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Upper Extremity Amputation and Physiatry: A Survey of Prosthetic and Rehabilitation Needs

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Clinical Vignette

DG is a 32-year-old right hand dominant chemical plant worker without significant past medical history who initially presented to the ED after a chemical storage tank exploded with shrapnel pieces resulting in traumatic right upper extremity (RUE) transhumeral amputation. A tourniquet was applied in the field and he had extensive degloving with amputation at the distal upper arm and was taken emergently for definitive amputation. His postoperative pain was initially managed with IV hydromorphone and nerve block, which was removed on postoperative day two. Initially, he denied complaints of pain, but after a few days he reported painful burning sensations in his absent right hand. Since being discharged, he also states that he has had new and increasing difficulty with concentration, poor sleep, and occasional emotional outbursts. He has not returned to work due to his emotional and physical symptoms. Prior to his amputation, DG worked as a chemical engineer performing computer modeling. He enjoyed being outdoors including hunting and fishing. He lives with his wife and two children in a two-story house and was previously independent in all his daily activities. DG presents to the UPMC Prosthetic Clinic approximately one month after his initial amputation and is asking about pain management and prosthetic options.

Definition of the Problem

More than two million people live with limb loss in the United States, and according to 2005 estimates, 8% are categorized as having major upper extremity (UE) amputation.[1-4] There are approximately 185,000 new, major amputations (excluding fingers and toes) that occur each year in the United States with lower extremity (LE) outnumbering UE 5 to 1, predominantly due to diabetes and peripheral vascular disease. Trauma is the most common cause of UE amputation,

and like other traumatic injuries, occurs more often in men (2-4:1). In the United States, motor vehicle accident is the most common etiology of major UE traumatic amputation, followed by machinery accident, motorcycle accident, cutting/piercing accident, and firearms. Military members are at particularly high risk with 1,700 Operation Enduring Freedom/Operation Iraqi Freedom Veterans and 5,000 Vietnam War Veterans suffering a traumatic amputation. Additional causes of UE amputation include malignancy, infection, vascular disease, burns and congenital limb deficiency.

By far, finger amputations are the most common UE amputation with ~80% occurring at the transphalangeal level leading to 45,000 traumatic finger amputations annually. According to the US National Trauma Database, traumatic major UE amputations occur most often at the transhumeral level (35%), followed by transradial (30%), through hand (15%), wrist disarticulation (9%), elbow disarticulation (7%) and shoulder disarticulation (4%).[2,5] The surgical level may differ between civilian and military patients based on a survey of US military veterans that reported a higher percentage of transradial (38%) versus transhumeral (28%) amputations.

Health disparities are defined as preventable differences between groups in healthcare and health outcomes based on race and ethnicity, religion, cultural identity, socioeconomic status, sex, age, disability, mental health, identified gender and expression, sexual orientation, or geographic location. Nationally, very little has been written about the disparities in major UE amputation, although based on similarities with other trauma and dysvascular amputation populations, they undoubtedly exist. Blacks are at a higher risk than Whites for an amputation following traumatic LE fracture and have been found to receive limb salvage surgeries less frequently.[6,7] Additionally, regional and socioeconomic differences have been found in LE trauma and amputation, and there is some evidence of differences in limb salvage and amputation rates after UE trauma.[8,9]

UE Amputation Surgical Technique

The goal for UE amputations is to preserve as much residual limb length as possible in order to maximize range of motion and lever arm strength.[10] For transradial amputations, approximately 5 cm of residual ulna length is ideal for prosthetic fit and elbow joint preservation. For transhumeral amputations, 5-7 cm of residual humerus is recommended. While disarticulation procedures at the elbow or wrist can be helpful for maintaining length, they can create unequal arm lengths due to prosthetic component build heights that can be cosmetically unappealing.

Common surgical options for amputation include myoplasty — the suturing of agonist–antagonist muscle pairs to each other or myodesis — direct suturing of residual limb musculature or tendon into bone/periosteum. Other less common procedures also include cineplasty — surgical isolation of muscle (usually biceps or pectoral) with attachment to a tension cable to control a terminal device via contraction. The Krukenberg procedure — the separation of radius and ulna — is usually indicated for blind, bilateral transradial amputees to preserve tactile function, but is more frequently done in developing countries. For transhumeral amputations, surgical options also include angulation osteotomy where the distal humerus is angulated to provide better suspension and rotation control of the prosthesis.

Advanced surgical procedures include osseointegration, targeted muscle reinnervation (TMR), and regenerative peripheral nerve interfaces (RPNIs). Osseointegration is the direct skeletal attachment of the prosthesis via titanium abutment protruding through skin from the end of cut bone. TMR reroutes residual nerves from the amputated limb to proximal muscles or nerve fascicles to enable intuitive control of externally powered prosthetics via proximal muscle contractions. RPNIs are created by placing residual nerves in autologous muscle bundles, also for enhanced signaling for externally powered prosthetics. Both TMR and RPNI's have been employed to control pain.

Phases of UE Prosthetics Rehabilitation

UE amputation rehabilitation consists of four main phases: the perioperative, pre-prosthetic, prosthetic training, and lifelong care. The perioperative phase begins from the decision for an amputation or immediately following an emergent amputation and continues until the residual limb wounds are fully healed. While there are numerous medical considerations during this phase, an important focus should be establishing patient goals and providing patient and family education. Education during this phase should focus on amputation level, residual limb management, pain management, mental health and a general overview of prosthetic options. Postoperatively, clinical focus includes wound healing, volume control, pain management, and monitoring for post-operative complications such as venous

Table 1: Assessment Tools for Patients with UE Amputations

Test/Assessment	Task	Measurement
Activities Measure for Upper Limb Amputees (AM-ULA)	18 items for household and self-care tasks.	Scoring considers task completion, speed, movement quality, skillfulness of prosthetic use, and independence. Administration requires 30 minutes.
Box and Block Test	Patient moves square blocks from one side of a box to another for 60 seconds.	The number of blocks moved is counted. Measures manual dexterity.
Modified Jebsen Hand Function Test Heavy Cans and Light Cans Tests	7 timed subtests related to functional tasks, including printing a sentence, simulated page turning, picking up small objects and placing them in a container, stacking checkers, simulated feeding, moving light cans, and moving heavy cans.	Score is the number of items completed per second for each task. Assesses dexterity.
***Quick*DASH**	11-item survey validated in transhumeral, transradial, and shoulder level UE amputees assessing patient's experiences with body function, activity, and participation.	Lower scores correspond to lower levels of disability. Should be completed by a patient with amputations at each clinical encounter.
University of New Brunswick Spontaneity and Skill Tests	Tasks range from tearing paper sheet, opening zipper pouch, tying shoelaces, using building blocks, slicing food.	Designed for pediatric amputees, with tests organized by age category. Scores based on consistency and skill of prosthetic use.

Adapted from (Resnik, Borgia, Silver, & Cancio, 2017)

thromboembolism, infection, hematoma, or sepsis to ensure safe transition into rehabilitation.

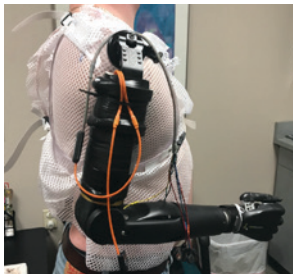
The pre-prosthetic/post-operative phase culminates with a prosthetic prescription. During this phase, patients prepare their residual limb for eventual prosthetic wear. Preparation of the limb consists of monitoring for proper wound healing, shaping, desensitization, pain management, strengthening, range of motion, therapies for single limb ADLs, and ongoing education. Monitoring wound healing and limb shaping occurs by close skin inspection, limb circumference and length measurements, and scar mobilization. Scar mobilization, which should occur just after the incision is healed but before the scar fully matures, is done to prevent adhesions to the underlying tissue as the dermis should glide easily over bony surfaces.

The prosthetic training phase begins with the delivery of a prosthesis and continues until the patient demonstrates successful functional use. During this phase, the patient focuses on learning the components of the prosthesis, donning and doffing, implementing a progressive wear schedule, and working on basic control and functional training. There is continued monitoring for pain, range of motion, and fluctuations in limb volume. Several assessment tools can be used to quantitatively measure function when utilizing a prosthetic device. These assessment tools are outlined in Table 1.[11] After prosthetic training, the final phase of lifelong care focuses on incorporating the prosthesis into activities of personal meaning to the patient including, but not limited to, sports, hobbies, art and work. The patient should be regularly followed to assess prosthetic utilization, emotional and adjustments issues, residual skin, pain and barriers to prosthetic use.

Prosthetic Assessment and Prescription

Range of motion should be assessed for all joints proximal to the amputation and can be objectively measured using a goniometer. Neurologic exam should include alterations in sensation, cognitive evaluation and strength testing. Throughout the history taking and physical exam, care should be taken to identify any possible barriers to prosthetic training such as dehiscence or hardness along the incision. If present, erythema within the residual limb should not increase in size after 72 hours; if it does, then infection should be considered.[12]

Table 2: Prosthetic Prescription Strategies

Prosthetic Type	Pros	Cons	
No Prosthesis	• Simplicity • Comfort • Sensation — no barriers to environment • Improved mobility • Cost	• Poor aesthetics • Necessitates either functioning as "one-handed" or "no-hands" (if bilateral) • Reduced ability for bimanual tasks	
Passive/Cosmetics Prosthesis	• Cosmetic appearance • No harnessing necessary for transradial level, minimal if higher level • Relatively lightweight and inexpensive • Semi-flexible fingers can be prepositioned for specific functions • Can accommodate any level of amputation without length discrepancy of sound limb	• No active control of fingers	
Body Powered	• Greater functional capacity • Durable, can be used for heavy duty activities • Proprioceptive feedback through harness and socket • Faster response than externally powered device • Less expensive than externally powered device • Lower maintenance	• Requires harnessing • Can be uncomfortable and restrict movement • Requires certain level of strength and ROM • Decreased grip force compared to externally powered terminal devices • May lack cosmetic appeal • Axillary pressure from harness may lead to nerve entrapment	
Externally Powered	• Increased terminal device grip force compared to body powered • Potential for proportional control • Improved aesthetic compared to body powered • Adaptability of hand grips specific to user	• More expense to purchase and maintain • Challenging to set up and to learn how to use • Generally used for light duty activity/ basic ADLs • Lack of proprioceptive feedback in terminal device position • Increased weight • Must charge on regular basis • Must have excellent socket fit to maintain function • Perspiration affects EMG	
Hybrid	• Less expensive than completely externally powered • Lower weight than externally powered • Stronger grip than body powered	• Harness needed for body powered function (elbow control) • For shorter limbs, more demand on strength and residual ROM to get full ROM in prosthetic joint • Potential for more maintenance	
Specialty/Adaptive	• Customized to specific function/ask • Can empower individual to return to same activities	• Limited function outside intended purpose	

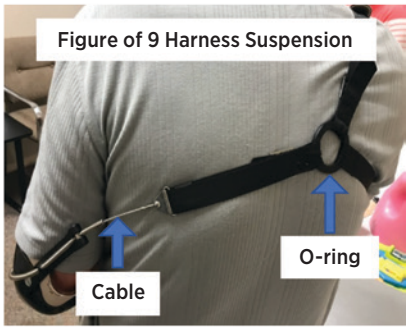
Adapted from (Fantini, 2014b)

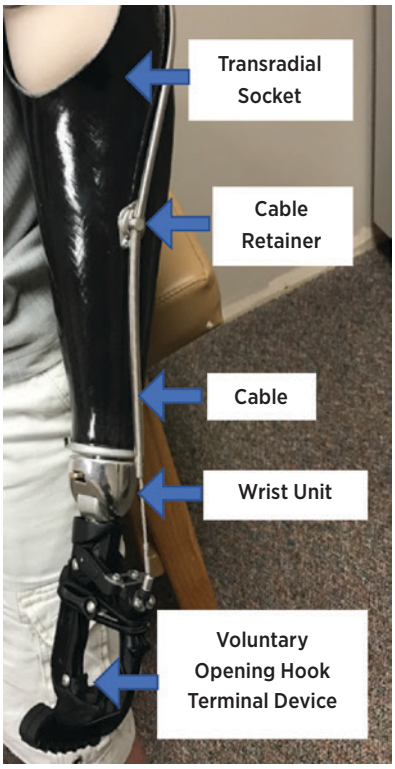
Not all patients are good candidates for a UE prosthesis and key factors in determining appropriateness include: (1) cognitive or behavioral barriers to participating in the fitting and training process, (2) profound residual limb pain/allodynia that interferes with donning a prosthesis, (3) significant weakness in the residual limb including brachial plexopathy — although there are design strategies that can be implemented if the patient is motivated — and (4) chronic non-healing wounds.

Unfortunately, UE prosthesis technology does not come close to replicating the sound limb and is limited in dexterity and adaptability. For example, body powered UE prosthetics, which utilize cable control systems, are durable, can provide proprioceptive feedback via straps, and are lower maintenance. However, they are bulky, uncomfortable to wear, and rely on a greater degree of patient strength and range of motion. Externally powered devices, such as those relying on myoelectric EMG control of residual muscles, can be programmable and have stronger grips, but are also expensive, heavier, and require more maintenance. The different UE prosthetic control strategies include cosmetic, body-powered, externally powered, hybrid, and specialty/adaptive. Control strategies for UE prosthetics are further detailed in Table 2.[13] *(See page 4)*

Table 3: Prosthetic Components

Interface (Socket)	• Silicone or gel liner • Can be "hard" carbon fiber socket or can be separated from a frame
Suspension Method	**Harness** • Figure of 8 design • Chest strap/shoulder saddle: better for carrying heavier loads with prosthetic, minimizes axillary pressure • Figure of 9 design **Self-suspending** • Can be used for lighter prosthetics, those with longer residual limbs
Wrist Unit	• **Standard friction** - passive wrist rotation, uses friction to control rotation • **Quick disconnect** – locking wrist, allows for quick changing of terminal device, locks in position of terminal device during grasping and lifting • **Wrist flexion** – allow up to 3 locking positions in flexion/extension to position terminal device • **Ball and socket** – passive, multidirectional wrist movement limited by adjustable friction • **Electric wrist rotator** – powered wrist rotation, significantly longer device due to controls
Terminal Device	**Types** • **Hooks** – more durable/rugged than hands, less energy to use, lighter, better visual feedback when using • **Hands** – more cosmetically appealing, but may block user's field of view • **Custom devices** – highly individualized, more expensive, can enhance functionality of specific tasks **Control** • **Voluntary opening** – do not need to maintain tension while holding object, force limited by number of bands • **Voluntary closing** – more proportional control of grip, but needs to be applied continuously • **Externally powered** – offer variety of grip patterns, strong grip, they break, slow





Adapted from (Fantini, 2014b)

Four basic components comprise UE prosthetics: prosthetic interface (socket), suspension method, wrist unit, and terminal device. The socket is in direct contact with the residual limb and is custom fabricated to fit comfortably and support the other components. It must conform to the shape of the residual limb while meeting multiple demands, including maximizing range of motion, spreading forces across the residual limb, stabilizing against rotation, and supporting vertical loading. The socket may be the most important component determining prosthesis wear because a poorly fitting socket that causes pain may lead to early rejection.

The suspension supports the prosthetic socket onto the residual limb. It can be self-suspended over the humeral condyles in transradial patients or accomplished with a distal locking liner, similar to lower extremity prosthetics, or a harness that crosses the shoulders. The purpose of the suspension is to provide resistance to vertical loading, distribute the weight of the prosthesis and provide the framework for cables used for body-powered control. The harness is made of custom fitted Dacron webbing using multiple designs based on patient comfort. The figure of 8 design distributes weight over both shoulders with bilateral axillary loops, while the figure of 9 design loops the suspension around only the contralateral shoulder. The chest strap with shoulder saddle harness is an option that allows for more vertical loading and is an option when lifting heavier loads is required.

The purpose of the wrist unit is to augment wrist supination and pronation with possible additional attachments for flexion and extension. It also provides an attachment for the terminal device. Wrist units have a variety of options such as standard friction, quick disconnect, ball and socket, and electric wrist rotator. The purpose of the terminal device — which can range in design from hooks to hands — is to restore the interaction with the patient's surroundings. For body powered systems, terminal device control has two main strategies: voluntary opening with the default closed position or voluntary closing with the default open position. Componentry is further detailed in Table 3. *(See page 5)*

While the basic components of a prosthesis are important to optimize functionality, it is important to remember that prosthetic design can also be an extension of personal expression. Advances in material sciences and 3D printing can enable highly individualized prosthetic designs that can be both functional and expressive for patients. Specific examples can be viewed at https://thealternativelimbproject.com/

Complications Impacting UE Prosthetic Rehabilitation

Pain can be a major barrier for prosthetic use and occurs from multiple causes. Studies have documented that almost all patients (90%) reporting pain, with phantom limb and residual limb pain being the most prevalent followed by back, neck, and non-amputated limb pain 6 months after initial UE amputation.[14]

Somatic types of pain after UE amputation include immediate post-operative pain and residual limb pain. While post-operative pain and acute residual limb pain occur due to the direct tissue trauma following amputation, persistent residual limb pain can have other etiologies. Causes of persistent or chronic residual limb pain include infection, ischemia due to poor perfusion, neuromas, chronic wounds or heterotopic ossification.[15,16] During prosthetic training, residual limb pain can be mechanical due to poor prosthetic socket fit, which can lead to bruising or skin breakdown.

Neck and shoulder pain are more prominent in patients with UE amputations as compared to the general populace.[14] Musculoskeletal pain can be attributed to overuse injuries and cumulative trauma disorders which have been estimated to be three times as common in UE patients as compared to the general population.[17] These generally occur due to compensatory movements and excessive motion at intact joints, which change the normal positioning and kinematics of the shoulder, neck, and back. Changing position and kinematics can even progress to lower extremity overuse injuries in UE amputees.[18] Of the overuse injuries in UE amputation patients, rotator cuff pathologies are among the most common. Additionally, the suspension system can also contribute to musculoskeletal pain due to improper positioning. For example, if a patient using a figure of 8 harness for suspension has a control strap that is not fitting well, it would require forceful shoulder flexion to operate predisposing to an overuse injury. Another example is if the cross strap of a figure of 8 harness is not properly positioned on the cervical/thoracic neck, it can result in localized pressure on the neck. Treatments for these musculoskeletal injuries are similar for patients without

Table 4: Treatment Options for Phantom Limb Pain

Strategy	Option	Comments
Pharmacologic[27]	Opioids	Effective in decreasing pain intensity in the short-term Adverse effects: Constipation, sedation, tiredness, dizziness, sweating, voiding difficulty, vertigo, itching, and respiratory problems
	N-methyl D-aspartate (NMDA) receptor antagonists (Ketamine, dextromethorphan, memantine)	Improvement of short term PLP with dextromethorphan, ketamine. No improvement with memantine Adverse effects: loss of consciousness, sedation, hallucinations, hearing and position impairment, and insobriety
	Anticonvulsants (gabapentin)	Conflicting, but combining the results favored treatment group over control Did not improve function, depression score, or sleep quality Adverse events: somnolence, dizziness, headache, and nausea
	Botulinum toxin injections	No improvement in PLP based on RCTs
	Local anesthesia	Some short-term improvement noted with bupivacaine 0.25% when given as contralateral myofascial injection
	TCAs (Amitriptyline)	No improvement in PLP based on RCTs Adverse effects: Anticholinergic properties
	Calcitonin	No improvement in PLP based on RCTs Adverse effects: facial flushing, nausea, sedation, headache
Surgical	Dorsal root entry zone lesioning	Immediate decrease, but no long-term improvement. High recurrence of central pain
	Targeted sensory reinnervation	Favorable reduction but not statistically significant[31]
Neuromodulation	Spinal cord/DRG Stimulation	Shown to be effective in short term, but effects diminish over time in some patients, with implants sometimes having to be removed. Most studies did not have follow-up data beyond around 2 years[29]
	Peripheral Nerve Stimulation	Randomized controlled trials demonstrated efficacy for chronic phantom and residual limb pain in lower extremity amputees up to 1 year after 60-day implants[30]
Physical Therapies	TENS	No RCTs assessing efficacy and safety[22]
	Mirror therapy Virtual reality	Mechanisms based on cortical reorganization with simulation of missing limb[23,24]

amputations but must also include addressing the underlying prosthetic problem. In order to address all possible complications related to prosthetic componentry and fit, good communication and a working relationship with a prosthetist is crucial.

Neuropathic sensations, both painful and nonpainful, include phantom limb pain (PLP) and phantom limb sensation. While the exact incidence varies, studies specific to UE amputees have estimated that PLP occurs in ~50% patients and phantom limb sensations occur in ~75% of patients.[19] PLP is specifically pain that is perceived in the absent/amputated part of the body and is often described in terms of other types of neuropathic pain (i.e. burning, tingling). However, it has also been described in terms of more nociceptive pains as well (i.e. squeezing, crushing). Phantom limb sensations, while not painful like PLP, can still be a barrier for patients. Descriptions can range from perceived

normal anatomy of the missing limb to painless paresthesia or proprioception of the limb. Proposed CNS mechanisms include cortical remapping of the somatosensory cortex as well as mismatching of visual feedback from the missing limb resulting in excessive pain. PNS mechanisms include hyperexcitability of neurons in the dorsal root ganglion (DRG) resulting in ectopic discharges and aberrant signaling resulting in pain.[20] Risk factors for developing PLP include the severity and duration of perioperative pain and premorbid and postoperative depression.[21]

Treatment for PLP includes both pharmacologic and nonpharmacologic modalities with varying degrees of success (Table 4) *(See page 7)*. Non-pharmacologic modalities include TENS, mirror therapy, virtual reality, and desensitization techniques. While randomized controlled trials have not shown statistical benefits utilizing TENS, the risk of adverse effects are low and can often be part of multimodal treatment.[22] Smaller prospective studies have shown that mirror therapy and more recently virtual reality may have potential benefits with PLP.[23,24] These interventions are theorized to treat PLP by addressing the visual dissonance of the amputation and promote cortical reorganization by simulating movement of the missing limb.[23,24] Desensitization techniques including massaging, tapping, vibration, wrapping, and friction rubbing.[25] Prosthetic use itself is effective in the management of PLP due to the restoration of visual feedback and reduced pathologic cortical reorganization.[26]

A 2016 Cochrane review reported that medications such as gabapentin, ketamine, and opioids currently have the strongest efficacy based on small randomized controlled trials.[27] Other medications that helped residual limb pain, but not phantom pain, include botulinum toxin injections, corticosteroids, and lidocaine injections.[28]

In more refractory cases, neuromodulation techniques of the spinal cord and DRG have been utilized with some long-term success, but further research is needed for definite proof of efficacy.[29] One recent randomized controlled trial showed successful long-term treatment of chronic PLP in lower extremity amputees up to one year after placement of a 60-day peripheral nerve stimulator implant.[30] Surgical options include dorsal root entry zone (DREZ) lesioning and targeted muscle reinnervation (TMR). DREZ lesioning can result in immediate decrease of PLP but has not shown long-term improvement and can have a high recurrence of central pain. TMR, which reroutes residual nerves from the amputated limb to intact muscle, shows potential but not statistically significant reduction in PLP.[31] Additionally, while surgical excision of neuromas alone has historically shown to have a high rate of recurrence, incorporation of TMR with surgical resection has demonstrated potential for prolonged pain relief and reduced recurrence of neuromas.[32,33] Most recently, RPNIs have been shown to prophylactically reduce incidence of neuromas and phantom limb pain.[34] In addition to these modalities, psychological complications such as PTSD, depression, and shame due to body image changes should be screened as a part of a multidisciplinary approach to pain management.

Brachial plexopathies can be an additional barrier to successful amputation rehabilitation. Additional surgeries that can be considered also include nerve grafting to replace a damaged nerve, nerve transfers from one muscle to another can occur to provide alternate innervation to a major muscle group, or tendon and muscle transfers to restore joint movement. One recent study looking at five patients with global brachial plexopathies due to trauma who subsequently underwent transhumeral amputations demonstrated successful ability to use myoelectric prosthetic devices after undergoing nerve grafts and muscle transfers with significant decrease in perceived disability.[35] Even after such surgeries, intensive cognitive signal training may still be required for functional myoelectric prosthetic use.

Psychosocial complications can negatively impact patient acceptance of a prosthesis. Overall, adults with disability experience mental distress at significantly higher rates than adults without a disability. Unlike LE amputation which occurs more often due to dysvascular disease, trauma is more frequent in UE individuals causing unique mental health impairments. Depression has been reported in 50% of UE amputees while 25% noted PTSD and 20% had co-existing PTSD and depression. Additionally, women and people of color appear to be at a higher risk of both depression and PTSD after UE amputation compared to white males. These emotional and psychological complications can significantly affect patients' abilities to participate in work and school and to socialize with loved ones.

Cautionary Tale: Prosthetic Rejection

Rejection of the upper limb prosthesis occurs more frequently than in LE amputation. Currently there is a gap in knowledge regarding the exact rate of prosthetic rejections for patients with upper extremity amputations. The level of amputation is the strongest factor impacting prosthesis acceptance with less use the more proximal the amputation.[36,37] However, bilateral UE amputees are more likely to use a prosthesis regardless of level. There is contradictory evidence surrounding prosthesis use after the loss of a dominant hand versus non-dominant hand, and whether the loss of the dominant hand plays a role. Patients with ongoing phantom limb, residual limb, neck and back pain are less likely to use a prosthesis. Brachial plexus injury is associated with higher rates of rejection. Sex has historically not been strongly linked with prosthesis use, but a recent survey of Veterans found that women were less likely than men to have ever used or currently use a prosthesis.[38]

There is contradictory evidence regarding prosthetic and rehabilitative factors, such as timing of prosthesis fitting and availability of training. Because UE amputation is less common, the availability of a local prosthetist with the knowledge and experience to fabricate a comfortable, well-fitting and functional prosthesis may be the biggest barrier. Early prosthesis fitting has not consistently been shown to increase use but having multiple terminal devices specific to different tasks does. While rehabilitation training can improve function, it has not been shown to increase daily use. Additionally, due to poor proprioceptive feedback of traditional prostheses and the improved sensation of the skin from the residual limb when manipulating objects, a more functional option may be not using a prosthesis during some tasks, especially in transradial patients.

Clinical Outcome

For DG's right arm phantom pain, he was initiated on a trial of gabapentin 300 mg TID. Additionally, he was educated on desensitization, TENS, and mirror therapy that were incorporated into treatment with his physical and occupational therapy teams. Regarding his symptoms of mood and sleep change, DG was educated on symptoms of post-traumatic stress disorder and began venlafaxine ER for dual benefit for his mood and phantom neuropathic pain. He was also referred to psychiatry and rehabilitation psychology.

DG's initial prosthetic prescription included a body-powered prosthesis due to its durability, lower maintenance, and higher degree of functioning for his outdoor hobbies. He was prescribed a silicon liner with a distal pin locking suspension and a figure of 8 harness. He was given a standard wrist friction unit with quick release for more fine-tuned control of passive wrist rotation. For the terminal device, he had a voluntary opening hook to prioritize durability and allow him to hold objects in a variety of home and work settings. For his hobbies, he was fitted with a personalized terminal device that can clasp onto his fishing rod for easy casting.

DG again presented for follow up one month after receiving his prosthesis. He reported that he is using his prosthetic device up to eight hours a day. While he notices occasional phantom limb pain and sensations, the pain is only a 2/10 and relieved with desensitization techniques and prosthetic use. In collaboration with the prosthetist, the patient's figure of 8 straps were adjusted to improve the fit and comfort. DG reports improvement in mood swings and sleep disturbances and has been able to resume hunting and fishing that were very important to him. He has returned to work at the chemical plant with new work equipment such as one-handed keyboards and ergonomic office equipment. He has additional work accommodations such as weight limits on carrying industrial items to reduce any musculoskeletal strain. Additionally, he has begun a leadership role for improved workplace safety.

Take Home Points

- Upper extremity amputation rehabilitation has four main phases: the perioperative, pre-prosthetic, prosthetic training, and lifelong care.
- During UE rehabilitation, it is important to monitor for musculoskeletal and neuropathic pain, as well as psychosocial complications that can limit functional improvement.
- Phantom limb pain has non-pharmacologic, pharmacologic and interventional approaches for successful treatment.
- Prosthetic prescriptions are a highly individualized process requiring close collaboration between the patient, physiatrist, and prosthetist as well as a good understanding of different control strategies and componentry.

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