cases.

Morgan Kohls highly focused during Wednesday education

Guttu Maskalo, Rebekah Belayneh, and Dr. Hogan's research fellow Garcia Findlay take a selfie together after a case.



Ehab Nazzal dedicated to maintaining sleep hygiene



Rebekah Belayneh and Melissa Tang take a quick break between cases in the OR lounge.

The UPMC Presbyterian trauma team takes a quick refuel in the cafeteria.

Dr. Olgun leads an ortho trauma sawbones teaching session with the interns.

Dr. Lin's OR squad during a shoulder case

Dr. Lin with visiting fellows

One of Dr. Lin's patients displays some incredible artwork that he created, inspired by Pittsburgh Ortho.


Dr. Lin with former Pitt sports medicine fellows Dr. James Bullock and Dr. Akere Atte


Dr. Lin with the shoulder squad


Dr. Lin in the OR


Dr. Lin with the UPMC East OR staff

Dr. Lee and resident Nya Wagala doing an Illuminoss case

Our squad of residents attending hand/upper-extremity fellowship interviews

Dr. Lin poses with his team of fellows, residents, medical students, and research fellows after a day in clinic.

Throwing up the deuces in Lin OR

Ortho resident Nick Drain works so hard that one phone just isn't enough.

Dr. Lin, Danielle, and Michelle pose for a photo during clinic.

Resident Stephen Canton staying hydrated on call

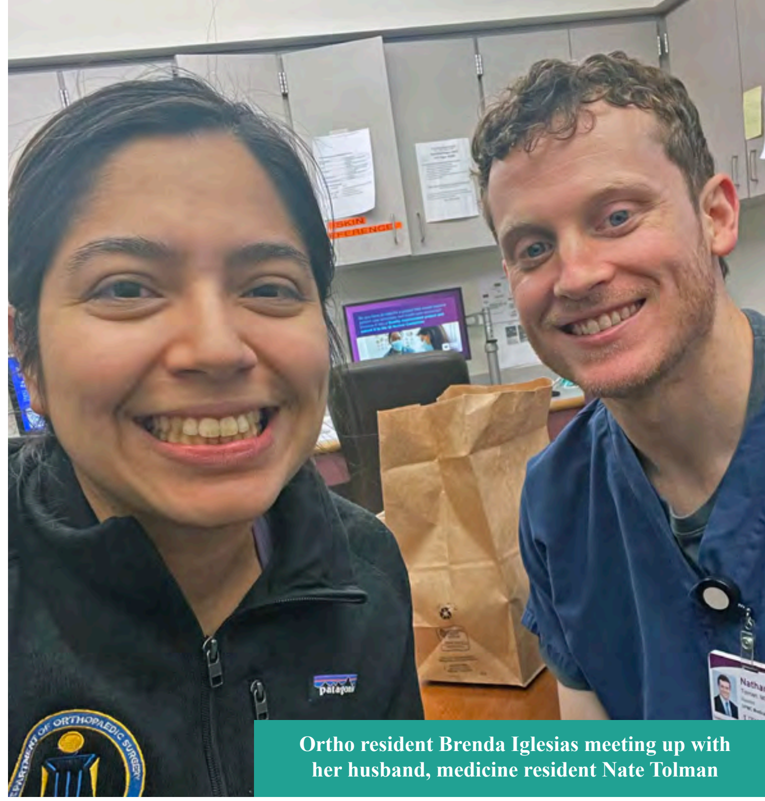
Stephen Chen pushing the boundaries of resident education with some virtual reality

Resident Xi Chen, trauma fellow Saad Mohammad, and resident Brenda Iglesias get festive with cement during a holiday trauma case.

Resident Stephen Canton demonstrates some fiber glass mastery at UPMC Children's Hospital of Pittsburgh.


Superchiefs Rebekah Belayneh and Dukens LaBaze walking one of the M4 ortho rotators through a sawbones case demonstration

Dr. Weiss leads resident education with his bandolier of carbonated beverages, as is tradition.


Ortho resident Brenda Iglesias meeting up with her husband, medicine resident Nate Tolman


Devon Scott does a fantastic job playing the patient for Cortez Brown, Clark Roth, and Matt Gong.


Dr. Hogan and resident Chinemerem Nwosu resecting PVNS from an ankle

AAHKS Meeting

Dr. Plate and Dr. David Pollock at the AAHKS 2023 meeting

Pitt Ortho alums Dr. Alan Wilson and Dr. Malcolm Dombrowski take a selfie at the at AAHKS 2023 meeting in Dallas.

The Pitt Ortho alumni dinner at the AAHKS 2023 meeting

AOFAS Meeting

From left to right, current foot and ankle fellow Jay Patel, former Pitt resident Chris Murawski, current Pitt resident Rebekah Belayneh, former foot and ankle fellow (and current UPMC St. Margaret attending) Omar Yaldo, and former foot and ankle faculty Alan Yan attend the AOFAS meeting in Louisville, Kentucky.

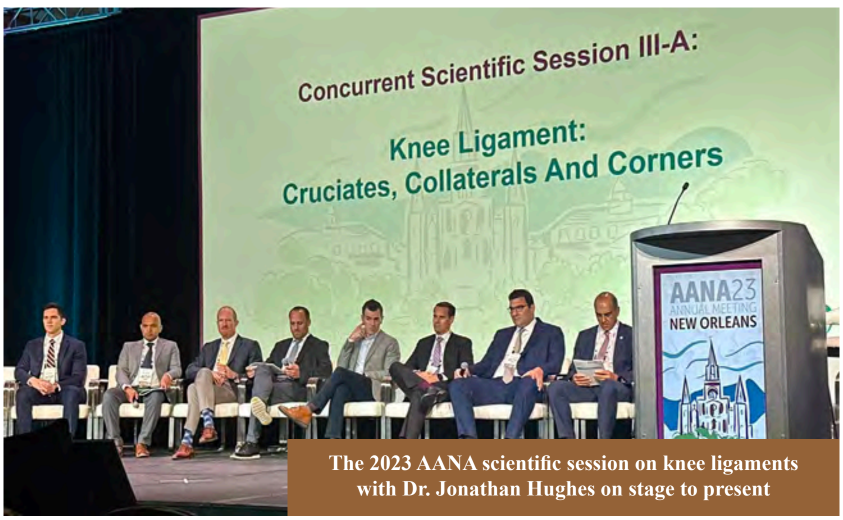
Recent Pitt Ortho graduate, and current foot and ankle fellow Chris Murawski and resident Rebekah Belayneh brush up on their regional dialects at AOFAS.

From left to right, former Hogan research fellow Dwayne Carney, new foot and ankle faculty Lauren Lewis, resident Rebekah Belayneh, and current Pitt foot and ankle fellow Ric Smith attend the AOFAS meeting in Louisville, Kentucky.

Dr. Lin and Dr. Hughes with current sports fellows Ariana Lott and Abigail Boduch and residents Mike Fox and Ben Rothrauff at the AANA meeting

AANA Meeting

Dr. Hogan on stage at the 2023 AANA meeting



The 2023 AANA scientific session on knee ligaments with Dr. Jonathan Hughes on stage to present

Dr. Hogan with Dr. James Stone, immediate past president of the AANA, at the 2023 AANA meeting. Dr. Hogan's award recognizes his appointment as the Diversity Lecturer for the meeting.

Shaquille Charles and Dr. Lin pose as they enter the AANA meeting

Albert Lin poses with our two intrepid program coordinators, Noreen Corcoran and Amanda Sites, at AAOS 2024.

John Fowler repping the Bethel Musculoskeletal Research Center at the AAOS meeting in San Francisco, California

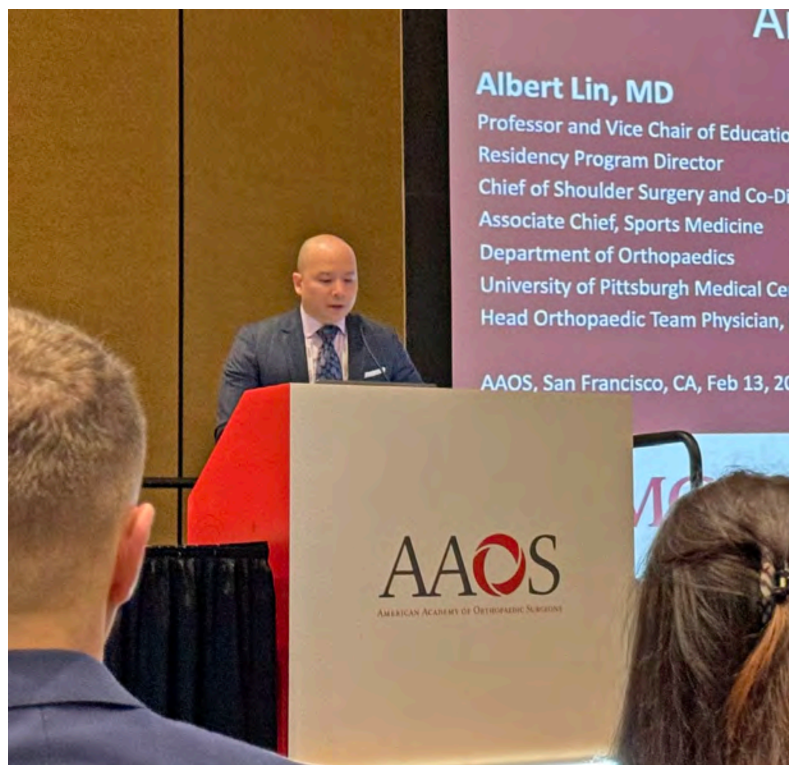
Albert Lin and his current research fellow Sophia McMahon at AAOS 2024

AAOS Meeting

From left to right, Temple ortho resident Kamali Thompson, MD, MBA, Pitt ortho residency alum Dr. Vonda Wright, and Dr. Hogan take part in an expert panel at AAOS.

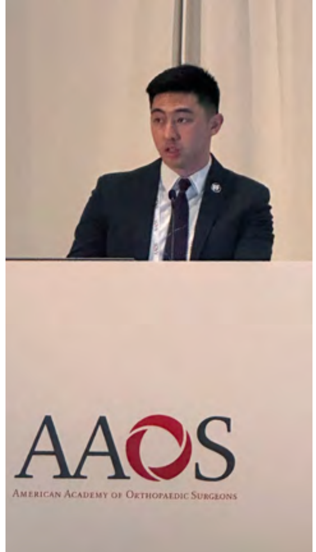
Dr. Musahl with other ortho luminaries at dinner at the AAOS meeting in San Francisco, California

Clockwise from left, resident Cortez Brown, Albert Lin, former sports fellow Andrew Shehaan, current sports fellow Stephen Marcaccio, Musahl research fellow Janina Kaarre, and international fellow Camila Grandberg dine at the Harborview Restaurant & Bar, a perennial favorite of Freddie Fu, during AAOS 2024 in San Francisco, California.



Dr. Lin imparting some shoulder expertise and new research at AAOS

Dr. Lin and current sports medicine fellow, Stephen Marcaccio after Dr. Lin's Instructional Course Lecture at AAOS 2024



Matt Gong makes us proud at the podium at AAOS.

Celebrating Dr. Lin's birthday with Dr. Baratz at AAOS

Dr. Eric Wagner from Emory, Dr. Rob Hartzler from San Antonio Orthopedic Group, and Dr. Lin at the Instructional Course lecture at AAOS 2024

Albert Lin poses with Pitt Ortho alum and current spine/tumor faculty at Montefiore Mitch Fourman at AAOS.

Instructional Course Lecture faculty Dr. Jon Dickens from Duke, Dr. Lin, Dr. Lesniak, and Dr. Andrew Sheean from San Antonio Military Center gather at AAOS.

Dr. Armand Hatzidakis from Colorado, Dr. Andrew Jawa from New England Baptist, Dr. Surena Namdari from Rothman, our very own Dr. Lin, Dr. Jay Keener from Wash U, Dr. Rob Gillespie from Case Western, and Dr. Joaquin Sanchez-Sotelo from Mayo Clinic at the AAOS faculty symposia

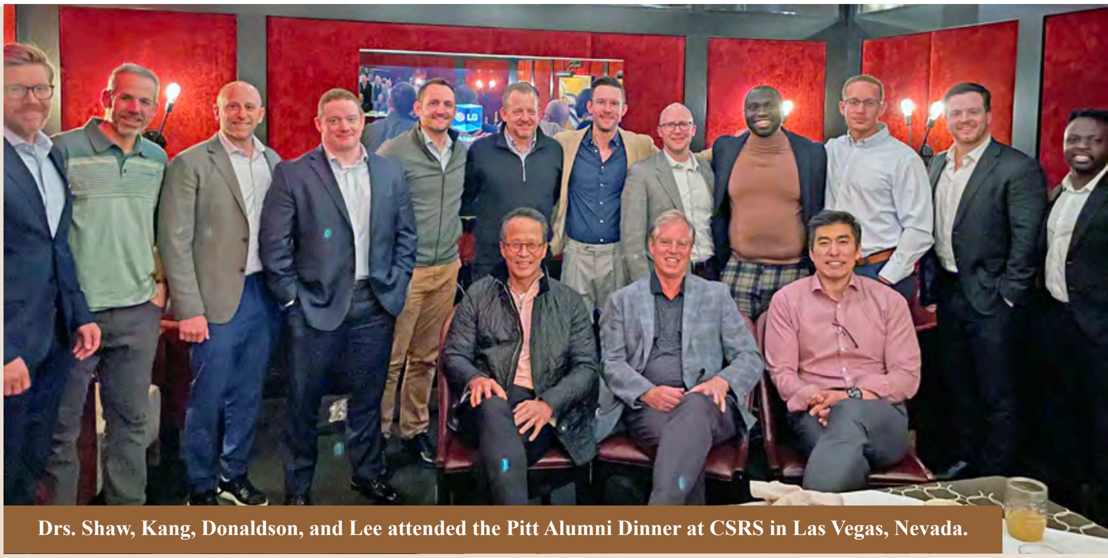
Dr. Lesniak and Dr. Lin with their team of research fellows and future orthopaedic surgeons at AAOS

Dr. Zelle, alum of both Pitt Ortho residency and trauma fellowship, accepts the Diversity Award at AAOS 2024.

Volker Musahl and Jonathan Hughes represent Pitt Ortho in a group photo after a fantastic few days in Niseko, Japan, at the ACL Study Group 2024 Biennial Meeting.

ACL Study Meeting

CSRS Meeting



Drs. Shaw, Kang, Donaldson, and Lee attended the Pitt Alumni Dinner at CSRS in Las Vegas, Nevada.

The annual Pitt Ortho alumni dinner is held at CSRS in Las Vegas, Nevada.

Former Pitt Ortho spine fellow Emmett Gannon and ortho spine faculty Jeremy Shaw at the CSRS Pitt alumni dinner

Dr. Lin and Dr. Bradley with a big group of ortho sports medicine all-stars at AOSSM


Dr. Hogan poses with Dr. Kirk McCullough, MD, at AOSSM.


Pitt Sports medicine legends Drs. James Irrgang, Dharmesh Vyas, James Bradley, Volker Musahl, Albert Lin, and Bryson Lesniak at AOSSM

AOSSM Meeting


Dr. Lin with Pitt alum Dr. Ting Cong and recent graduate Dr. Stephanie Boden with their awards from AOSSM

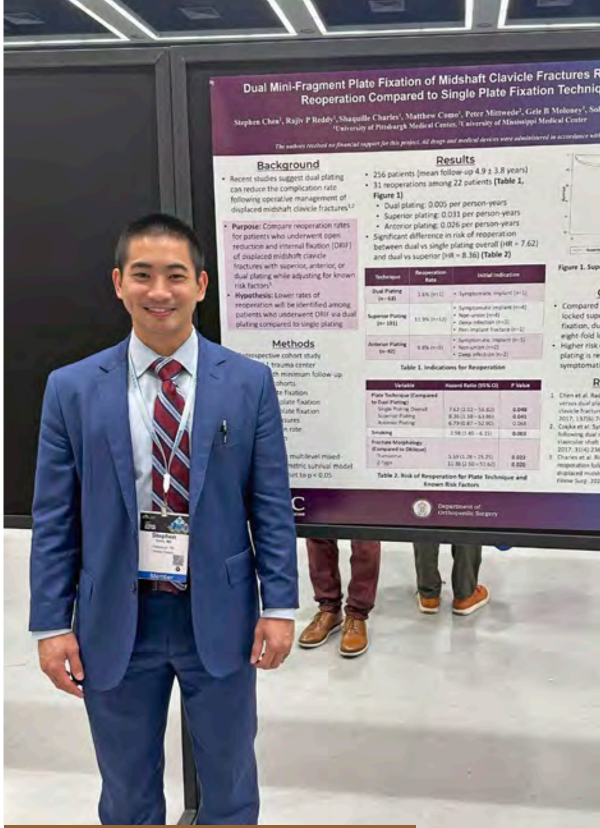

Two former Fu fellows meet up at AOSSM: Current resident Nick Drain poses with Rothman faculty and Pitt sports medicine fellowship alum Dr. William Gomez.


Dr. Lin delivers a lecture at AOSSM.


Dr. Musahl on stage at AOSSM

Pitt Ortho trauma squad meeting up at OTA: Current faculty Dr. Siska and Dr. Moloney, recently graduated residents Humza Shaikh and Maggie Hankins, and current resident Stephen Chen

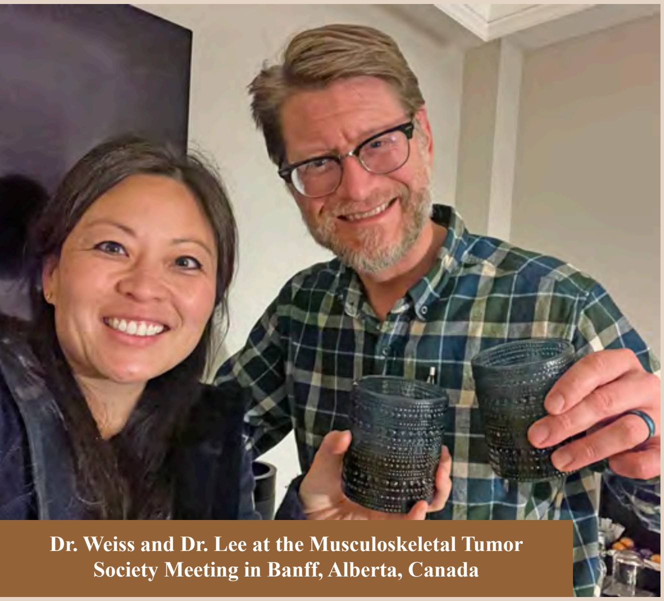
OTA Meeting



Current resident Stephen Chen presents research at OTA.

Dr. Lee and Dr. Weiss discussing the latest research on orthopaedic oncology at MSTS

MSTS Meeting



Dr. Weiss and Dr. Lee at the Musculoskeletal Tumor Society Meeting in Banff, Alberta, Canada

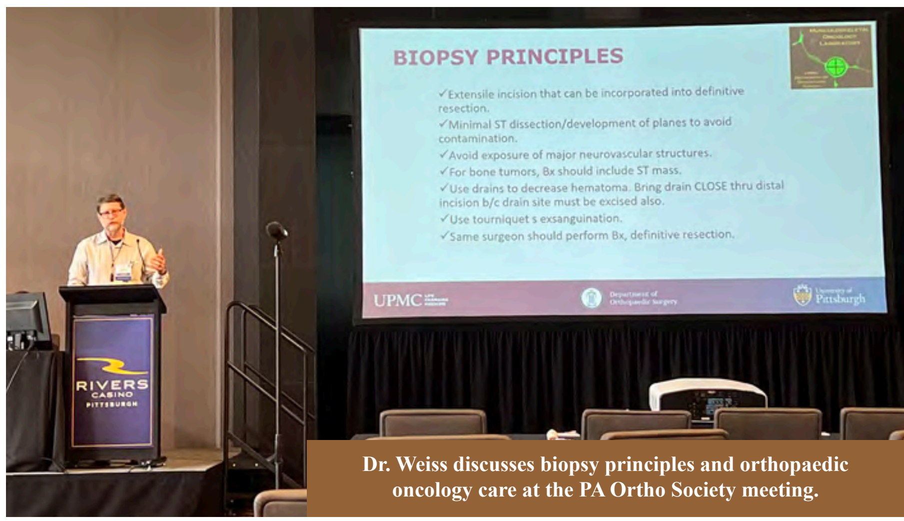
Dr. Lee taking part in a panel discussion at MSTS

Dr. Lin with UPMC sports medicine fellow Nahom Tecle at the MASES conference

Dr. Lin presents at the MASES meeting.

MASES Meeting

Medical student Matt Como, research fellow Janina Kaarre, and resident Mike Fox at Pennsylvania Orthopaedic Society Meeting



Dr. Weiss discusses biopsy principles and orthopaedic oncology care at the PA Ortho Society meeting.

PA Ortho Meeting

Dr. Volker Musahl and research fellow Janina Kaarre at the annual Pennsylvania Orthopaedic Society Meeting

Dr. Moloney gives a lecture on fracture care at the PA Ortho meeting.

ASSH Meeting

Dr. Mark Baratz with a bevy of future hand surgeons at the ASSH meeting in Toronto

Dr. Mark Baratz rocks out with Colin Beckwitt at ASSH in Toronto.

Christopher Gibbs, Dr. Fowler, Maria Munsch, Morgan Kohls, Susane Boden, Colin Beckwitt, and Dr. Goitz excited to be at this year's ASSH meeting in Toronto

Ortho Summit

Dr. Albert Lin presenting a clinical case at OSET

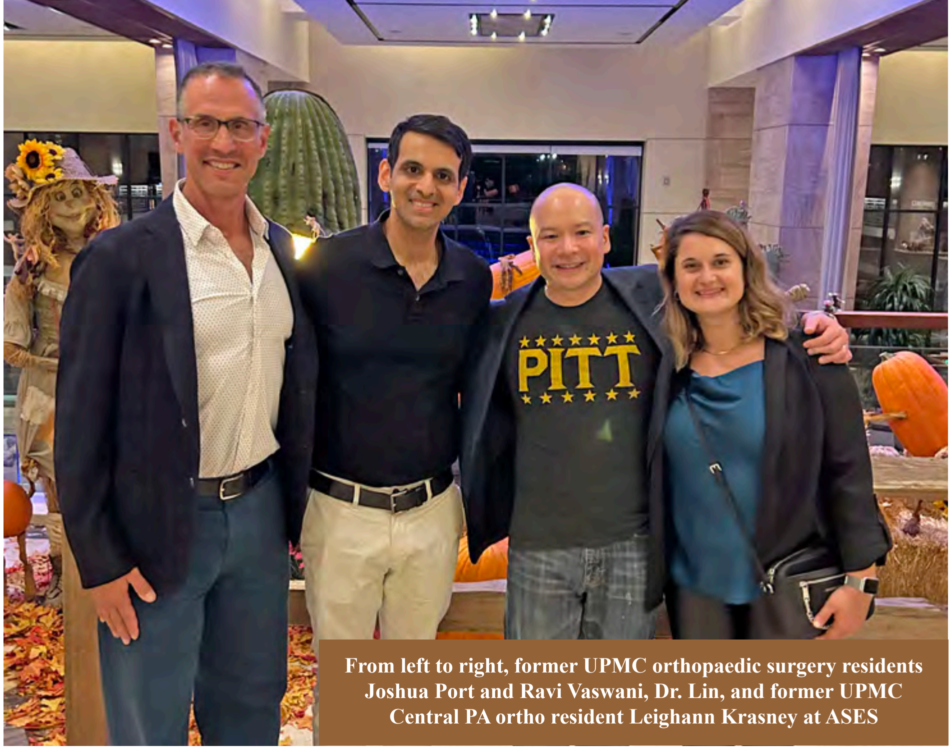
Fritz Steuer receives the award for the best overall paper at the Orthopaedic Summit (OSET) with Mike Fox, Gillian Kane, Ehab Nazzal, Ajinkya Rai, and Ting Cong.

ISAKOS Meeting

Past president of ISAKOS with Dr. Fu's family and Dr. Musahl during the inaugural presentation of the ISAKOS Freddie Fu Lifetime Achievement Award

Amin Karimi, Rajiv Reddy, Neilen Benvegnu, Dr. Lin, Matt Como, and the ISAKOS traveling fellows have dinner at Altius in Pittsburgh.

ASES Meeting



From left to right, former UPMC orthopaedic surgery residents Joshua Port and Ravi Vaswani, Dr. Lin, and former UPMC Central PA ortho resident Leighann Krasney at ASES

Shoulder experts Drs. Shariff Bishai and Lin meet up at ASES.

Pitt Ortho sports medicine fellowship alum, Dr. Rafael Buerba with Dr. Lin at ASES.

Dr. Ravi Vaswani, former Pitt resident, and Dr. Lin meet up at ASES.

Dr. Leighann Krasney, alum of UPMC Central PA ortho residency, with Dr. Lin at ASES

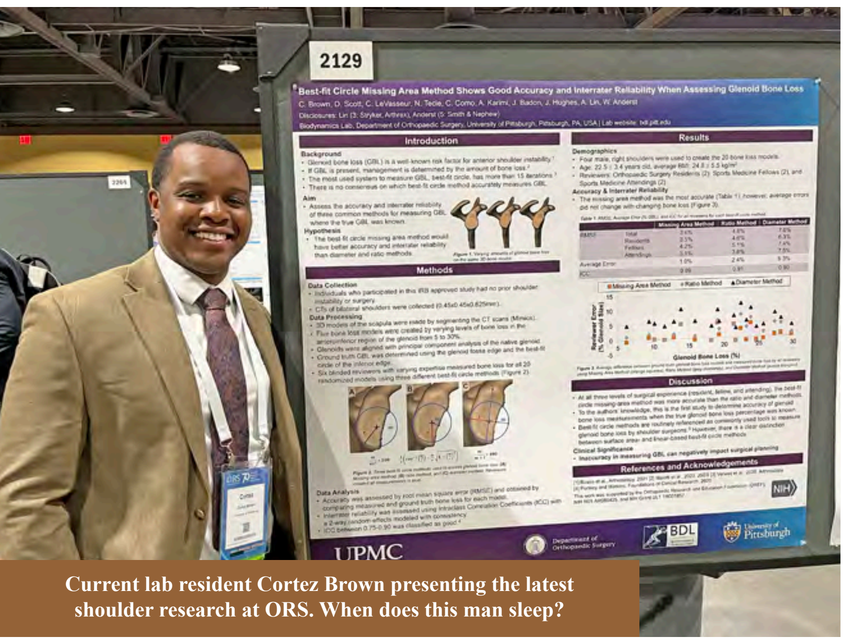
Pitt Ortho sports medicine alum Dr. Ting Cong poses with Dr. Lin at ASES.

Former Pitt sports medicine fellow Dr. Rafael Buerba, former UPMC Ortho resident Dr. Ravi Vaswani, Dr. Lin, and former UPMC Ortho resident Greg Gasbarro reunite at ASES.

Dr. Hogan and Dr. Lee enter this year's ORS conference.

Chris Como, Kim Hua, and Cortez Brown excited to show off their research at ORS

ORS Meeting

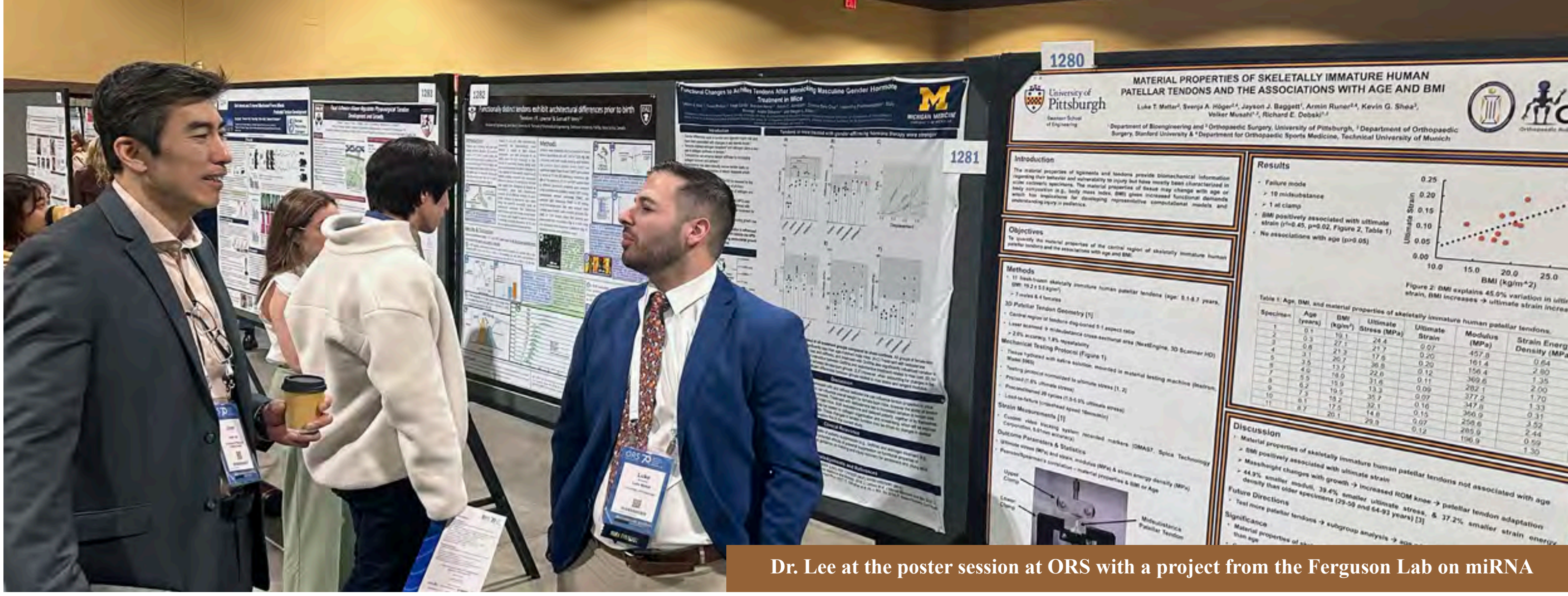


Current lab resident Cortez Brown presenting the latest shoulder research at ORS. When does this man sleep?

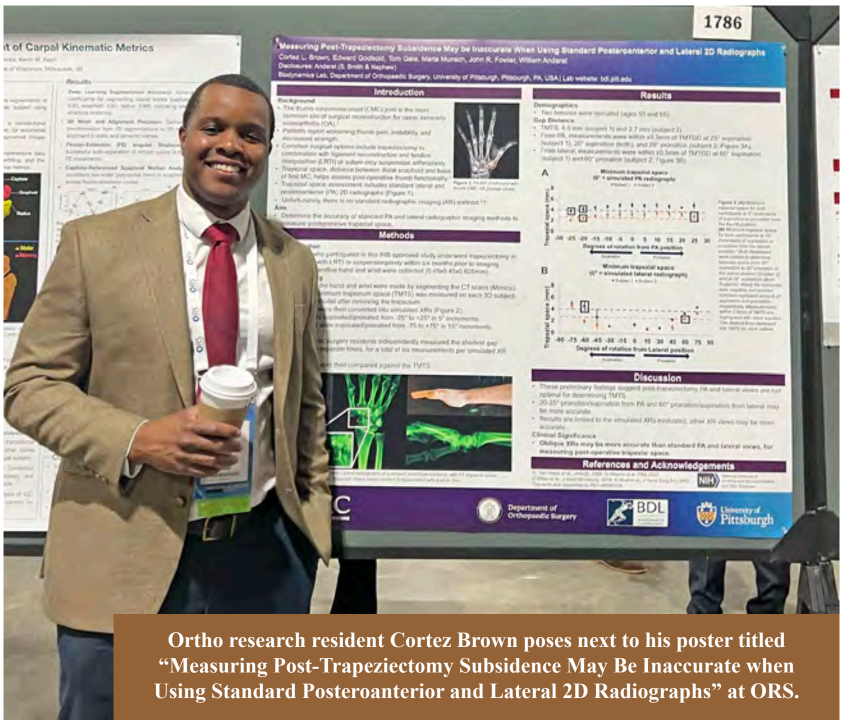
So much science at one table!

Dr. Weiss and bone/joint cell and molecular biologist Dr. Christopher Evans, PhD, from the Mayo Clinic at ORS

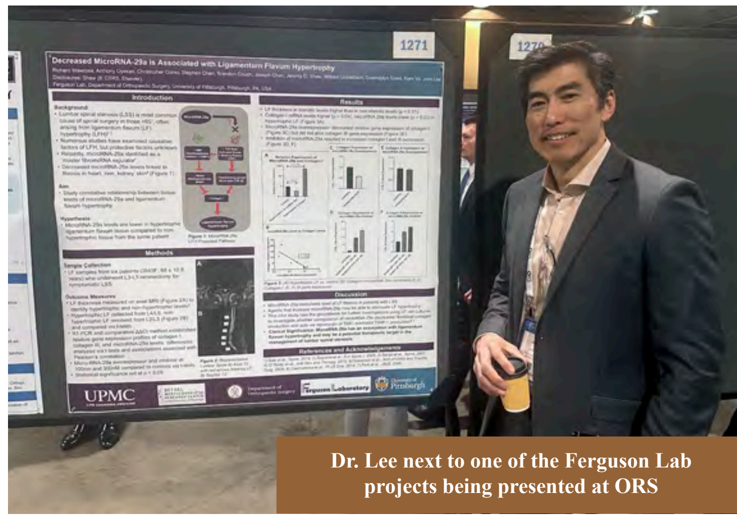
Dr. Lee and Dr. Hogan discuss research at ORS.



Dr. Lee at the poster session at ORS with a project from the Ferguson Lab on miRNA



Ortho research resident Cortez Brown poses next to his poster titled "Measuring Post-Trapeziectomy Subsidence May Be Inaccurate when Using Standard Posteroanterior and Lateral 2D Radiographs" at ORS.



Dr. Lee next to one of the Ferguson Lab projects being presented at ORS

Dr. Lee and Dr. Nam Vo representing the Bethel Musculoskeletal Research Center at ORS

Current ortho lab residents Chris Como, Gillian Ahrendt, Cortez Brown, and attending Dr. Weiss enjoy a night out after a day of heated academic discussion at ORS.

Bone Bash

Dr. Hogan was the medical honoree for the 2023 Bone Bash held at the Wyndham Grand Pittsburgh Downtown.

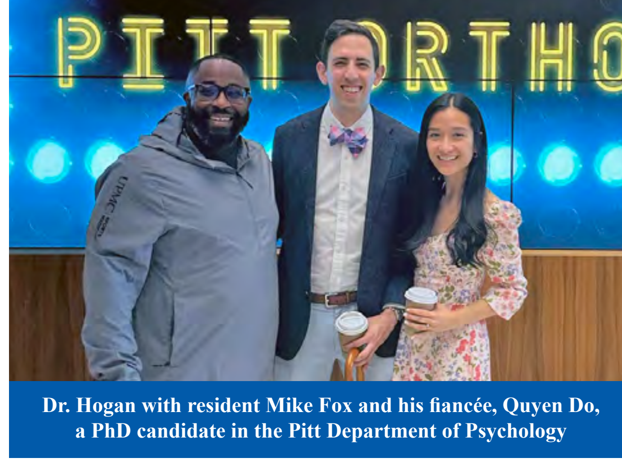
Dr. McCoy and Dr. Lin with residents Maria Munsch, Joshua Adjei, Stephen Canton, Guttu Maskalo, and Rebekah Belayneh celebrate an evening of charitable giving at the Arthritis Foundation's annual Bone Bash.

Dr. Hogan gets back in touch with his southern roots with Dr. Lin at the 2023 Arthritis Foundation Bone Bash.

Dr. Lin and Dr. Fowler treat the highest-earning OITE residents to a special dinner commemorating their academic excellence.

OITE Top Performers

Dr. Hogan, Dr. Lin, and their families pose at the Acrisure Stadium Welcome Picnic to kick off the orthopaedic residency academic year.


Dr. Hogan with resident Mike Fox and his fiancée, Quyen Do, a PhD candidate in the Pitt Department of Psychology

Welcome Picnic

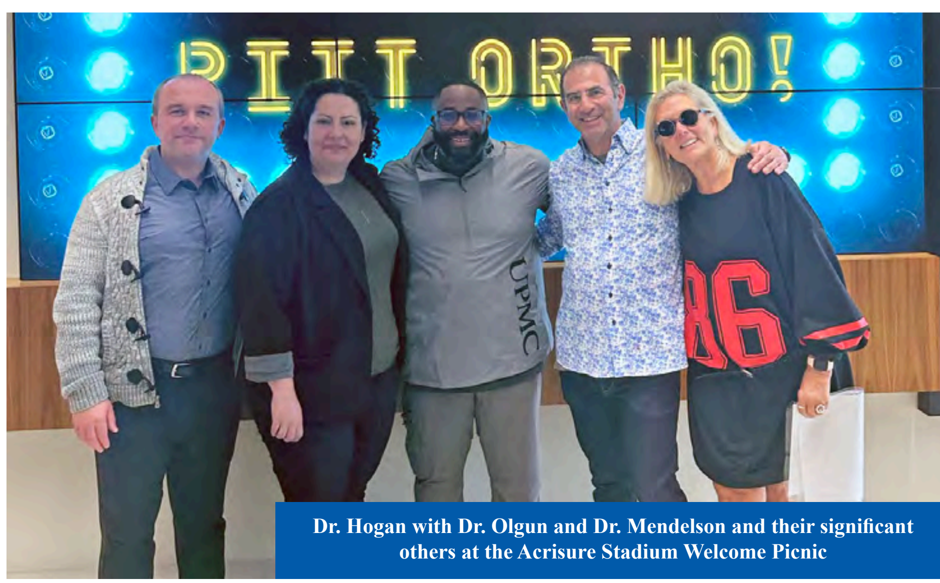

Dr. Hogan and new foot and ankle faculty Dr. Lauren Lewis

Dr. Hogan with Dr. Fowler and his family posing at the Acrisure Stadium Welcome Picnic to kick off the orthopaedic residency academic year


Dr. Plate gets a portrait at Acrisure Stadium.


Dr. Hogan with new interns Zino Kuhn, Gabriel Brandner, and their wives at the Acrisure Welcome Picnic

Dr. Hogan with his research fellows at Acrisure Stadium



Dr. Hogan with Dr. Olgun and Dr. Mendelson and their significant others at the Acrisure Stadium Welcome Picnic

Group photo from the Pitt Ortho Research Retreat at the O'Hara Student Center

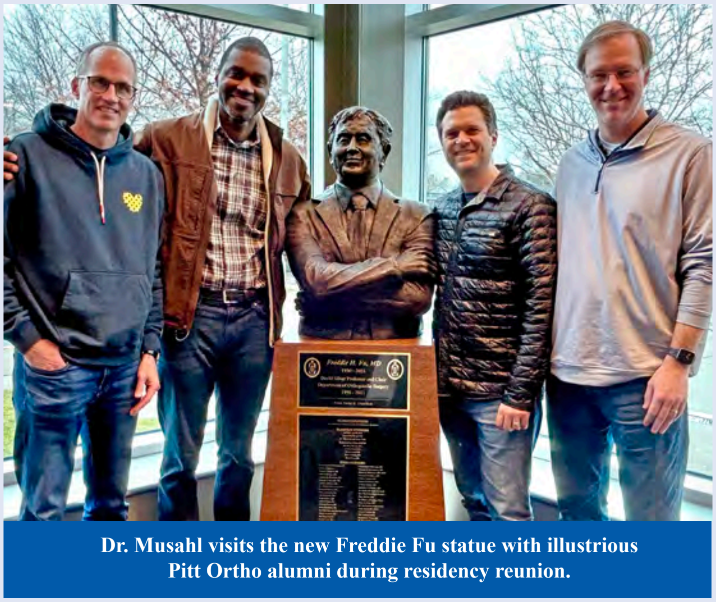
Research Retreat

Dr. Lee and Dr. Hogan at ORS

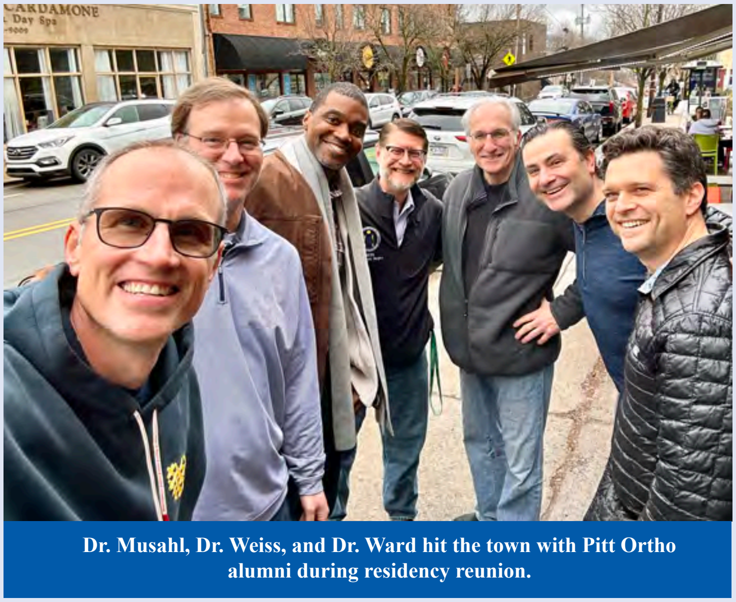
Dr. Wang, PhD, lectures at the Orthopaedic Surgery Research Retreat.

Dr. Hogan lectures at the Orthopaedic Surgery Research Retreat.

Residency Reunion



Dr. Musahl visits the new Freddie Fu statue with illustrious Pitt Ortho alumni during residency reunion.



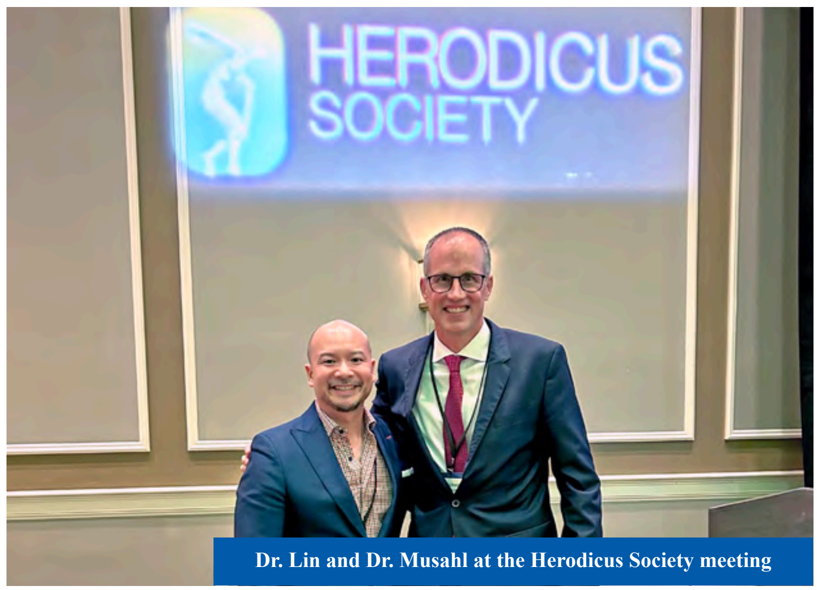
Dr. Musahl, Dr. Weiss, and Dr. Ward hit the town with Pitt Ortho alumni during residency reunion.

Lin Medical Student Mentor Award

Dr. Albert Lin celebrates winning the 2024 Medical Student Research Mentoring Merit Award with his team of current and former research fellows.

Dr. Lin receives the Medical Student Research Mentoring Merit Award at the University of Pittsburgh School of Medicine's 2024 Scholars Day.

Dr. Lin and Dr. Seth Sherman at their induction ceremony into the Herodicus Society



Dr. Lin and Dr. Musahl at the Herodicus Society meeting

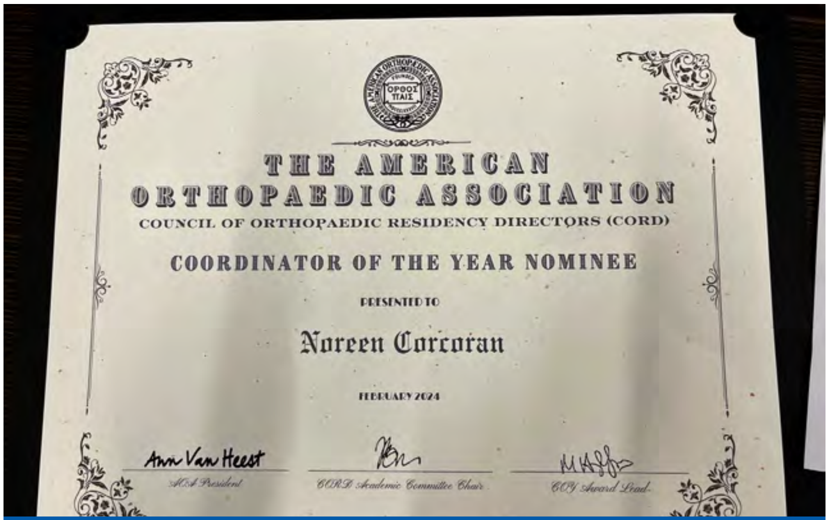
Herodicus 2023

Dr. Lin and Dr. Amir Shahein celebrate Dr. Lin's induction into the Herodicus Society at their most recent meeting in Clearwater, Alabama.

Dr. Seth Sherman, Dr. Lin, Dr. Musahl, and Dr. Bryan Wolf hang out at the Herodicus Society meeting.

Ferguson Lab picnic on a beautiful day in the 'Burgh!

Ferguson Lab Picnic



Noreen Corcoran is honored as a Program Coordinator of the Year nominee from the American Orthopaedic Association. Congrats to Noreen, and thanks for all you do for us!

Sports Medicine Fellowship Research Day

Sports Medicine Fellowship Research Day

Liane Miller accepting the award for best presentation at UPMC Sports Medicine Fellowship Research Day

2024 Perry Initiative

Current Pitt Ortho faculty Dr. Stella Lee, Dr. Gele Moloney, Dr. Amanda McCoy, and Dr. Deniz Olgun run an awesome didactics session and hands-on lab for a meeting of the Perry Initiative.

Dr. Lin with the Rotator Cuff Study Group, which had their inaugural meeting in Gubbio, Perugia, Italy, in September 2023

Rotator Cuff Study Group

Dr. Lin and colleagues attend the Rotator Cuff Study Group meeting in Italy.

Dr. Lin grabs refreshments with members of the Rotator Cuff Study Group at their 2023 meeting in Italy.

MLK Day

Dr. Hogan was invited to speak at St. Francis University in Lorretto, Pennsylvania, for its annual Martin Luther King Jr. Day Convocation.

Congratulations to Dr. Albert and Karen Lin on the birth of their daughter, Gabrielle Celeste Lin, on May 29, 2023. A warm welcome to the Pitt Ortho family!

Young Orthopods

Miles Richard Roth

Congratulations to resident Christopher Gibbs on the birth of his daughter, Ruthea Hope Gibbs, on February 13, 2024

Congratulations to Stephen Chen and Chelsea Chen on the birth of their daughter, Olivia Chen, on February 24, 2024

Congratulations to Shaan and Lauren Sadhwani on the birth of their son, Shaan Bernard Sadhwani, on April 27, 2024

Stephen Chen and Olivia Chen

Olivia Thomas Chen


Congratulations to resident Clark Roth on the birth of his son, Miles Richard Roth, on May 2, 2024


Olivia Thomas Chen


Ruthea Hope Gibbs

Large group of current residents looking sharp at Colin Beckwitt's wedding

Weddings & Engagements

Residents at Colin Beckwitt's wedding

Eunice Amoako and Ben Rothrauff celebrate at their engagement party!

Current attending Dr. Justin Arner, Ben Rothrauff's groomsmen, Nya Wagala, and officiant, Fr. Maria Munsch having themselves a great time

Residents at Colin Beckwitt's wedding

Ben's groomsmen – Stephen Chen, Michael Fox, Jay Dalton, and Sumail Bhogal – escaping the Florida heat for a minute in the A/C

Eunice Amoako and Ben Rothrauff tie the knot in Fort Myers, Florida.

Orthopaedic residents and significant others at Ben Rothrauff's rehearsal dinner


MID-ATLANTIC
SURGICAL SYSTEMS
REPRESENTING Arthrex
Congratulations to the graduating
orthopedic residents and fellows from
the University of Pittsburgh Class of 2024!
For more information, go to:
www.masurgical.com | www.arthrex.com

NOTES


UPMC