

### Inside This Edition

- 1 Catheter-Directed Thrombolysis for the Treatment of Frostbite
- 3 UPMC Hamot Trauma Team
- 4 Trauma Forensics: Saving Lives and Preserving Evidence
- 6 Trauma Care for Blunt Cerebrovascular Injuries

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## Catheter-Directed Thrombolysis for the Treatment of Frostbite

by Steven Tamesis, MD, Shantanu Warhadpande, MD, Jenny Ziembicki, MD, and Alain Corcos, MD

When temperatures plummet in the winter months, the threat of frostbite is very real. Frostbite results from exposure of tissues to the environment, causing freezing at the tissue level. The populations most at risk for the development of frostbite are those who spend a great deal of time outdoors, such as homeless people, police officers, firefighters, and recreational skiers; suffer from psychiatric conditions, neuropathy, or peripheral arterial disease; are under the influence of alcohol; or are injured, exhausted, or dehydrated.<sup>1</sup>

Tissue insult from frostbite occurs mainly due to the formation of both intracellular and extracellular ice crystals leading to direct cellular damage, as well as vasoconstriction anoxia, vascular stasis, and thrombosis.<sup>1-3</sup>

There are varying degrees of frostbite. First-degree frostbite is superficial with partial skin freezing (see Figure 1). The skin is viable, not blistered but with an erythematous and edematous appearance. There is no long-term sequela associated with first-degree frostbite. Second-degree frostbite is full thickness skin freezing (see Figure 2). There is erythema, edema, and blister formation, containing clear fluid. At this point, there may be some long-term sequela; however, the prognosis is still favorable. Third-degree frostbite is full thickness skin with subcutaneous tissue freezing (see Figure 3).

(Continued on Page 2)



Figure 1. First-degree frostbite.



Figure 2. Second-degree frostbite.



Figure 3. Third-degree frostbite.

## Catheter-Directed Thrombolysis for the Treatment of Frostbite *(Continued from Page 1)*

There is bluish-gray discoloration of the skin with violaceous/hemorrhagic blister formation, and eventual skin necrosis. Fourth-degree frostbite is full thickness skin, subcutaneous tissue, muscle, tendon, and bone freezing. Skin appears mottled, deep red, or cyanotic. This ultimately progresses to a dry, black, and mummified appearance, and eventual auto-amputation.<sup>4,7</sup>

### Current Therapy and Outcomes

Prior to the initiation of frostbite treatment, it is highly important to address the patient's hypothermia if present. Passive and active rewarming techniques should be employed as indicated. The patient's core temperature should be at or above 35 degrees centigrade before frostbite rewarming. Once hypothermia is addressed, attention should turn to treating any tissue with evidence of frostbite. The treatment of frostbite consists mainly of rewarming the affected tissue. Initial therapy consists of removing all jewelry and any wet and constricting clothing. Any affected area should be submersed in water warmed to 37 to 39 degrees centigrade for 15 to 60 minutes.

The primary endpoint of rewarming is the return of perfusion as indicated by a pliable appearance of tissue, red to purple color, and return of sensation or pain.<sup>5</sup> The affected tissue must then be allowed to air dry.<sup>6</sup> Rubbing the affected tissue before or after rewarming is not recommended as this may cause additional trauma. Once rewarming is complete, the vascular status of the affected area should be assessed. Exam findings such as dusky, blue, gray, or pallorous skin color; capillary refill greater than two seconds; and decreased blood flow on a Doppler ultrasound indicate ongoing vascular compromise.<sup>7</sup>

After rewarming is complete, local wound care should be applied. Wounds are classified by their post-thaw appearance. Frost nip and first-degree frostbite should be treated with aloe vera gel four times daily and should be left open to air. Second- to fourth-degree frostbite should be assessed for blister formation. There is considerable controversy with unroofing blisters.

Unroofing blisters is thought to remove local chemokines, which compromises local wound healing and may even extend soft tissue damage. On the other hand, unroofing blisters may allow better visualization and characterization of the wound. The current recommendation and practice at UPMC Mercy is that if blisters cause any form of functional impairment, they should be deflated using the sterile needle technique. Otherwise, blisters should be left intact. All blistered areas should be dressed with aloe vera gel and covered with a loosely fitted dry bulky dressing to allow for edema formation. Wounds should be reevaluated and redressed daily.<sup>6,7</sup>

Analgesics and anxiolytics should be administered as needed. Tetanus prophylaxis should also be given. Other important adjuncts to the treatment of frostbite are smoking cessation and withholding of any products that contain nicotine, and bedrest until resolution of edema and ambulation with special protective footwear for frostbite that involves the feet. Systemic antibiotics are reserved for those with evidence of surrounding cellulitis.<sup>6,7</sup>

### Catheter-Directed Thrombolysis for the Treatment of Frostbite

In 2017, UPMC Mercy initiated a catheter-directed thrombolysis protocol for the treatment of patients with severe frostbite (third- and fourth-degree). After appropriate thawing and rewarming, we evaluate the affected extremities for ongoing vascular compromise using a dye study called angiography, which is similar to cardiac catheterization. Indications for catheter-directed angiography are pallor or dusky skin appearance, decreased distal pulses, prolonged capillary refill, decreased Doppler signal, cool skin after rewarming, and hemorrhagic blister formation.

If any of these findings are present, the angiogram is performed urgently by our interventional radiologists. Patients with evidence of vascular compromise are then treated with regional delivery of tissue plasminogen activator (tPA), heparin, and papaverine by continuous infusion. Patients must present within 24 hours from the time of injury to be considered candidates for

intervention; they are admitted to the ICU for close hemodynamic monitoring and intra-arterial catheter care. The infusion is continued until angiographic evidence of reperfusion or for a total of 48 hours.

### Outcomes

Our initial experience with catheter-directed thrombolysis for severe frostbite has been very encouraging. A review conducted by Warhadpande et al. looked at six patients who presented with severe frostbite and were evaluated with angiography. Of these six patients, five (49 digits) were shown to have evidence of vascular compromise and were treated with catheter-directed thrombolysis. In total, 29 digits were shown to have angiographic evidence of revascularization on the first post-lytic angiogram. All of these digits were eventually salvaged. The remaining 20 digits continued to show evidence of vascular compromise on angiogram and were ultimately unsalvageable. This study suggests that patients who respond early to catheter-directed therapy can expect a high digit salvage rate.<sup>8</sup>

### Conclusion

Frostbite results from exposure of tissues to the environment, causing freezing at the tissue level. Tissue insult from frostbite occurs mainly due to the formation of both intracellular and extracellular ice crystals leading to direct cellular damage, as well as vasoconstriction anoxia, vascular stasis, and thrombosis. There are varying degrees of frostbite with first- and second-degree injuries being mild and recoverable, and third- and fourth-degree injuries being severe, often leading to tissue necrosis and amputation. The mainstay of treatment for frostbite continues to be rewarming and local wound care. For patients with severe frostbite, assessment for evidence of vascular compromise after rewarming using angiography can identify some patients who will benefit from catheter-directed thrombolysis, a new and exciting therapeutic option. Our institutional experience shows that for digits with angiographic evidence of response to catheter-directed thrombolysis on the first day after lytic therapy, the digit salvage rate is 100%.

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# Trauma Forensics: Saving Lives and Preserving Evidence

by Louis Alarcon, MD, and Jeffrey Nine, MD

Emergency medical service providers, emergency medicine physicians, and trauma surgeons often care for patients who are victims of interpersonal violence. In addition to our responsibility to treat these injured patients, we have a duty to preserve the forensic evidence. Most physicians have little or no training in the forensic aspects of trauma and may inadvertently discard or improperly handle necessary evidence. This can hamper the legal authorities in an investigation or prosecution. Clinical forensic medicine is a discipline that addresses both the legal and medical aspects of patient care. Physicians caring for patients who sustain intentional injury are responsible for documenting the injuries, as well as collecting and preserving potential evidence. Physicians may be called upon to testify in civil or criminal cases involving these patients, and appropriate documentation of the injuries, the care provided, and evidence obtained is extremely helpful in this regard.

## Protocols for Collecting and Documenting Physical Evidence

The types of physical evidence that may be encountered in the course of caring for trauma patients include clothing, bullets, shrapnel, impaled weapons, bloodstains, hairs, fibers, and fragments of other material such as metal, glass, paint, and wood. Preservation of evidence requires simple steps and some forethought. Removal of the patient's clothing in the trauma bay often requires cutting clothing off a patient. When possible, avoid cutting through defects or holes, as this area may contain gunshot residue and other important evidence necessary for the investigation. Each item of the patient's clothing and belongings should be placed into separate paper bags, labeled with patient identifiers, date, and initials of the person who collected the items, and turned over to legal authorities per hospital protocols. Plastic bags should be avoided, as these retain moisture and may cause evidence degradation from fungal or bacterial growth.

Documentation of injuries in the medical record should be clear and concise, and involves simple descriptions of the pertinent physical findings. Physicians should document only what they participated in or directly observed. While it is appropriate to

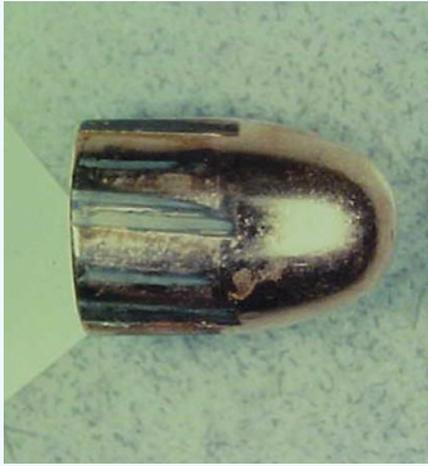
document the patient's account of the event, medical documentation should be factual; the physician should not conjecture about the intent of the injury, what occurred before the patient arrived at the emergency department, or the nature of the injury outside of his or her expertise and training. Physicians should not attempt to classify a gunshot wound as "entrance" or "exit." From a clinical perspective, whether a wound is entrance or exit is immaterial. Instead of speculating about direction of travel, they should simply document the location of the wound and its appearance. Inconsistent descriptions between the physicians (who in general are not forensic experts) and the medical examiner may hinder the legal case.

Supplementing the written description with diagrams or photographs of the injuries can be very useful. From a clinical perspective, it is important to remember that the number of gunshot wounds plus the number of bullets on radiographs should equal an even number. Otherwise, either a wound or a bullet has not been accounted for and further examination and radiographs may be indicated. Caveats are that bullets may fragment when they pass through bone or other dense material, and it is possible that retained foreign bodies seen on X-ray scans may be the result of previous injury.

Whenever possible, surgical procedures (for example, chest tube insertion) should not be done through existing wounds. Otherwise, if a procedure will alter a wound, this should be documented (see Figure 1). For example, if a laparotomy incision goes through a gunshot wound, documentation of the location and description of the wound



**Figure 1:** Close-range entrance gunshot wound with gunpowder soot and tattooing — vital gunshot information that can inadvertently be wiped off while cleaning or preparing wounds. Consider covering these types of wounds with gauze without cleaning them if possible, or photographing prior to cleaning.



**Figure 2:** Recovered bullet with rifling marks — important forensic evidence that can easily be damaged without proper surgical precautions.

before it was altered should occur. Likewise, if surgical instruments (sutures, clamps, retractors, etc.) have altered the skin wounds, this should be clearly documented in the procedure reports.

Bullets and other projectiles embedded in a patient may be important physical evidence, but should be removed if clinically indicated and accessible, not simply for forensic reasons. These objects should be removed without damaging or deforming. A gloved hand or 4"×4" gauze should be used to handle the foreign body. Metal instruments should not be used to handle bullets, as doing so may alter the rifling marks in the soft metal that can be used to identify the gun from which it was shot (see Figure 2). Each bullet should be placed in a separate specimen container, which is labeled with patient identifiers, and turned over to authorities according to hospital policy. The physician should document where each bullet was found or the site it was removed from.

Impaled knives or other foreign bodies in general should be removed in the operating room. The object may have injured major blood vessels or other organs. The embedded object may tamponade bleeding, which may become active if the object is removed. The surgeon should be prepared to manage

these injuries immediately if encountered. If possible, documenting the type of knife or object (serrated knife, butcher knife, pocket knife, rebar, arrow, etc.) can aid in later forensic examination of the wound. Impaled objects that are removed during surgery should be handled in the same manner as retrieved bullets, carefully and to avoid any extraneous damage to the weapon or object. Any weapons found in the possession of a patient or removed from a patient should be handled by security.

An important concept in the handling of potential evidence is the preservation of the chain of evidence. This means accounting for the whereabouts of the evidence at all times, until it is turned over to the legal authorities. Failure to maintain a clear chain of evidence may render it inadmissible in a court of law. Hospitals should have protocols in place for documenting and securing all such items. Any belongings, foreign bodies, or bodily fluids removed from the patient should be considered potential evidence.

## Conclusion

Health care providers involved in the care of trauma patients should have an understanding of clinical forensic medicine. Hospital and emergency departments should have protocols in place to manage potential forensic evidence. In addition to our responsibility to save lives, we also have a responsibility to collect and preserve forensic evidence.

## Additional Reading

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# Trauma Care for Blunt Cerebrovascular Injuries

by Shelley Reynolds-Hill, MD, and Lindsey Roach, DO

Defined as any traumatic injury to the carotid or vertebral arteries as a result of non-penetrating trauma,<sup>1</sup> blunt cerebrovascular injuries (BCVIs) carry true risks for neurologic morbidity and mortality. Once thought to be rare injuries occurring in approximately 0.1% of all trauma patients, the incidence is now known to be anywhere from 1.0-2.7%, thanks to increased awareness and the development of screening and treatment protocols.<sup>2-4</sup> Despite this increase in awareness and the development of practice management guidelines for screening and treatment from both the Eastern Association for the Surgery of Trauma (EAST) and the Western Trauma Association (WTA), there is some controversy in the trauma literature regarding which patients to screen and how best to treat them.

## Screening for Blunt Cerebrovascular Injuries

The incidence of cerebrovascular injuries has been reported in 15-25% of penetrating neck injuries and up to 2.7% of blunt head and neck trauma injuries.<sup>5</sup> It is important to recognize these injuries, as failure to identify and treat BCVIs in asymptomatic patients results in an increased risk of a neurologic ischemic event. The risk of developing a significant neurologic deficit in a previously asymptomatic patient with an untreated BCVI is thought to be highest in the first 10 to 72 hours after injury, so timely evaluation and management is essential.<sup>5</sup> Stroke rates of up to 15% for vertebral injuries and 30-40% for carotid injuries have been reported.<sup>1</sup> Stroke resulting from BCVI carries a significant morbidity and mortality risk, 58% and 33%, respectively.<sup>3</sup> If the injury is diagnosed after symptoms appear, neurologic morbidity increases to 80% and mortality to 40%.<sup>6</sup> Early screening for these injuries and treating appropriate patients can significantly reduce the risk of stroke.

While digital subtraction angiography (DSA), which provides an image of blood vessels in the brain, was the gold standard for detection of BCVI, there is concern regarding its availability and invasiveness. Because of this, screening protocols have been developed replacing DSA with computed tomography angiography (CTA). There was initially concern due to a high rate of false negative tests in CTA studies, but more recent studies have shown that there seems to be a higher rate of false positive

tests, reported as up to 45-47% in one series.<sup>1</sup> As CT technology has improved, so has the sensitivity of CTA for BCVI. Injury detection rates are improved with the use of scanners that capture 64 or more slices per rotation, as well as when the test is read by an experienced neuroradiologist. The major benefits of CTA include wider availability, speed, decreased invasiveness, and ability to be read remotely by an offsite neuroradiologist. There are several acknowledged risks of DSA including, but not limited to, complications related to catheter insertion (incidence of 1-2%), contrast reactions including kidney injury and anaphylaxis (1-2%), or cerebrovascular accident (CVA) resulting from thromboemboli from the procedure itself.<sup>2</sup>

## BCVI Screening Protocols

Despite the high morbidity and mortality, choosing which patients to screen remains somewhat controversial. According to the EAST practice management guideline, there is no Level 1 evidence to support specific risk factors that should result in screening. In general, risk of BCVI increases with trauma mechanisms associated with hyperextension, exaggerated rotation, or hyperflexion of the cervical spine as well as direct blows to the neck.<sup>6</sup>

When a screening protocol is put into practice, the detection of these injuries increases 10-fold.<sup>6</sup> The 2016 updated Denver Health Medical Center BCVI screening guideline<sup>4</sup> recommends screening asymptomatic patients using the criteria shown in Table 1. CTA is the preferred screening modality.

## Treatment of BCVI

Treatment of BCVI depends upon the grade of the injury. Injuries are graded on a scale of I to V according to the Biffi criteria, ranging from mild intimal injuries or irregularities to vessel transection, with risk of stroke increasing with increasing severity of injury.<sup>2</sup> Grade I injuries include mild intimal injuries or irregularities; grade II injuries occur when dissection with raised intimal flap/or intramural hematoma result in >25% luminal narrowing or intraluminal thrombosis. Grade III injuries include pseudoaneurysms; grade IV, vessel occlusion or thrombosis; and grade V, vessel transection.<sup>2</sup> Grade I-II injuries can be treated with anticoagulation or antiplatelet therapy alone and may heal spontaneously, while grade III and IV injuries sometimes require endovascular or surgical treatment. Grade V injuries always require intervention if not immediately lethal. WTA recommends full anticoagulation for grades I-IV for the first seven to 10 days after detection if able to be followed by repeat CTA. Heparin is preferred in the acute setting due to easy reversibility for patients at high risk for bleeding. Grade I and II injuries may heal within that timeframe and anticoagulation may be able to be discontinued.

If the injury is stable, treatment is antiplatelet therapy for three months, followed by a surveillance CTA. If the injury progresses to >75% luminal narrowing or a pseudoaneurysm remains, endovascular therapy should be considered at that time. The

WTA suggests that all grade II or above extracranial and accessible injuries should be considered for surgery at the initial detection,<sup>6</sup> but in practice, low-grade injuries are generally managed with anticoagulation alone while grade III and IV injuries are more likely to be treated with endovascular stenting in conjunction with antithrombotics. It is notable that several of these patients have concomitant injuries, which preclude full anticoagulation, but the risk of cerebral ischemia drops from 21% to 0.53% in patients who are able to be anticoagulated after detection.<sup>2</sup>

### Conclusion

In general, undetected cerebrovascular injuries carry a substantial risk of morbidity and mortality from neurologic ischemic events, and implementation of a protocol to identify high-risk patients prior to development of symptoms may significantly reduce this risk. While DSA remains the gold standard for definitive diagnosis of BCVI, 64-slice or greater CTA is the screening modality of choice, and most injuries can be managed based on the results of CTA alone. DSA remains useful in equivocal cases or when endovascular intervention is required.

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**Table 1: Updated Denver BCVI Screening Guideline (2016).<sup>4</sup>**

<b>Signs/Symptoms of BCVI</b>	<ul style="list-style-type: none"> <li>• Potential arterial hemorrhage from neck/nose/mouth</li> <li>• Cervical bruit in patient &lt;50 years old</li> <li>• Expanding cervical hematoma</li> <li>• Focal neurologic defect: transient ischemic attack (TIA), hemiparesis, vertebrobasilar symptoms, Horner's syndrome</li> <li>• Neurologic deficit inconsistent with head CT</li> <li>• Stroke on CT or MRI</li> </ul>
<b>Risk Factors for BCVI</b>	<ul style="list-style-type: none"> <li>• High-energy transfer mechanism</li> <li>• Displaced mid-face fracture (LeFort II or III)</li> <li>• Mandible fracture</li> <li>• Complex skull fracture/basilar skull fracture/occipital condyle fracture</li> <li>• Severe traumatic brain injury (TBI) with GCS &lt;6</li> <li>• Cervical spine fracture, subluxation or ligamentous injury at any level</li> <li>• Near hanging with anoxic brain injury</li> <li>• Clothesline-type injury or seat belt abrasion with significant swelling, pain, or altered mental status</li> <li>• TBI with thoracic injuries</li> <li>• Scalp degloving</li> <li>• Thoracic vascular injuries</li> <li>• Blunt cardiac rupture</li> <li>• Upper rib fractures</li> </ul>

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