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Stop the Bleed!

STOP THE BLEED

Source: U.S. Department of Homeland Security

by Louis Alarcon, MD, FACS, FCCM

Worldwide, 5 million people die secondary to trauma every year, and in the United States, trauma is the number one cause of death for people under the age of 45.[1] Hemorrhage is the leading cause of death following traumatic injury, and failure to control hemorrhage is the most common cause of preventable death after injury.[2] Furthermore, external hemorrhage is a major cause of potentially preventable death following severe injury. Experience in the Iraq and Afghanistan conflicts led to military guidelines for routine tourniquet use, with a significant reduction in the number of deaths due to extremity hemorrhage.[3] In the military experience, tourniquets have been shown to save lives when applied before the onset of shock.[4]

The lessons learned from the military experience were adopted in civilian practice, and the Boston Marathon bombing event in 2013 highlighted this issue.[5] In this incident, two separate explosive devices detonated, killing three people at the scene and injuring approximately 264 others. While many of these patients sustained exsanguinating lower extremity injuries, it is noteworthy that not one patient who arrived at a hospital subsequently died. This remarkable survival rate was due to the rapid response of bystanders and EMS providers, who applied tourniquets (in some cases, makeshift tourniquets were fashioned out of pieces of clothing), along with expert field triage, rapid transport to appropriate facilities including trauma centers, coordination among trauma resources, and mass casualty preparedness and planning prior to this event.

Bystanders Can Save Lives

Uncontrolled hemorrhage after trauma can occur after natural and man-made disasters and everyday accidents. Severe bleeding can kill patients in minutes, even before trained EMS crews can arrive. Recognizing that bystanders are the first to encounter an injured patient, in October 2015 the White House and the Department of Homeland Security launched a nationwide "Stop the Bleed" campaign.[6] A goal of this campaign is to provide

(Continued on Page 2)

Stop the Bleed! *(Continued from Page 1)*

bystanders with the skills and knowledge to stop life-threatening bleeding. Studies have shown that bystanders with little or no medical training can have an impact. Similar to the use of CPR, increasing public awareness about how to identify and control hemorrhage may help save lives.

The recommendation is that if a bystander encounters a person who is bleeding, they should first move themselves and the injured person to safety if necessary. Next, they should call 911. Following that, there are three basic steps that should be taken:

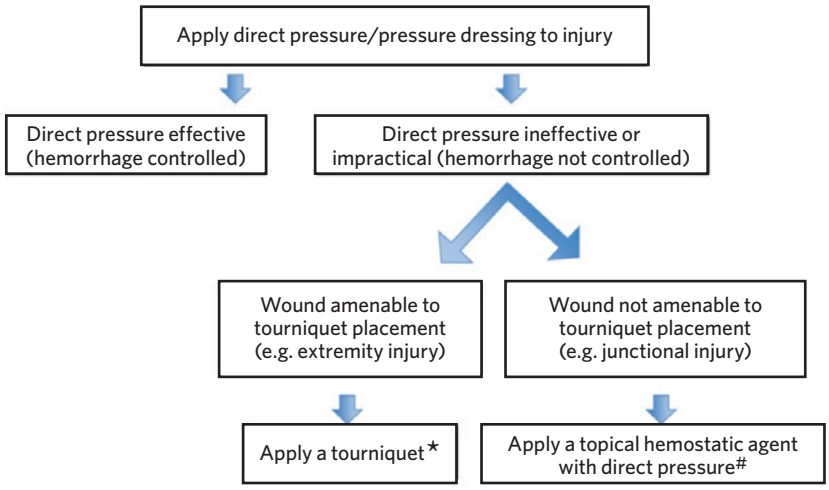
1. **Compress**. The bleeding site should be exposed, and firm steady pressure should be held over the site with bandages or clothing.
2. **Tourniquet**. If compression does not stop bleeding, a tourniquet 2 to 3 inches above the bleeding site should be applied.
3. **Compress again**. If bleeding doesn't stop, a second tourniquet should be applied proximal to the first one.

The focus of this initiative is to empower the general public to be aware of these simple steps that save lives, and to promote public access to "Bleeding Control Kits," which contain tourniquets, gauze, and gloves.

EMS Providers: Minimizing Prehospital Time and Saving Lives

With advances in EMS training, the ability to perform potentially life-saving procedures in the field has increased. However, prehospital interventions beyond the basic life support (BLS) level have not been shown to impact survival, leading to the concept that it is preferable to "scoop and run" than to "stay and play." This is particularly true in an urban setting, where, due to the relatively short transport times to trauma centers, it may be best to rapidly transport the patient to the hospital, rather than to attempt major interventions at the scene. There may be a need for advanced techniques in the rural setting or when transport times are prolonged, and there is certainly a need for further research into subsets of patients who may benefit from field interventions.

Figure 1: Prehospital External Hemorrhage Control Protocol



Reprinted with permission from Taylor & Francis Group. This figure originally appeared in "An Evidence-based Prehospital Guideline for External Hemorrhage Control: American College of Surgeons Committee on Trauma," by Eileen M. Bulger, David Snyder, Karen Schoelles, et al, in *Prehospital Emergency Care*'s April 2014 issue, published by Taylor & Francis Group.

* Use of tourniquet for extremity hemorrhage is strongly recommended if sustained direct pressure is ineffective or impractical. Use a commercially produced, windlass, pneumatic, or ratcheting device, which has been demonstrated to occlude arterial flow, and avoid narrow, elastic, or bungee-type devices. Utilize improvised tourniquets only if no commercial device is available. Do not release a properly applied tourniquet until the patient reaches definitive care.

Apply a topical hemostatic agent, in combination with direct pressure, for wounds in anatomic areas where tourniquets cannot be applied and sustained direct pressure alone is ineffective or impractical. Only apply topical hemostatic agents in a gauze format that supports wound packing. Only utilize topical hemostatic agents which have been determined to be effective and safe in a standardized laboratory injury model.

The concept of minimizing prehospital interventions and prioritizing rapid transport to a trauma center is further illustrated by the concept of hypotensive resuscitation.[7] Hypotensive patients with penetrating torso trauma were randomized to receive immediate fluid resuscitation versus delayed fluid resuscitation, in which no fluids are given until the patient is in the operating room at a trauma center. This study showed that for hypotensive patients with penetrating torso trauma, delay of fluid resuscitation until operative control of hemorrhage improves survival.

Similar to the recommendation for tourniquet use by bystanders, there is now strong support for tourniquet use by EMS providers. After a systematic review of the literature, a consensus panel recommended the use of tourniquets in the prehospital setting for the control of significant extremity hemorrhage if direct pressure is ineffective or impractical (see Figure 1).[8]

Pennsylvania protocols now require EMS crews to carry commercially available tourniquets and emphasize their early use. Police and firefighters should also carry tourniquets and be trained in their use prior to EMS arrival.

At the Trauma Center: Every Minute Counts

For patients who are hypotensive due to bleeding from traumatic injuries, studies have shown that time to surgical control of hemorrhage directly correlates with mortality. A study conducted with data from the Pennsylvania Trauma Systems Foundation demonstrated that for the patient undergoing emergent laparotomy for intra-abdominal bleeding after trauma, the probability of death increases by 1% for each three minutes spent in the emergency department.[9] A multicenter study of massive transfusion in trauma, of which UPMC was a participating center, found that in hypotensive trauma patients with hemoperitoneum, a 20-minute delay in surgery was associated with a 10% increase in mortality.[10] Thus, when the patient is bleeding to death, time is of the essence, and every minute matters. Anything that delays definitive surgical control of hemorrhage increases mortality.

Trauma centers, including those at UPMC, employ a number of strategies to stop hemorrhage, ranging from innovative minimally invasive endovascular procedures to emergency surgery and damage control techniques, where the priority is to control hemorrhage and contamination from bowel injuries, while aggressively preventing and treating the associated coagulopathy of trauma, which is a leading cause of death after major injury. Using massive transfusion protocols (see accompanying article, "Hemostatic Resuscitation" on Page 6), guided by endpoints of resuscitation using advanced point-of-care devices, such as thromboelastography, we are saving more lives today than ever, resulting in the so-called "unexpected survivors."

Conclusion

For patients who are bleeding after major trauma, time is of the essence. The key concept is early control of hemorrhage. Immediate actions by bystanders at the scene can save lives by controlling compressible hemorrhage. The life-saving maneuvers performed by EMS providers include control of external bleeding and rapid transport to a trauma center for definitive treatment: surgical control of hemorrhage. The UPMC Trauma Care System and the Copeland Regional Trauma Council are taking the initiative to promote the "Stop the Bleed" concept in western Pennsylvania. The Copeland Regional Trauma Council includes all trauma centers in this region.

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Hydrofluoric Acid Burns

by Jenny Ziembicki, MD

Hydrofluoric acid is a dangerous inorganic acid that is used in both industrial and domestic settings. It has been used for the polishing and etching of glass and in the manufacturing of chemicals and electronics. It is also an active ingredient in rust removers and other heavy-duty cleaners. Hydrofluoric acid (HF) exists in two forms: purified (>99% concentration) as anhydrous hydrofluoric acid, and in a dilute form called aqueous hydrofluoric acid. Hydrofluoric acid may enter the body through the skin, mucosa, alimentary tract, or respiratory tract and causes severe tissue destruction as well as systemic toxicity.

Hydrofluoric acid causes injury through two separate mechanisms. First, high concentrations of hydrogen ions cause coagulative protein necrosis and direct destruction of exposed tissues. Additionally, HF can readily cross lipid membranes, move to deep tissue layers, and release the freely dissociable fluoride ions. The fluoride ions bind intracellular calcium and magnesium, causing increased permeability of the cell membrane for potassium ions, nerve stimulation, and severe pain. As the fluoride ions penetrate through skin, they produce extensive liquefactive necrosis of soft tissues and decalcification and corrosion of bone. This secondary damage is more significant than the initial corrosive burn and may continue for several days if left untreated.

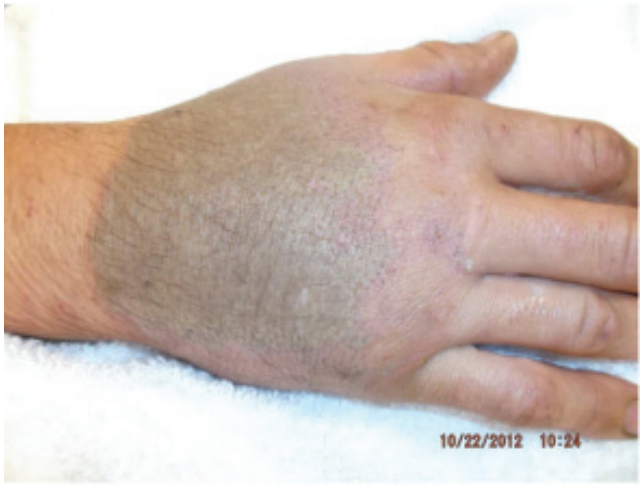

Figure 1: Hydrofluoric acid burn to the hand. This patient was successfully treated with topical gel and arterial infusion.

The clinical presentation of HF burns varies, based on the route of exposure, concentration of the acid, duration of contact, and characteristics of the exposed tissue. When highly concentrated, the acid will cause immediate tissue destruction and pain, whereas exposure to dilute concentrations may not become symptomatic until as late as 24 hours after exposure. Skin lesions may initially appear blanched with surrounding erythema. The wounds may then become edematous, blistered, or gray, and may progress to ulceration and necrosis.

All patients with hydrofluoric acid burns must be assessed for possible systemic toxicity. Even small amounts of hydrofluoric acid may disturb metabolism and cause major electrolyte imbalances. Hypocalcemia, hypomagnesaemia, and hyper- or hypokalemia may occur. Sudden death and fatal cardiac arrhythmias have been documented. Massive exposure occurs from as little as 1% total body surface area exposed to a >50% hydrofluoric acid solution, or >5% total body surface area exposed to hydrofluoric acid of any concentration.

The diagnosis of hydrofluoric acid burns is relatively straightforward, given that most patients provide a clear history of their exposure. The goals of management are to remove residual acid, neutralize free fluoride ions, and prevent ongoing tissue destruction. Initial management mirrors any chemical burn treatment. Universal precautions should be maintained and care taken with removal of any affected clothing so that one does not contaminate themselves. For cutaneous injury, lavage performed with tap water or saline should be immediate and continue for at least 30 minutes. As with any chemical burn, care should be taken to avoid spreading the chemical over previously unaffected areas. Lavage, however, is ineffective at neutralizing any fluoride ions that have already penetrated through the skin into deep tissues.

A topical treatment of insoluble salts can neutralize fluoride ions. Both calcium and magnesium may bind fluoride ions and can be in the form of wet soaks and gels. Calcium gluconate 2.5 g may be easily mixed with 100 mL of K-Y Jelly and liberally applied to the burn wound. Application should last for at least 30 minutes and should continue for at least 15 minutes after the pain subsides. Surgical gloves may be filled with the gel and applied to hand burns. This process may be repeated every 30 to 60 minutes until pain resolves. Pain relief is the primary indicator of the therapy's effectiveness. Because calcium and magnesium ions have poor tissue penetrability, topical applications work best to neutralize fluoride ions in the superficial layers of the skin.

Lavage and topical calcium gluconate are essential first-line therapies for hydrofluoric acid burns and may be all that is needed for many patients. These treatments should be initiated as soon as possible following exposure, by EMS providers or emergency department personnel. Patients should then be transferred to a burn center, regardless of the size of exposure or ongoing symptoms. If these initial interventions fail to relieve pain, a qualified burn team may take the following additional measures.

Subcutaneous injections of calcium gluconate may overcome the limitation of poor tissue penetrability of external agents and bind to fluoride ions to limit deep tissue destruction. This therapy may be considered for patients who are unresponsive to topical therapy or whose initial treatment is delayed. It may also be used as part of multimodal therapy for large HF burns. Subcutaneous injections should be used cautiously in areas with limited tissue space, such as the digits, as they may increase tissue pressure and result in a compartment syndrome.

Intra-arterial infusion may be used for HF burns with clear arterial distributions, such as the hands or digits, when topical therapy has been ineffective or in cases of massive HF exposure. Patients must be placed on telemetry and monitored for hypercalcemia and arrhythmia.

Surgery to perform wide debridement is reserved for patients with persistent pain, which is an indicator of ongoing tissue destruction despite topical therapy, arterial infusions, and/or subcutaneous injections. Surgery may also be life saving for massive HF exposure.

All patients with hydrofluoric acid burns should be assessed for systemic toxicity. Hypocalcemia, hypomagnesaemia, acidosis and hypo- or hyperkalemia may occur. Electrocardiogram monitoring and serial serum calcium determination is essential. For patients with significant exposure, multimodal therapy may be required, and calcium supplementation should begin prior to electrolyte analysis results. Patients with inhalational injury or digestion of hydrofluoric acid may be particularly susceptible to systemic toxicity.

In summary, hydrofluoric acid is an inorganic compound with the potential for both severe tissue destruction and systemic toxicity. Baseline treatment begins with lavage and application of calcium gluconate gel, followed by immediate transfer to a burn center for ongoing monitoring and treatment. The UPMC Mercy Trauma and Burn Center specializes in the care of all types of burns, in addition to general trauma. Trauma-burn surgeons at UPMC Mercy are always available and can be reached for consultation or transfer 24/7 at 412-647-7000.

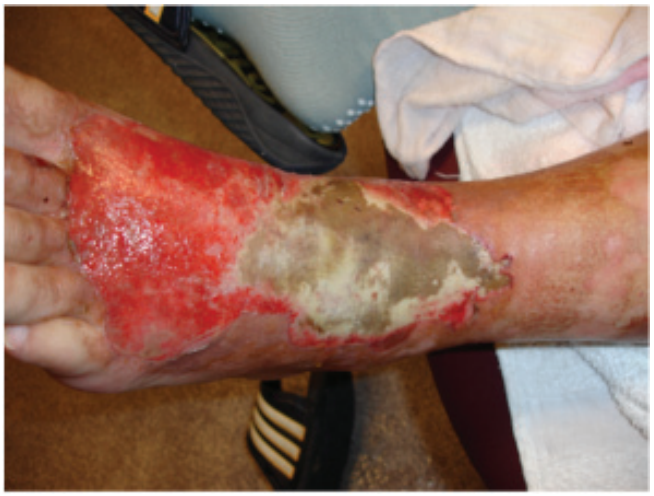

Figure 2: Hydrofluoric acid burn to the foot. Patient ultimately required excision for ongoing tissue destruction.

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Hemostatic Resuscitation

by Matthew D. Neal, MD, and Louis Alarcon, MD, FACS, FCCM

Trauma resuscitation practices have changed substantially over the last two decades. In the past, the goal was to normalize blood pressure as quickly as possible. Starting in the field and continuing in the trauma bay, clinicians infused large volumes of crystalloids before surgical hemostasis had been achieved. Transfusion of blood products was started relatively late, while plasma and platelets were administered even later. Dilutional anemia and coagulopathy were relatively common. Patients with large-volume blood loss often died from what was termed "the bloody vicious cycle" of hypothermia, acidosis, and coagulopathy. Excessive administration of crystalloids led to the development of acute lung injury and compartment syndromes, in addition to worsening acidosis and coagulopathy.

Experience and research from civilian trauma centers and the military have changed this paradigm. Surgical techniques of damage control have been incorporated into clinical practice.[1] Damage control surgery is defined as abbreviated initial surgery to control life-threatening bleeding and contamination, followed by correction of physiologic abnormalities and subsequent definitive surgical management. In addition, the use of permissive hypotension until surgical control of hemorrhage has been proven to be an effective strategy in two randomized control trials.[2,3] This practice is now widely applied in many trauma systems, particularly for patients who do not have associated brain or spinal cord injuries.

The past five years have been perhaps the most practice-changing interval in the history of civilian trauma resuscitation, led in part by a number of landmark papers in the field. Previously, retrospective data supported the notion of approximating whole blood by transfusing plasma, platelets, and packed red blood cells (PRBCs). This concept, referred to as hemostatic resuscitation, gained solidifying evidence in the form of two major trials. The Prospective, Observational, Multicenter, Major Trauma Transfusion (PROMMTT) study, in which UPMC was a participating center, demonstrated that higher ratios of blood products to PRBCs (ratios approaching 1:1:1 plasma:platelets: PRBCs) reduced early mortality.[4] This concept was rigorously studied in the recently published Pragmatic Randomized Optimal Platelet and Plasma Ratios (PROPPR) trial, and although a mortality benefit was not documented in the group receiving 1:1:1, these patients achieved hemostasis faster with fewer deaths due to exsanguination.[5] These studies have solidified the practice of high-ratio blood product to red-cell transfusion.

In addition to PROMMTT and PROPPR, the CRASH-2 trial was a recent, large randomized control trial of trauma patients who were deemed to be at risk of significant bleeding. This trial demonstrated that all-cause mortality was reduced in patients who received tranexamic acid (TXA, an antifibrinolytic agent) compared with controls.[6] This resulted in a low-cost, low-risk medication becoming a part of the standard of care for many trauma centers in the resuscitation of massively bleeding patients. Finally, the recent identification that trauma patients present with a unique, endogenous coagulopathy (called the Acute Coagulopathy of Trauma, or ACT) has resulted in a focus on personalized measurement of coagulation and goal-directed resuscitation. Multiple authors have shown that viscoelastic testing, such as thromboelastography (TEG) is superior to the use of conventional coagulation testing in bleeding trauma patients. The advantage of TEG is that it is a global measurement of the entire clotting and coagulation systems, and the results are available in minutes — unlike prothrombin time, international normalize ratio (INR), and partial thromboplastin time, which can take 45 minutes or longer to acquire. TEG has been shown to be superior to INR in trauma patients[7] and is now part of the American College of Surgeons' recommendation for use by all Level 1 and Level 2 trauma centers. Furthermore, based on the CONTROL trial,[8] we no longer routinely use activated factor VIIa in bleeding trauma patients. In the non-head-injured patient, there is now little evidence to support the routine use of factor VIIa to treat or prevent coagulopathy after trauma.

At UPMC, our massive transfusion protocol addresses these issues. In addition to advocating the early surgical control of hemorrhage, minimizing infusion of crystalloids, and preventing hypothermia, we advocate starting with a 1:1:1 plasma:platelets: PRBCs transfusion ratio in trauma patients expected to require massive transfusion (defined as the requirement of 10 or more units of PRBCs in the first 24 hours after injury). However, we do not wait to reach the 10th unit of PRBC to begin infusing plasma and platelets. Instead, we employ the Assessment of Blood Consumption (ABC) score to predict the need for massive transfusion in trauma patients.[9] The massive transfusion protocol is then activated, and blood products are given in a 1:1:1 ratio if the patient meets two or more of the ABC criteria: penetrating mechanism, positive focus abdominal sonography for trauma (FAST), systolic blood pressure (SBP) ≤ 90 mm Hg, or a heart rate ≥ 120 beats per minute (bpm). Based on the data from CRASH-2, we administer TXA to all trauma patients with an SBP ≤ 90 mm Hg or heart rate ≥ 110 bpm, or both; as well as those who require at least one unit of PRBC. The dose of TXA is a 1 g bolus over 10 minutes, followed by an infusion of 1 g over eight hours. TXA administration should begin within three hours of injury. Future investigation may indicate whether TXA should be carried by EMS

crews and administered in the field or en route to a trauma center for injured patients deemed to be at risk of bleeding. At UPMC, we use TEG immediately following activation of the massive transfusion protocol to guide resuscitation, and TEG is regularly used in the operating room as an end point of hemostatic resuscitation. This provides for a highly personalized and specific resuscitation after starting with a 1:1:1 approach.

There is little question that hemostatic resuscitation has changed the way that many trauma centers practice. Ongoing research is exploring the use of blood products in the prehospital setting to initiate early and rapid correction of coagulation disturbances. In addition to providing PRBCs to patients with signs of hemorrhagic shock flown in STAT MedEvac helicopters, UPMC and the Division of Trauma and Acute Care Surgery are conducting two multicenter large randomized clinical trials to investigate the use of prehospital fresh frozen plasma (in the Prehospital Air Medical Plasma, or PAMPer, trial)[10] and TXA (in the Study of Tranexamic Acid during Air Medical Prehospital Transport, or STAAMP, trial). These interventional trials bring the blood bank to the field with the aim of intervening rapidly and studying whether early correction of coagulation disturbance provides a mortality benefit to our patients.

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