Screening for blunt cerebrovascular injury: selection criteria for use of angiography

Clinical article

ANDREW J. RINGER, M.D.,¹,² ELIZABETH MATERN, R.N.,³ SAMIR PARikh, M.D.,¹ AND NICHOLAS B. LEVINE, M.D.¹

¹Department of Neurosurgery, University of Cincinnati Neuroscience Institute and University of Cincinnati College of Medicine; ²Mayfield Clinic; and ³Department of Radiology, University Hospital, Cincinnati, Ohio

Object. Blunt cerebrovascular injury (BCI) to the carotid and vertebral arteries is being recognized with increasing frequency in trauma victims. Yet, only broadly defined criteria exist for the use of screening angiography. In this study, the authors systematically identified the associated injuries that predict BCI and provide guidelines for the types of injuries best evaluated by angiography.

Methods. Criteria for screening angiography were developed with intentionally broad inclusion to maximize sensitivity. Screening criteria for each patient and angiographic results (5-point scale of BCI) were recorded prospectively. Injuries most often associated with a positive angiogram were identified. Dissection grades of 0–1 were classified as minor.

Results. Of 365 patients evaluated for trauma by angiography between January 2000 and December 2005, 40 patients with penetrating trauma were excluded. Of the 325 patients included in the study, 100 (30.8%) had positive angiographic findings, including 79 (24.3%) with major injuries. Fractures of the cervical spine and midface (or mandibular ramus) were associated with major BCI (identified in 30.7% of patients with cervical fractures and 30.8% of patients with midface fractures). However, thoracic trauma and soft tissue injury of the neck were rarely associated with a significant BCI (0 and 3 cases, respectively). Horner syndrome and cervical bruit were associated with arterial dissection in 9 of 10 patients. Skull base fractures and unexplained neurological findings were associated with major BCI in 13 (18.3%) of 71 and 11 (16.9%) of 65 patients, respectively.

Conclusions. Cervical and facial fractures resulting from blunt trauma were highly associated with BCI. After significant thoracic trauma or soft tissue injury to the neck, angiography should be reserved for patients with unexplained neurological findings or expanding hematomas of the neck. (DOI: 10.3171/2009.6.JNS08416)

Key Words • angiography • carotid artery dissection • screening • trauma

Abbreviations used in this paper: BCI = blunt cerebrovascular injury; CA = carotid artery; ICA = internal CA; VA = vertebral artery.
Blunt cerebrovascular injury

rived from review of the literature. We categorized injuries believed to be associated with a high risk of BCI into 8 groups (Table 1). Patients were admitted to The University Hospital in Cincinnati, a Level 1 trauma center, between January 2000 and December 2005 with the study approved by the Institutional Review Board. Included were patients injured in motor vehicle collisions, falls from a height (or down a flight of stairs), and similar high-velocity injuries, and excluded were patients with nondisplaced fractures or fractures from a low-velocity trauma. After initial examination for serious, life-threatening injuries, patients were evaluated by standard protocol for intracranial, spinal, or thoracic injuries. Thoracic and soft-tissue injuries were evaluated by our Level 1 trauma surgeon. Skull, cervical spine, and facial fractures were evaluated by neurosurgeons. If any injuries consistent with the criteria listed in Table 1 were identified by the trauma surgeon or neurosurgeon, the patient was evaluated with cervical-cerebral angiography.

Four-vessel angiography was performed in each patient who underwent both cervical and intracranial imaging. Images were evaluated for changes in vessel cali, raised intimal flaps, or filling defects consistent with intraluminal thrombus. The indication for angiography, which we termed the injury category, was entered prospectively in our database by the angiographer, and the accuracy of the stated indication was confirmed later by chart review (E.M.); angiographers were always aware of the indication for angiography and were not blinded. Positive findings were graded according to the grading scale for BCIs proposed by Biffl et al.:3 Grade I, luminal irregularity with <25% reduction of intraluminal diameter; Grade II, dissection accompanied by intramural hematoma, ≥25% reduction of intraluminal diameter, intraluminal thrombus, or a raised intimal flap; Grade III, pseudoaneurysm; Grade IV, occlusion; and Grade V, transection with free extravasation. Injuries classified as Grade II or III were treated with heparin anticoagulation in the absence of contraindications due to other injuries or with aspirin (325 mg daily) in the presence of contra-indications to heparin therapy. Patients with evidence of BCI on initial angiography were then reevaluated by angiography after 1 week of therapy. Progressive injury despite therapy was subsequently considered for endovascular stent repair.

Findings from all patients evaluated with angiography were entered prospectively into our database. Data collected included patient age, mechanism of injury, indication for angiography (including injury category), and findings on angiography (including BCI grade). Data were then analyzed to calculate the incidence of clinically significant BCI within each injury category. For the purpose of comparison, findings of BCI Grades II–V were considered clinically significant and Grade I was considered clinically insignificant.

Results

Between January 2000 and December 2005, 365 patients were identified with injuries that met criteria for cerebral angiography (Table 1). Forty patients with penetrating trauma were excluded. Of 325 patients evaluated for blunt trauma, 100 had positive findings on angiograms (30.8% of all angiographic studies). Grade I BCI was identified in 21 (6.5%) studies and was considered clinically insignificant. Among the 79 patients (24.3%) whose studies demonstrated clinically significant BCI, injury was Grade II in 44 (13.5% of the patients included in the study), Grade III in 21 (6.5%), Grade IV in 11 (3.4%), and Grade V in 3 (0.9%). There were no complications related to the angiographic procedures.

When the data were analyzed by trauma category, we identified significant differences in the rate of positive findings (Table 2). Of 71 studies performed for Category 1 trauma (neurological injury or finding not explained by other injuries), 13 (18.3%) demonstrated clinically significant BCI. Studies performed for Category 2 or 3 trauma (Horner syndrome and cervical bruit) demonstrated sig-

<table>
<thead>
<tr>
<th>Injury Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>signs or symptoms of stroke or TIA, including infarction on intracranial imaging, not explained by intracranial injuries or mass lesions</td>
</tr>
<tr>
<td>2</td>
<td>Raeder or Horner syndrome</td>
</tr>
<tr>
<td>3</td>
<td>cervical bruit</td>
</tr>
<tr>
<td>4</td>
<td>skull base fractures through or near the carotid canal</td>
</tr>
<tr>
<td>5</td>
<td>midface fractures, including fractures of the mandibular ramus, but excluding fractures of the mentum &amp; isolated nasal fractures</td>
</tr>
<tr>
<td>6</td>
<td>fracture/dislocation of the cervical spine</td>
</tr>
<tr>
<td>7</td>
<td>signs of significant soft tissue injury to the neck including near-hanging injuries, evidence of shoulder harness injury, &amp;/or soft tissue swelling in the setting of blunt trauma</td>
</tr>
<tr>
<td>8</td>
<td>significant thoracic injuries, including but not limited to first rib fracture, flail chest, pulmonary contusion, or sternal fractures</td>
</tr>
</tbody>
</table>

* Patients were referred for angiography within 24 hours of high-velocity blunt injury or identification of the indication and were screened for BCI on the basis of mechanism of injury, associated injuries, signs, and symptoms. Abbreviation: TIA = transient ischemic attack.
significant BCI in 4 of 5 and 5 of 5 cases, respectively. Category 4 trauma (skull base fractures) led to 65 angiograms, with clinically significant BCI identified in 11 (16.9%) of the studies. Category 5 trauma (midface fractures) led to significant BCI in 8 (30.8%) of 26 studies. The 114 angiograms performed for Category 6 injuries (cervical spine fractures) led to a diagnosis of significant BCI in 35 studies (30.7%). Among studies performed for Category 7 (soft tissue injuries to the neck) and Category 8 (major thoracic injury) injuries, however, angiograms obtained in only 3 (10%) of 30 and none (0%) of 9 patients, respectively, demonstrated significant BCI.

Of note was the finding that not all angiographically defined BCI correlated precisely with the location of injury identified as the indication for angiography. For example, 2 patients with cervical spine fractures involving the foramen transversarium had CA dissections on angiography with no apparent injury to the VA on the side of the fracture. Likewise, 2 patients with skull base fractures involving the carotid canal had VA injuries in addition to their CA injuries.

Discussion

Our findings indicate that a high frequency of BCI occurred in patients with fractures of the cervical spine, midface, and cranial base after high-velocity trauma. These findings are similar to those suggested by Biffl et al. in 1999. Our prospective study provides some similar findings to those in the retrospective studies of Biffl et al., specifically regarding the similar rates of positive findings on examinations for BCI and an association with skull base, midface, and cervical spine fractures. Our study not only found an association between cervical spine fractures and carotid artery injuries but also an association between cervical spine fractures and VA injuries. While Biffl et al. associated positive findings on angiograms with a Glasgow Coma Scale score < 6, we found that lateralizing neurological deficit consistent with hemispheric ischemia was a better predictor. Therefore, our prospective data both confirm and further refine many of the criteria identified by the retrospective study of Biffl et al. Conversely, isolated thoracic injuries and soft tissue injuries to the neck were only associated with BCI in 3 of 30 angiographic studies.

Causes of BCI

Blunt cerebrovascular injury rarely occurs after a low-energy trauma but can develop from apparently trivial trauma secondary to predisposing arterial and bony abnormalities. Several risk factors reported in association with spontaneous dissection include hypertension, Marfan syndrome, Ehlers-Danlos syndrome Type IV, autosomal dominant polycystic kidney disease, osteogenesis imperfecta Type I, fibromuscular dysplasia, syphilis, arteriopathies, and Erdheim cystic medial necrosis.

Although the majority of blunt vascular injuries are attributed to motor vehicle collisions, other mechanisms that play a significant role include motorcycle collisions, falls, near hangings, and biking and snow sports accidents. Based on our results, it appears that traumatic energy sufficient to produce BCI typically also suffices to produce trauma to bony structures.

Blunt cerebrovascular injury can involve both the CAs and VAs after direct forces to the neck or after stretching, tearing, and compressive mechanisms. Virtually any mechanism that involves acute hyperextension, flexion, or rotation of the neck can result in blunt injury. Specific anatomical features of the ICA make it susceptible to BCI. The Cl–3 vertebral body transverse processes lie just dorsal to the ascending cervical ICA. The petrous portion of the ICA is also susceptible to injury by the surrounding bone as it traverses the carotid canal in the petrous portion of the temporal bone; it then turns to traverse the foramen lacerum, where it is tethered by the petrolingual ligament. Thus, skull base fractures in this region may cause arterial dissection.

Cervical spine injury is the only independent risk factor for VA injury. The second segment of the VA, which ascends through the transverse foramina, is frequently injured when cervical fractures involve the foramina. The horizontal portion of the third segment of the VA curves posteriorly behind the lateral mass of the atlas and lies in a groove, which itself can have anatomical osseous variations, on the upper surface of the posterior arch of C-1. Because of the high frequency of cervical fractures and ligamentous injuries in this region, as well as stretching and compression at the atlantoaxial and atlantooccipital joints during head rotation, the third segment of the VA extending from C-2 to the dura mater is particularly prone to injury during blunt trauma.

Our findings indicating that a high frequency of BCI occurred in patients with fractures of the cervical spine, midface, and cranial base after high-velocity trauma are

<table>
<thead>
<tr>
<th>Injury Category</th>
<th>No. of Angiograms</th>
<th>No. of Significant BCIs (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>71</td>
<td>13 (18.3)</td>
</tr>
<tr>
<td>2</td>
<td>5</td>
<td>4 (80)</td>
</tr>
<tr>
<td>3</td>
<td>5</td>
<td>5 (100)</td>
</tr>
<tr>
<td>4</td>
<td>65</td>
<td>11 (16.9)</td>
</tr>
<tr>
<td>5</td>
<td>26</td>
<td>8 (30.8)</td>
</tr>
<tr>
<td>6</td>
<td>114</td>
<td>35 (30.7)</td>
</tr>
<tr>
<td>7</td>
<td>30</td>
<td>3 (10)</td>
</tr>
<tr>
<td>8</td>
<td>9</td>
<td>0 (0)</td>
</tr>
</tbody>
</table>

* Results are divided by the category of injury for which the angiogram was indicated.
very similar to those suggested by Biffl et al. in 1999. Patients also at risk for BCI have lateralizing neurological deficits that are not completely explained by other injuries. Conversely, isolated thoracic injuries and soft tissue injuries to the neck are not commonly associated with BCI as evidenced by the only 3 positive findings by angiography in 30 studies.

Indications for Screening Cerebral Angiography

We conclude that screening cerebral angiography is indicated after high-velocity blunt trauma, including motor vehicle collisions and other mechanisms aforementioned, when associated with neurological deficits not explained by findings on intracranial imaging and when associated with fracture of the cervical spine, midface, or skull base. Screening cerebral angiography is not indicated in patients after isolated thoracic injuries or soft tissue injuries of the neck. In a 2006 study, Biffl et al. suggested that screening with CT angiography can be performed with an accuracy approaching that of cerebral angiography. We believe that our screening criteria can be applied to CT angiography screening as well as cerebral angiography.

Consistent with the theory that the energy of trauma dictates the risk of BCI, our results indicate that the location of cervical spine and skull fractures did not necessarily correlate with the location of BCI. For example, a patient with spinal trauma to the foramen transversarium requires evaluation of more than just the ipsilateral VA. Likewise, visualization of the CAs in the neck at the level of a fracture and/or dislocation alone may miss BCI at the skull base. For this reason, we recommend complete cervical and intracranial screening for BCI in patients who meet our screening criteria.

Biffl et al. demonstrated that the presence of significant BCI (Grade II and higher) was associated with significant neurological morbidity and mortality. Identification of BCI after high-velocity trauma is an important clinical issue as previous studies have demonstrated a high morbidity and mortality. Early identification can reduce morbidity by allowing treatment with anticoagulation.

Conclusions

Identification of BCI early after blunt trauma is important to facilitate its treatment. In this prospective study, we identified the specific injuries associated with BCI and thereby could identify patients likely to benefit from routine screening. We recommend complete cervical and intracranial screening in patients after high-velocity trauma that results in fracture of the cervical spine, midface, or cranial base. Screening cerebral angiography is not indicated in patients after isolated thoracic injuries or soft tissue injuries of the neck.

Disclaimer

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

References


Manuscript submitted April 30, 2008. Accepted June 3, 2009. Please include this information when citing this paper: published online July 31, 2009; DOI: 10.3171/2009.6.JNS08416.

Address correspondence to: Andrew J. Ringer, M.D., c/o Editorial Office, Department of Neurosurgery, ML 0515, 231 Albert Sabin Way, Cincinnati, Ohio, 45267. email: editor@mayfieldclinic.com.