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BLUNT CEREBROVASCULAR INJURIES

SUMMARY

Blunt cerebrovascular injury (BCVI) may be present in greater than 1% of those with blunt trauma. Aggressive screening strategies uncover injuries in up to 44% of those screened. Many such injuries are responsible for significant morbidity, and mortality if not appropriately diagnosed and treated in a timely fashion. Aggressive screening protocols are feasible using newer generation, multi-detector helical scanners capable of detecting small intimal defects in a relatively non-invasive manner.

RECOMMENDATIONS

- **Level 1**
 - **None**
- **Level 2**
 - **Patients with the following injury patterns/presentation should be screened:**
 - **Coma unexplained by CT findings**
 - **Lateralizing neurological deficits**
 - **Cervical spine injuries**
 - **Subluxations at any level**
 - **Fractures from C1 to C3**
 - **Fractures through the transverse foramen at any level**
 - **Lefort II or III facial fractures**
 - **Severe epistaxis**
 - **Horner's syndrome**
 - **Skull base fractures involving the foramen lacerum**
 - **Significant neck soft tissue injury / neck seat belt sign**
 - **A history of strangulation or near hanging**
 - **GCS < 8**
 - **CT Angiography is the preferred method to screen for BCVI**
- **Level 3**
 - **None**

INTRODUCTION

BCVI involving the carotid and/or vertebral vessels is a potentially devastating and likely underdiagnosed injury that may be more frequent than previously thought. Most of injuries occur with rapid deceleration, hyperextension, and rotation of the neck, all of which stretch the internal carotid artery (ICA) and can produce an intimal tear with resultant thrombosis and embolization. Pseudoaneurysms may form that can bleed, enlarge, and compress adjacent structures or be a source of emboli. Many other mechanisms and patterns of injury may be present and are beyond the scope of this review. Because outcome is compromised by diagnostic delay, maintaining a high index of suspicion for these injuries among patients at risk is very important. Focal neurological deficits that do not correlate with cranial CT results are a

EVIDENCE DEFINITIONS

- **Class I:** Prospective randomized controlled trial.
- **Class II:** Prospective clinical study or retrospective analysis of reliable data. Includes observational, cohort, prevalence, or case control studies.
- **Class III:** Retrospective study. Includes database or registry reviews, large series of case reports, expert opinion.
- **Technology assessment:** A technology study which does not lend itself to classification in the above-mentioned format. Devices are evaluated in terms of their accuracy, reliability, therapeutic potential, or cost effectiveness.

LEVEL OF RECOMMENDATION DEFINITIONS

- **Level 1:** Convincingly justifiable based on available scientific information alone. Usually based on Class I data or strong Class II evidence if randomized testing is inappropriate. Conversely, low quality or contradictory Class I data may be insufficient to support a Level I recommendation.
- **Level 2:** Reasonably justifiable based on available scientific evidence and strongly supported by expert opinion. Usually supported by Class II data or a preponderance of Class III evidence.
- **Level 3:** Supported by available data, but scientific evidence is lacking. Generally supported by Class III data. Useful for educational purposes and in guiding future clinical research.

common, yet often late finding. The ultimate goal should be to diagnose and treat this injury early *prior to* the patient becoming symptomatic through the use of broad scale diagnostic screening programs directed at populations at risk as delays in treatment can be catastrophic.

After one decides that an individual is at increased risk for injury to the extracranial cerebrovasculature, the next question centers around choosing the appropriate diagnostic test. Angiography has long been considered the gold standard. This test is invasive, costly, time consuming, and requires specialized staff that may not be immediately available. Early reports evaluating the diagnostic accuracy of CT angiography (CTA) and magnetic resonance angiography (MRA) showed that these modalities may miss injuries that are clinically significant. With the advent of multi-detector helical scanners, however, it appears that CTA is the diagnostic test of choice to detect these injuries.

LITERATURE REVIEW

Incidence / Identifying Groups At Risk

In a landmark paper in 1996, Fabian's group from Memphis retrospectively reviewed the records of 67 patients with 87 blunt injuries treated over nearly 11 years and found that blunt carotid injury (BCI) was present in 0.67% of patients admitted after motor vehicle crashes (1 in every 150 patients), and in 0.33% of blunt injuries in general (1 in every 304 patients). The circumstances that prompted clinical suspicion and angiographic diagnosis for BCI were: 1) physical findings demonstrating soft-tissue injury to the anterior neck (41%); 2) a neurological examination that was not compatible with the brain CT (34%); 3) development of a neurological deficit subsequent to hospital admission (43%) and; 4) Horner's syndrome (9%). Overall mortality rate was 31%, with 76% of the deaths directly related to BCI-induced strokes. Of the 46 survivors, 63% had good neurological outcome, 17% had a moderate outcome, and 20% had a bad outcome. The majority of the patients were treated with heparin, which was the only independently significant factor associated with improvement in neurological outcome ($p < 0.01$) (1).

In 1997, a retrospective review was performed on patients sustaining BCI over a 6 year period ($n=20$) (2). Those patients with combined head and chest trauma were found to have a 14-fold increase in the likelihood of carotid injury. In this series, there was an incidence of 0.24% among blunt trauma patients. 53% of patients presented with abnormal neurological finding not explained by cranial CT. Focal neurological findings were present in 42% of patients. Of the survivors, 45% of patients had significant impairment. The overall mortality was 5% (2).

In an attempt to further classify these types of injuries, Biffi et al. described a BCVI grading scale in 1999:

- Grade 1 = irregularity of the vessel wall or luminal dissection with less than 25% luminal stenosis
- Grade 2 = intraluminal thrombus OR a raised intimal flap OR dissections with associated luminal narrowing more than 25%
- Grade 3 = pseudoaneurysms
- Grade 4 = vessel occlusions
- Grade 5 = complete vessel transection with free contrast extravasation.

Biffi found the overall incidence of BCI to be 0.38%. However, with more aggressive screening of asymptomatic patients, the incidence was found to be an astonishing 1.07%. Head injury was present in 61%, and 25% had basilar skull fractures with involvement of the carotid canal. Facial fractures were present in 34%, and 25% had cervical spinal (CS) column fractures. The overall mortality was 17% and of the survivors, 32% suffered permanent severe neurological disability. Stroke rate increased with grade. 7% of grade 1 injuries progressed as compared to 70% of grade 2 injuries, despite anticoagulation. Heparin therapy was protective against stroke in patients with grade 4 injury. Grade 5 injuries were typically found to be devastating (3).

The following four risk factors for carotid artery injury were identified based on multiple regression analysis: 1) GCS score ≤ 6 , 2) petrous fracture, 3) diffuse axonal brain injury, and 4) Le Forte II or III

fractures. If a patient had all 4 risk factors, they had a 93% probability of carotid artery. If the patient had a CS fracture, they had a 33% probability of having a vertebral artery injury (VAI) (4).

Berne et al. reported a BCVI incidence of 0.49%. Overall mortality was 59%, and 80% of the deaths were directly attributable to the BCVI. The median time until diagnosis was 12.5 hours in all patients with BCVI and 19.5 hours in non-survivors. Five patients had a delay in diagnosis of greater than 48 hours, all of which developed complications. Six patients presented with a GCS of 15 and 4 of them died (5).

In 2002, Fabian et al. prospectively evaluated an aggressive screening protocol utilizing angiography. The screened population included all patients with CS fractures, LeFort II or III facial fractures, Horner's syndrome, skull base fractures involving the foramen lacerum, neck soft tissue injury or neurological abnormalities unexplained by intracranial injuries. They identified an incidence of BCVI of 1.03% among blunt admissions and had a screening yield of 29%. 79% of patients with carotid artery injury (CAI) were diagnosed before the onset of ischemia. VAI were found in 33% of those with CS fractures. Overall mortality in the group screened was 5%. Stroke rate in those patients with BCVI in this series was 33% (all carotid injuries) (6). This study clearly shows that screening patients at risk identifies injuries. It also demonstrates the improvement of morbidity and mortality with earlier diagnosis.

In 2001, Fabian et al. followed up their previous studies with a 5 year review after a heightened institutional awareness for these types of injuries (8). Angiography was used liberally for the following indications: neurological deficit not consistent with brain imaging, neck hematoma, Horner's syndrome, basilar skull fracture through the foramen lacerum, CS fracture through the transverse foramen, and severe complex facial fracture. CAI was diagnosed in 1 of every 191 blunt trauma patients (0.5%) and VAI was diagnosed in 1 of every 233 blunt trauma patients (0.4%). Stroke attributable mortality was less than the 24% in the previous study ($p=0.03$). Signs of ischemia were less (34% vs. 77%; $p<0.001$) leading one to believe that these lesions were being diagnosed and treated earlier, with resultant improved outcomes. Those diagnosed and treated prior to the onset of ischemia had better outcomes. As in the prior study, those treated with heparin had better neurological outcomes.

In 2001, Kerwin et al. evaluated their aggressive BCVI screening program in 48 patients among whom 21 injuries were identified (44% of those screened). The overall incidence of BCVI for blunt trauma was 1.1%. The frequency of abnormal angiograms for the indications listed was: fracture through the foramen transversarium (60%), unexplained paresis (44%), basilar skull fracture (42%), unexplained neurological examination (38%), and anisocoria (33%) (9).

In 2002, Miller et al evaluated Fabian's screening protocol by obtaining a four vessel angiography on all patients with CS fractures, LeFort II or III facial fractures, Horner's syndrome, skull base fractures involving the foramen lacerum, neck soft tissue injury or those with neurological abnormalities unexplained by intracranial injuries(10). Overall screening yield was 29%. The incidence of CAI was similar to the previous study, however, the incidence of VAI increased (8,10). The stroke rate in VAI was markedly lower at 0% as compared to 14% in the previous study.

In 2003, Biffi et al. sought to determine which CS fracture patterns were predictive of VAI's through the use of a prospective, aggressive screening protocol using angiography. 605 patients underwent diagnostic angiography and 92 patients were found to have a VAI (15% of those screened). 77% had associated CS fractures and the majority of the fracture patterns were subluxations (55%) or involved extension of the fracture through the transverse foramen (26%). Excluding subluxations, 13 of 15 patients with VAI's and fractures were located in the upper spine from C1 to C3. 9 patients had an associated CAI. One third of patients with these high-risk fracture patterns had a VAI (7).

Although many centers have decided to implement screening protocols, there is still a general lack of consensus. The American Association for the Surgery of Trauma (AAST) has recently opened a multicenter study to prospectively collect data on screened patients.

METHOD OF EVALUATION

In a prospective evaluation completed in 2004, Berne and colleagues evaluated the use of Helical CT as a method for BCVI screening. Their indications for screening were similar to those described above. Angiograms were only performed if the studies were equivocal or unclear for any reason. The incidence of BCVI was 0.60% for all blunt trauma patients and 3.7% among those screened. Results of CTA for BCVI were as follows: sensitivity, 100%; specificity, 94%; positive predictive value (PPV), 37.5%; and negative predictive value (NPV), 100%. It should be noted that these CTA's were not all compared to the gold standard angiogram, thus a true sensitivity and specificity was not obtained. Frequent clinical examinations were performed to determine if a patient did not have an injury. Perhaps low grade injuries were missed that did not have clinical consequence. Another part of this study deserves mention. The study was initially done with a 4 slice scanner and subsequently with a 16 slice scanner. In comparing these subgroups, the incidence of BCVI increased (0.38% to 1.05%) and the prevalence increased (2.5% to 6.9%) with the use of the newer technology. Specificity increased from 90.8% to 98.7% and PPV improved from 22.2% to 83.3% (11).

In 2005, Bub et al. performed a retrospective review of patients that had both a CTA and angiography that were independently reviewed by radiologists in a blinded fashion. There was not a protocol in place with regard to which patients received these studies. 32 patient studies were evaluated. Most of the CTA studies were performed on a 4-slice scanner. Among the three radiologists reviewing the studies, sensitivity of CTA for CAI ranged from 83% to 92% and specificity from 88% to 98%. For VAI, sensitivity was 40% to 60% and specificity was 90% to 97%. Interestingly, inter-observer variability was greater for angiography than CTA, reinforcing the fact that even the gold standard is not perfect (12).

In 2006, Schneidereit evaluated the use of an eight-slice multi-detector CT scanner. The overall incidence of BCVI increased from 0.17% to 1.1% with the use of aggressive screening protocols. Delayed stroke rate and injury-specific mortality fell from 67% to 0% ($p < 0.001$) and 38% to 0% ($p = 0.002$) respectively. Mortality fell from 38% to 10.5% ($p = 0.049$). When evaluating patients that had both CTA and angiography performed, the specificity for CTA was found to be 58% (there were 8 falsely positive CTA studies for a variety of reasons). No patient with a negative screening CTA developed delayed neurological sequelae attributable to BCVI. Using univariate logistic regression analysis, only the presence of a CS injury was predictive of BCVI (13).

Four months later, three consecutive issues of the *Journal of Trauma* contained reports evaluating CTA in the evaluation of BCVI. Biffi and colleagues evaluated 16-slice CTA (331 patients) and concluded that it detected all clinically significant injuries. 5.4% of those screened and 0.66% of blunt trauma admissions were found to have suffered a BCVI. 17 injuries were imaged with both CTA and angiography. Four patients had false-positive CTA studies. No patient with a normal CTA developed neurological signs or symptoms consistent with BCVI (14).

In the following issue, Eastman and colleagues further evaluated CTA with the use of a 16-channel scanner and did a prospective head to head comparison with angiography, which was the largest study to date. The overall incidence of BCVI was 1.25% and the incidence within the screened population was 28.4%. 146 patients received both CTA and angiography and 43 had a BCVI. In 98% the results of the CTA and angiography were concordant. There was a single false negative CTA in a patient with a grade I vertebral injury. The overall sensitivity, specificity, PPV, NPV, and accuracy for the diagnosis of BCVI were 97.7%, 100%, 100%, 99.3%, and 99.3% respectively. The authors concluded that a 16-channel, multislice CTA is a safe, effective and sensitive diagnostic test modality for the detection of BCVI (15).

Most recently, Berne and colleagues reported their 2 year experience with 16-slice multi-detector CTA in the evaluation of BCVI. 435 patients were screened and 24 patients had injuries for an overall incidence of 1.2% and 5.5% of those screened. These results were statistically higher than their numbers during the "4-slice era" (0.38% and 2.4% respectively, $p < 0.01$). Overall mortality was 25%. Angiograms were performed to further evaluate positive studies. Interestingly, a detailed description of the angiography findings was not disclosed in the study. No patient with a negative CTA was subsequently identified as having, or developed neurological symptoms attributable to a missed BCVI (16).

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