Blunt Cerebrovascular Injuries

Deb Stein, MD and Alexander Eastman, MD

Editorial Review: Clay Cothren Burlew, MD
Marc deMoya, MD
Therese Duane, MD
Eric Toschlog, MD
Kimberly A. Davis, MD
Grace S. Rozycki, MD

Objectives: At the completion of this module, fellows will be able to:

1) **Identify the screening indications for patients with potential blunt cerebrovascular injuries (BCVI).**
2) **Discuss the management options for patients diagnosed with BCVI.**
3) **Understand the outcomes for patients by treatment modality.**

Background

- Frequency of injury
  - BCVI is thought to occur in approximately 0.1% of all trauma admissions.
  - This number rises to nearly 2% when liberal screening is applied to patients with blunt trauma.
- Acuity of injury - ie associated rates of morbidity and mortality
  - The main morbidity and subsequent mortality from BCVI are due to the development of cerebral ischemia from thrombosis at the site of injury or embolization.
  - Overall stroke rates are reported to be between 4-20% and are related to the grade of injury.
- Antithrombotic treatment can mitigate the stroke risk with significant success, however some patients have a contraindication to treatment due to concomitant injuries.
- These patients are multiply injured; overall mortality in patients with BCVI is 15-40% in most series.
- When stroke occurs, it is a highly lethal event with stroke-related mortality approaching 25-50% and a morbidity rate for moderate to severe permanent neurologic deficit approximating 25% to 40% in survivors.

Stroke Rate by Grade of Injury		
Grade of Injury	Carotid Injury	Vertebral Injury
I	3-8%	6%
II	9-14%	14-38%
III	9-26%	27%
IV	50-58%	28%
V	100%	N/A

Evaluation/Diagnostics

- All patients with high energy mechanism of blunt injury are at risk for BCVI.
- There are identified risk factors and signs and symptoms that are associated with BCVI.
- Up to 20% of patients with BCVI may have no identifiable risk factor so a high index of suspicion is needed.

Signs/Symptoms/Risk Factors
Mechanism
Hanging or near-hanging
Choking
Direct blow to neck
Cervical hyperextension or hyperflexion injury
Cervical distraction injury
Exam Findings/Signs
Arterial hemorrhage or expanding neck hematoma
Cervical bruit
Neurologic exam inconsistent with brain CT findings
Seat belt sign with associated pain, swelling, hematoma or altered mental status
Horner's syndrome
Severe epistaxis
Acute stroke on CT scan
Associated injuries
Severe TBI (GCS<9) or DAI
Cervical spine fractures (isolated spinous process may not require imaging)
Cervical spine subluxation or ligamentous injury
Cervical spinal cord injury (SCI)
Basilar skull fracture or occipital condyle fracture
Midface fractures (LeForte II or III, facial smash, naso-ethmoidal complex)
Mandible fractures
Severe thoracic trauma (AIS>3)
Upper rib fractures (1-3)
Scalp degloving injury
TBI with thoracic injuries

- Digital subtraction angiography (DSA) is considered the gold standard for diagnosis and historically this was the only reliable diagnostic test for these injuries.
- Multislice CT-angiography (CTA) has largely replaced DSA and is now the most commonly used diagnostic imaging with reported sensitivities of up to 97% and a specificity of 100%.
- Despite early enthusiasm for the use of duplex ultrasonography as a diagnostic study, the majority of injuries are obscured by adjacent bony structures (skull base for carotid artery injuries and transverse foramen for vertebral artery injuries). The presence of a cervical collar and the need for spinal precautions often precludes adequate visualization. Therefore, duplex ultrasonography has a limited sensitivity and specificity for BCVI. There may be a role for duplex in serial follow up of lesions.
- While MRI is very useful for the evaluation of cerebral or cerebellar ischemia, the sensitivity and specificity of MRA for BCVI is poor.
- BCVIs are graded according to the Denver grading scale which is incorporated into the AAST Organ Injury Scale (OIS) for cervical vascular injury.

Grade of BCVI	
Grade of Injury	Description
I	Irregularity of vessel wall or dissection/intramural hematoma with <25% luminal stenosis
II	Intraluminal thrombus or raised intimal flap visualized, or dissection/intramural hematoma with ≥25% luminal stenosis
III	Pseudoaneurysm
IV	Vessel occlusion
V	Vessel transection

- Repeat imaging with CTA is typically performed at postinjury day 7-10 and 3-6 months following injury to evaluate for progression or improvement in injury which may alter duration and type of therapy.
- Repeat imaging for high-grade injuries (grade III and IV) may be individualized based upon documented low healing rates and/or a patient's need for antithrombotic treatment for comorbid conditions (coronary artery disease, atrial fibrillation, deep venous thrombosis, etc).

Management

- Medical Management:
  - The management of BCVI is focused on stroke prevention.
  - Strokes can be embolic or thrombotic in nature.
  - Heparin has largely been considered the treatment of choice, but antiplatelet agents appear to be an acceptable alternative. Treatment with anticoagulation or antiplatelet agents is associated with markedly lower stroke rates than patients who are not treated.
  - In patients with symptomatic BCVI, anticoagulation with heparin was originally utilized based upon early publications (1980s and 1990s) demonstrating improved outcomes with this treatment modality. Subsequent studies in the BCVI population have not evaluated treatment modalities or impact on outcome for BCVI-related stroke. Based upon the 2013 American Heart Association/ASA Guidelines for the Early Management of Patients with Acute Ischemic Stroke, early (within 24-48 hours) administration of aspirin is recommended for the treatment of most patients. Systemic heparinization may risk hemorrhagic conversion of the stroke, and should be individualized. Delayed institution of anticoagulation may have a role in the management of BCVI.
  - Patients may have initial contraindications to antithrombotic therapy (TBI, solid organ injury, unstable pelvic fracture); early evaluation of the risks and benefits to

starting antithrombotic treatment for BCVI must weigh the risk of bleeding versus the risk of stroke.

- Endovascular therapy:
  - Despite early enthusiasm for endovascular stenting of BCVI, it may be associated with a higher stroke and complication rate if used early after injury or if dual antiplatelet agents are not instituted promptly after stenting and then continued.
  - Stenting is usually reserved for patients with significant progression of lesions on follow up imaging despite adequate medical therapy, and for those with TIA symptoms.
  - Endovascular embolization of pseudoaneurysms that are anatomically amenable is sometimes employed.
  - Endovascular embolization of the entire vessel may be considered in patients with significant stenosis or occlusion (grades II-IV) as a method to prevent embolic stroke if medical therapy is contraindicated; adequate collateral flow through the Circle of Willis must be demonstrated.
  - Endovascular therapy is the preferred approach for grade V injuries.

Operative Techniques

- There is little role for operative intervention for BCVI as lesions tend to be surgically inaccessible:
  - Carotid artery injuries typically occur high in the internal carotid, near the base of the skull.
  - Vertebral artery injuries are located within the transverse process of the cervical vertebrae.
- Rarely, a common carotid injury is encountered that may be amenable to open operative intervention.

Complications

- The major complication of BCVI is the development of stroke.
- Anticoagulation/antiplatelet therapy results in a marked reduction in strokes.
- Strokes tend to occur:
  - in patients with a contraindication to antithrombotic therapy.
  - within 1-2 hours of injury, prior to imaging.
  - in patients with no injuries to the head, neck or torso (less than 1% of patients) and hence have no clear screening criteria at admission.

Special Populations

1. Pediatric
   - There is a relative paucity of data on BCVI.
   - There may be a reluctance to perform CTA in young patients.
   - In addition to described adult screening criteria, prior studies indicate nonbasilar skull fractures, chest trauma (including isolated clavicle fractures), and TBI to have an association with BCVI in this patient population.

- To date, many pediatric patients less than 12 years old with BCVI manifest stroke as the presenting symptomatology.

Pearls from the Experts: Drs. Timothy C. Fabian and Walter L. Biffl

- It has been difficult to establish uniform screening criteria for BCVI, as most reports are based on institution-specific criteria and there is inherent bias in which patients were selected for diagnostic imaging. Consequently, there has not been a study in which 100% of patients were studied. In order to identify every patient with BCVI, a study from the NTDB determined that 96% of patients would need to undergo diagnostic evaluation. It is recommended that institution-specific criteria be established based on patient population and resource availability, in order to minimize variation in practice and delayed diagnosis of BCVI.
- The accuracy of CTA has been questioned, and arteriography remains the "gold standard." However, for the purpose of screening asymptomatic individuals, most individuals and centers have determined that invasive cervical arteriography, given its cost, resource utilization, complication risk (1% stroke or major vascular injury requiring intervention), is unacceptable as a primary screening modality. It should be reserved for clarification of equivocal noninvasive studies, or if intervention is to be performed.
- Utilizing current technology, 64 channel CTA for BCVI diagnosis, the Memphis group has found a high false positive rate (45%). Total reliance on CTA would result in a high number of patients treated unnecessarily. Therefore, they continue to use DSA for patients with positive CTA examinations. The same study found a 68% sensitivity of 64 channel CTA; missed injuries are low grade and do not result in stroke when untreated. Therefore, they do no further investigations in patients with negative CTA examinations.
- Advancing imaging technology will likely improve diagnostic accuracy, and lead to modified screening and treatment algorithms.
- Normal Circle of Willis (CoW) anatomy is present in only 20% of patients. A preliminary study evaluating the CoW in patients with BCVI indicated that normal anatomy is not protective of stroke, but that persistent fetal circulation (enlarged posterior communicating artery) is likely protective. Further studies should provide better direction for therapy.
- Delaying initiation of therapy (heparin or anti-platelet) for BCVI increases the risk of stroke.
- Nearly all patients with BCVI should have heparin initiated at the time of diagnosis with a goal PTT of 40-50 seconds and close monitoring. A recent evaluation by the Memphis group of 119 patients with BCVI and associated injuries (74 TBI, 26 solid organ, and 19 with both) were matched with a cohort of similarly injured patients without BCVI. No evidence of worsening of TBI or solid organ injury (no increased bleeding) was found with immediate initiation of anticoagulation.
- Bare metal stents should generally be used for treatment of ICA injuries with $\geq$ 70% stenosis, or pseudoaneurysms that are large (i.e. equal to or greater than the size of the native ICA) or have been found to significantly increase in size (i.e. doubling) at the time of follow-up examination.

- When a stent has been utilized in treatment of BCVI, dual anti-platelet therapy must be continued without interruption for a minimum of 3 months. Interruption results in a high rate of stent thrombosis and stroke.
- Patients with BCVI who require secondary surgical procedures (orthopedic, neurosurgical, etc.) should not have a stent placed until all secondary procedures have been performed due to the risk of stroke associated with interruption of antiplatelet medications.
- Every "contraindication" to antithrombotic therapy is relative. An assessment of risk and consequences of stroke versus risk and consequences of bleeding complications. A high-grade injury presents much greater threat to the well-being of the patient than bleeding from a grade III splenic injury. Laparotomy and splenectomy are not on the same level of life-changing experiences as a stroke.
- Heparin may be marginally more effective in stroke prevention and is reversible; thus, it may be considered a more appropriate "first-line" therapy in the acute phase. On the other hand, there is no evidence that warfarin is more beneficial in long-term stroke prevention, and so aspirin is an appropriate long-term prophylactic medication. In patients in whom delayed imaging shows a persistent injury, or who fail to follow up, daily aspirin therapy can be considered safe and effective.

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