Blunt Cerebrovascular Injuries: Etiology, Classification, Screening, and Management

by Ramesh Grandhi, MD, David O. Okonkwo, MD, PhD, and Brian T. Jankowitz, MD

Blunt cerebrovascular injury (BCVI) is defined by the presence of damage to the carotid or vertebral arteries as a result of non-penetrating trauma. With an incidence of 1 percent among patients with non-penetrating trauma, the resulting neurologic morbidity may be as high as 80 percent with a mortality of nearly 40 percent in patients who develop symptoms of a stroke.1 Importantly, the vast majority of patients who experience BCVI are asymptomatic at presentation. Studies have estimated that neurological sequelae most commonly occur between 10 and 72 hours after injury.2, 3, 4, 5 In order to minimize the risk of this potentially devastating outcome, expeditious screening and diagnosis of BCVI is paramount during this clinically silent period, followed by appropriate management involving a multidisciplinary team including trauma surgeons, neurosurgeons, vascular surgeons, and neurointerventional specialists.

Etiology and Classification of BCVI
As previously mentioned, BCVI involves damage to the cervical carotid or vertebral arteries and typically occurs secondary to stretch injury from extreme hyperextension/rotation, direct vascular injury, intraoral trauma, or direct laceration of the involved artery from bony fragments.6 Motor vehicle collisions, falls, assaults, hangings, and sporting injuries are the most common causes of BCVI in adults.7 Pediatric patients are less likely to experience BCVI.8 Classification of BCVI is based on injury morphology and is subdivided into five grades, ranging from Grade I injuries, in which an intimal irregularity is present with minimal perturbation of arterial blood flow, to Grade V injuries, in which the artery is transected and active extravasation of blood occurs (Table 1). Among patients with carotid injuries, worsening BCVI grade portends a worse prognosis.5, 9

Screening for BCVI
Although BCVI was first described in the literature nearly 40 years ago, centers did not routinely screen adult trauma patients until the late 1990s. Over the past decade, there has been significant debate over which individuals should undergo a screening study, especially with the widespread availability of non-invasive imaging modalities10 such as duplex sonography, magnetic resonance angiography (MRA), and computer tomographic angiography (CTA). Studies have demonstrated a low sensitivity of duplex sonography and MRA for diagnosing BCVI11; thus, these two radiologic studies are currently not

(Continued on Page 2)
Blunt Cerebrovascular Injuries (Continued from Page 1)

Table 1: Classification of Blunt Cerebrovascular Injury (Adapted from Berne et al. and Cothren et al.)

<table>
<thead>
<tr>
<th>Injury Grade</th>
<th>Description of Injury</th>
<th>Proportion of All Blunt Trauma-Related Carotid Artery Injuries/Associated Mortality</th>
<th>Proportion of All Blunt Trauma-Related Vertebral Artery Injuries/Associated Mortality</th>
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<tbody>
<tr>
<td>I</td>
<td>Luminal irregularity with &lt;25% luminal narrowing</td>
<td>61%/11%</td>
<td>67%/31%</td>
</tr>
<tr>
<td>II</td>
<td>Vessel injury with ≥25% luminal narrowing, intraluminal thrombus, or raised intimal flap</td>
<td>17%/11%</td>
<td>24%/0%</td>
</tr>
<tr>
<td>III</td>
<td>Vessel injury with presence of traumatic pseudoaneurysm</td>
<td>15%/11%</td>
<td>8%/13%</td>
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<tr>
<td>IV</td>
<td>Occlusion of vessel</td>
<td>5%/22%</td>
<td>26%/11%</td>
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<tr>
<td>V</td>
<td>Transection of vessel with extravasation</td>
<td>4%/100%</td>
<td>Not available</td>
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recommended for screening patients. While a catheter-based four-vessel cerebral angiogram remains the gold standard test, use of multi-slice, multi-detector CTA has shown to be cost-effective and reliable for screening for clinically significant BCVI.

One widely used protocol published by a group of trauma physicians from the Denver Health Medical Center, called the Denver Screening Criteria, has been prospectively studied and validated to capture 80 percent of patients with BCVI. However, given that upwards of 20 percent of patients with BCVI do not meet standard screening criteria, earlier this year, the Denver group published a more expansive set of screening guidelines (Table 2). Thus, at UPMC, based on the updated Denver Screening Criteria for BCVI, our protocol is to perform a CTA of the head and neck in trauma patients who present with signs or symptoms that can potentially be attributed to BCVI or in those who have specific risk factors that would place them at an increased likelihood of having sustained BCVI.

Management of BCVI

To date, there have been no prospective, randomized trials involving the management of patients with BCVI, which may consist of medical therapy, surgical intervention, or both. Regardless of the specific modality employed, the fundamental concept is that early detection and management of BCVI during the latent window — before patients experience a neurologic deficit — is paramount. Multiple retrospective studies have shown a significant reduction in the rate of stroke in patients who undergo treatment versus those who do not. Treatment may involve intravenous heparin as a bridge to warfarin or antiplatelets such as aspirin or clopidogrel. No study has shown the superiority of one over the other. As such, heparin is usually favored in the short term due to its reversibility, while aspirin is favored over the long term due to its ease of use.

The treatment of BCVI via traditional open surgical options includes vessel ligation, thrombectomy, direct suturing of intimal injury, replacement of injured vessels with interposition grafts, and bypass grafting. Although potentially warranted in certain situations, open surgery has been replaced by endovascular therapy as the interventional treatment modality of choice at most institutions, owing to its overall efficacy and putatively better safety profile. Dependent on the patient’s presentation and specific pathology, endovascular options include stenting, embolization of traumatic aneurysms with coils or liquid embolic agents, intra-arterial thrombolysis, and endovascular occlusion for vessel sacrifice (Figure 1). In general, endovascular management of patients is reserved for those with Grade II lesions with symptomatic, flow-limiting stenosis or extensive thrombus; large or growing pseudoaneurysms (Grade III injuries); traumatic occlusions (Grade IV injuries) causing symptomatolgy from cerebral hypoperfusion or distal emboli; or Grade V injuries. Patients who fail medical management comprise another subgroup that warrants endovascular therapy.

Conclusion

BCVI is commonly seen after trauma and carries with it significant morbidity and mortality if left undiagnosed or untreated. Based on existing guidelines, we agree with selectively screening patients based on type of injury with a CTA of the head and neck. Diagnosis should prompt immediate treatment with either intravenous heparin.
Table 2: Updated Denver Health Medical Center Blunt Cerebrovascular Injury Screening Guidelines
(Adapted from Burlew et al.10)

<table>
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<tr>
<th>Signs and Symptoms of BCVI</th>
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<tr>
<td>Arterial hemorrhage from neck/nose/mouth</td>
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<tr>
<td>Cervical bruise in patient under 50 years of age</td>
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<tr>
<td>Expanding cervical hematoma</td>
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<tr>
<td>Focal neurologic deficit</td>
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<tr>
<td>Neurologic exam incongruous with head CT scan findings</td>
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<td>Stroke on CT scan</td>
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<th>Risk Factors for BCVI</th>
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<tr>
<td>High-energy transfer mechanism with:</td>
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<tr>
<td>• LeFort II or III fracture</td>
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<tr>
<td>• Mandible fracture</td>
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<tr>
<td>• Complex skull fracture, basilar skull fracture, petrous bone fracture, or occipital condyle fracture</td>
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<tr>
<td>• Traumatic brain injury consistent with diffuse axonal injury and GCS score of less than 6</td>
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<tr>
<td>• Cervical subluxation or ligamentous injury</td>
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<tr>
<td>• Cervical vertebral body fractures, fractures extending into transverse foramina, or fracture involving C1–C3</td>
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<tr>
<td>• Near hanging with anoxic brain injury</td>
</tr>
<tr>
<td>• Clothesline-type injury or seatbelt abrasion with significant swelling, pain, or altered mental status</td>
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<tr>
<td>• Traumatic brain injury with thoracic injuries</td>
</tr>
<tr>
<td>• Scalp degloving</td>
</tr>
<tr>
<td>• Thoracic vascular injuries</td>
</tr>
<tr>
<td>• Blunt cardiac rupture</td>
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or aspirin. Patients with BCVI constitute an especially acute segment of the trauma population and should be managed by a multidisciplinary team including trauma surgeons, neurosurgeons, vascular surgeons, and neurointerventional specialists.

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References
Thoracic Trauma: Hemothorax/Pneumothorax

by Gregory Beard, DO

Blunt and penetrating trauma to the chest is a major source of morbidity and mortality, and it is seen with remarkable frequency in both major trauma centers and community hospitals. The prompt recognition and treatment of significant chest trauma is the prime determinant in averting significant morbidity and mortality.

Chest injuries occur in 60 percent of multiply-traumatized patients, most frequently being associated with high-speed blunt and penetrating mechanisms. The injuries are frequently severe, with 25 percent of all traumatic deaths being directly related to injuries sustained within the chest cavity. While much of this mortality is immediate and unavoidable, there exists opportunity for improvement within even the most sophisticated systems, and early, aggressive treatment of these injuries is critical.

Approximately 300,000 cases of traumatic hemothorax are identified yearly in the United States. Early diagnosis and management are crucial in avoiding morbidity, lessening length of hospital stay, and diminishing the need for subsequent painful and disfiguring operations.

The initial diagnostic study of choice for identifying hemothorax and pneumothorax is the upright chest x-ray. This can identify hemothorax when fluid volumes in the chest are greater than 500cc. Unfortunately, the nature of trauma resuscitation necessitates that most initial chest x-rays be performed supine. A supine chest x-ray typically cannot detect hemothorax or pneumothorax unless at least 1000cc of fluid is present, thereby making this study less sensitive and specific than upright films for identification of these conditions.

Chest CT, on the other hand, is extremely sensitive for both hemothorax and pneumothorax. While typically quickly and easily accomplished by anyone with a modicum of training, specific circumstances require a more thoughtful and involved approach to subsequent treatment. Massive hemothorax is one of these circumstances and is defined by the following criteria:

1. More than 1500cc of blood evacuated immediately after insertion of chest tube.
2. Persistent bleeding exceeding 150-200cc for two to four hours after chest tube placement.
3. Persistent need for blood transfusion to maintain hemodynamic stability in the absence of other sources of bleeding.
4. Chest tube output exceeding 1500cc in 24 hours.

Surgical open thoracotomy remains the procedure of choice for instances of massive hemothorax. Video-Assisted Thoracoscopic Surgery (VATS) is not indicated and is rarely successful under these circumstances.
Retained or persistent hemothorax is a frequent occurrence despite early performance of closed tube thoracostomy. Upright chest x-ray is the diagnostic study of choice for the reevaluation of hemothorax initially treated with chest tube drainage, and it should be performed immediately or as soon as is practical after completion of the procedure. While CT is more sensitive for the presence of retained fluid, most outcome studies on the management of retained hemothorax define clinically significant retained fluid as greater than 500cc (as would be identified on upright chest x-ray). No controlled study data yet exist to determine the effect of a more aggressive diagnostic approach, such as CT or US, on outcomes of treatment for retained hemothorax.

For retained hemothorax after incomplete evacuation with tube thoracostomy, surgical intervention remains the mainstay of treatment. While the timing of surgical intervention is somewhat controversial, and while VATS is not recommended for initial treatment of massive hemothorax, outcomes data trend toward improvement with early rather than late intervention for retained or persistent hemothorax. Early VATS (defined as less than three days from presentation) tends to reduce the operative difficulty and time, the risk of contamination of the clot and infection, and hospital length of stay. While later VATS (three to 14 days after tube thoracostomy) is not a contraindication to operative management, conversion to open thoracotomy is much more likely after five days.

Another technique often incorrectly applied to management of retained hemothorax is the use of a second or multiple chest tubes in an attempt to effect more complete drainage in the face of retained fluid. This is strongly discouraged, as it has actually been shown to lead to longer duration of drainage, longer hospital length of stay, and greater costs than early surgical management, and it ultimately portends a higher rate for subsequent open surgical intervention. These realities negate the benefits of attempted conservative management with additional tubes.

Benefits of VATS over open thoracotomy for retained hemothorax include decreases in postoperative pulmonary complications, recovery time, long-term disability, and postoperative infectious complications. As a result, vigilance in the early identification and aggressive management of hemothorax and retained hemothorax are encouraged.

Chemical fibrinolysis is another potential treatment option for retained hemothorax. However, one must be mindful that its use should be reserved for those patients unable to tolerate an operative procedure as it generally leads to a much greater length of stay, greater cost, and a much higher rate of future need for thoracotomy than early primary VATS.

Occult pneumothorax is being identified with increasing frequency in the era of routine whole-body CT scans for trauma, or “pan-scans.” It is defined as pneumothorax identified on CT but not present on plain film chest x-ray. While management of most patients with traumatic pneumothorax involves chest tube placement, data suggest its use in occult pneumothorax is associated with increased hospital costs and length of stay. In particular, conservative observational management has the highest degree of success with occult anterior pneumothorax identified on CT. Additionally, positive pressure ventilation is not a contraindication to noninvasive management of occult pneumothorax, as most studies have trended toward noninferiority in their outcomes. Therefore, the decision to treat occult pneumothorax without thoracostomy tube placement will be physician-dependent and made clinically on a case-by-case basis.

Finally, 3 percent of patients who sustain chest trauma will ultimately develop empyema, which are abscesses or infections of the chest cavity. Risk factors for empyema include penetrating trauma, persistent hemothorax after thoracostomy, duration of chest tube drainage, and presence of multiple chest tubes. Empyema is a serious complication of chest trauma and is independently associated with morbidity, mortality, and long-term disability.

Early, aggressive, and thoughtful management of chest trauma as outlined in this review will markedly diminish rates of empyema, diminish long-term morbidity and mortality, and improve outcomes for the many victims of this frequently occurring problem.

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All-Terrain Vehicles and Pediatric Trauma

by Christine Vitale, RN, MSN

All-terrain vehicles (ATVs) are four-wheeled vehicles with motorcycle-style handlebars, a high center of gravity, and large, low-pressure tires designed for off-road use. They can weigh as much as 800 pounds, and most are designed for one driver and no passengers. Driving ATVs has grown from occupational use and a necessary tool in rural life to more of a pastime. Over the past decade, as recreational use has increased, so have the numbers of injuries and deaths, especially for children and teenagers.

From 1982 to 2011, the Consumer Product Safety Commission (CPSC) received reports of 2,865 ATV-related fatalities in the U.S. of children under age 16 — 25 percent of all ATV fatalities. Of those deaths, 1,226 (43 percent) were of children under age 12. In addition to fatalities, in 2011 an estimated 29,000 emergency department-treated ATV injuries (27 percent) were to children under age 16. Pennsylvania ranks third in the country for ATV-related deaths, behind California and Texas. At Children’s Hospital of Pittsburgh of UPMC, from 2001 to 2010, 7 percent (11) of the trauma-related deaths were due to ATV crashes. In 2012, 8 percent (137) of Children’s trauma admissions were due to ATV crashes. In addition, the severity of ATV injuries has remained above average compared to other trauma patients at Children’s for the past seven years (Figure 1).

Because of the way ATVs are designed, ATV crashes often result in rollover. The types of injuries most often seen are head and extremity injuries, including concussion, fractures, dislocations, lacerations, and contusions. Death from an ATV crash is most often related to traumatic brain injury. Children under age 16 are at higher risk for injury due to their smaller size, weight, and ability to handle the vehicle in a high-risk situation such as loss of control on unstable terrain. In addition, children do not have the judgment and decision-making capability to recognize and quickly adapt to dangerous situations. In Pennsylvania, teenagers cannot learn to drive before age 16, but they routinely operate ATVs — vehicles that can move as fast as a car but that have none of a car’s safety features.

Injury Prevention

Legislation has been somewhat effective in reducing ATV-related injuries and deaths. The 44 states that have some type of ATV law have significantly lowered ATV-related deaths as compared to states without ATV laws. Pennsylvania’s ATV law includes:

- No ATV shall be operated without a lighted headlight and taillight from 30 minutes after sunset to 30 minutes before sunrise.
- All ATVs must be titled and registered, with the owner receiving one numbered plate.
- Registration is to be renewed once every two years.
- No one under the age of 8 shall operate an ATV on state-owned land.
- No one between the ages of 8 and 15 may operate an ATV unless on a parent’s land or in possession of a safety training certificate.
- No one under the age of 16 may cross a highway or operate an ATV on designated roads unless in possession of a safety certificate and with an adult 18 or older.
- ATV use on any street or highway is prohibited, except to cross and except for roads designated as ATV roads.

Figure 1: Injury Severity Scores (ISS) at Children’s Hospital of Pittsburgh of UPMC

![Graph showing injury severity scores](image)

ATV GEAR

- Approved ATV helmet
- Boots
- Gloves
- Goggles
- Riding jacket, long-sleeved riding shirt, full-length riding pants
- Protective gear: elbow guards, neck guards, chest guards, kidney belts, shin guards, knee protectors
The American Academy of Pediatrics recommends that no one under the age of 16 drive or ride an ATV.

Safety training is an effective way to decrease ATV-related deaths and injuries. With the purchase of a new ATV, riders can receive free safety training classes through the ATV Safety Institute. For a small fee, the safety course is also available to anyone interested who has not made a new purchase.

Legislation and safety training are important, but the most significant factor in reducing ATV injuries and deaths among young people is parental involvement. Parents continue to be the biggest influence in their children’s lives and are able to ensure their safety by asking questions about ATV use. For example: Based on size, age, and judgment, should my child ride an ATV? Has my child attended an appropriate safety course and will they follow the rules they have learned? Is the ATV the appropriate size for my child? Do they have the appropriate gear?

There are many factors to consider before purchasing an ATV and unfortunately, some aspects are missed because many ATVs are bought online or through a private seller. If the decision to allow a child to ride an ATV is made, safety gear will add some protection.

Recreational ATV riding is a serious endeavor because the consequences of an ATV crash often are life-altering and can be life-ending. When considering recreational ATV riding, this question should be asked: would I give this person the keys to a car?

Christine Vitale, RN, MSN, is the injury prevention manager for Children's Hospital of Pittsburgh of UPMC and can be contacted at Christine.Vitale@chp.edu.

References
1. www.atvsafety.gov
2. www.injuryfree.org
3. www.aap.org
4. www.cpsc.gov

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UPMC Prehospital Care also hosts numerous continuing education classes in western Pennsylvania. For a full, up-to-date calendar and online registration, visit UPMC.com/PrehospitalClasses.

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<td>Diana Luketic <a href="mailto:lukedl@upmc.edu">lukedl@upmc.edu</a> 412-232-7786</td>
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<td>Noel Faust <a href="mailto:faustn@upmc.edu">faustn@upmc.edu</a> 412-232-7114</td>
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2. Based on TRISS methodology to calculate z scores and w values to compare actual with predicted mortality rates.