Blunt Cerebrovascular Injury
Practice Management Guidelines

East Practice Management Guidelines Committee

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Scope of the Problem:

Blunt injury to the carotid or vertebral vessels (blunt cerebrovascular injury – BCVI) is diagnosed in approximately 1/1000 (0.1%) patients hospitalized for trauma in the United States. However the vast majority of these injuries are diagnosed following the development of symptoms secondary to central nervous system ischemia with a resultant neurologic morbidity of up to 80% and associated mortality of up to 40%. When asymptomatic patients are screened for BCVI the incidence rises to 1% of all blunt trauma patients. Key issues that need to be addressed in the diagnosis and management of BCVI include what population (if any) merits screening for asymptomatic injury, what screening modality is best, what is the appropriate treatment for BCVI (both symptomatic and asymptomatic) and what constitutes appropriate follow-up for these injuries.

Process:

Identification of references

A computerized search of the National Library of Medicine/National Institute of Health, Medline database was performed utilizing citations from 1965 to 2005 inclusive. The search terms “cerebrovascular trauma,” or “carotid artery” or “vertebral artery” AND wounds and injuries (mesh heading), AND “blunt” limited to the English language returned approximately 1500 citations. Titles and abstracts were reviewed to determine relevance and isolated case reports, small case series, editorials, letters to the editor, and review articles were eliminated. The bibliographies of the resulting full text articles were searched for other relevant citations and these were obtained when appropriate. One hundred sixty two articles were selected for review and of these 60 met criteria for inclusion and are excerpted in the attached evidentiary table.

Quality of the references

The Eastern Association for the Surgery of Trauma “Utilizing Evidence Based Outcome Measures to Develop Practice Management Guidelines: A Primer” was utilized as the quality assessment instrument applied to the development of this protocol. Articles were classified as Class I, II, or III according to the following definitions:

Class I: Prospective, randomized, controlled trial (there were no Class I articles reviewed)

Class II: Clinical studies in which the data was collected prospectively, and retrospective analyses which were based on clearly reliable data. Types of studies so classified include: observational studies, cohort studies, prevalence studies, and case control studies. There were 23 Class II studies identified.

Class III: Studies based on retrospectively collected data. Evidence used in this class includes clinical series, database or registry reviews, large series of case reviews, and expert opinion. There were 37 Class III studies identified.

Establishment of recommendations

A committee consisting of 10 trauma surgeons was convened to review the data and establish these recommendations using these definitions:

Level 1: The recommendation is convincingly justifiable based on the available scientific information alone. This recommendation is usually based on Class I
data, however strong Class II evidence may form the basis for a Level 1 recommendation, especially if the issue does not lend itself to testing in a randomized format. Conversely, low quality or contradictory Class I data may not be able to support a Level 1 recommendation.

No Level 1 guidelines were supported by the literature.

**Level 2:** The recommendation is reasonably justifiable by available scientific evidence and strongly supported by expert opinion. This recommendation is usually supported by Class II data or a preponderance of Class III evidence.

Seven Level 2 guidelines were establish by the literature.

**Level 3:** The recommendation is supported by available data but adequate scientific evidence is lacking. This recommendation is generally supported by Class III data. This type of recommendation is useful for educational purposes and in guiding future clinical research.

Nine Level 3 guidelines are proposed for this topic.

**Recommendations**

**Question addressed:** What patients should be screened for blunt cerebrovascular injury?

**Level 1:** No Level 1 recommendations can be made.

**Level 2:**
1. Patients presenting with any neurologic abnormality that is unexplained by a diagnosed injury should be evaluated for BCVI.
2. Blunt trauma patients presenting with epistaxis from a suspected arterial source following trauma should be evaluated for BCVI.

**Level 3:**
1. Asymptomatic patients with significant blunt head trauma as defined below are at significantly increased risk for BCVI and screening should be considered.
   
   *Risk factors:*
   
   • GCS ≤8
   • Petrous bone fracture
   • Diffuse axonal injury
   • Cervical spine fracture
   • Fracture through the foramen transversum
   • Lefort II or III facial fractures

2. Pediatric trauma patients should be evaluated using the same criteria as the adult population.
**Question addressed:** What is the appropriate modality for the screening and diagnosis of BCVI?

**Level 1:** No Level 1 recommendations can be made.

**Level 2:**
1. Diagnostic four vessel cerebral angiography (FVCA) remains the gold standard for the diagnosis of BCVI.
2. Duplex ultrasound is **not** adequate for screening for BCVI.
3. CT angiography with a 4 (or less)-slice multidetector array is neither sensitive nor specific enough for screening for BCVI.

**Level 3:**
1. Multi-slice (8 or greater) multidetector CTA has the same rate of detection for BCVI when compared to historic control rates of diagnosis with FVCA and should be considered as a screening modality in place of FVCA.

**Question:** How should BCVI be treated? This references a grading scheme proposed by Biffl et al.6

**Grading scale**
- Grade I – intimal irregularity with <25% narrowing
- Grade II – dissection or intramural hematoma with >25% narrowing
- Grade III – pseudoaneurysm
- Grade IV – occlusion
- Grade V – transection with extravasation

**Level 1:** No Level 1 recommendations can be made.

**Level 2:**
1. Barring contraindications, Grade I and II injuries should be treated with antithrombotic agents such as aspirin or heparin.

**Level 3:**
1. Either heparin or antiplatelet therapy can be used with seemingly equivalent results. A number of authors still recommend heparinization if there is no contraindication, reserving anti-platelet agents for those patients with relative contraindications to heparinization.
2. If heparin is selected for treatment, the infusion should be started without a bolus and titrated to an aPTT of 50-60 sec.
3. In patients in whom anticoagulant therapy is chosen conversion to warfarin titrated to a PT INR of 2-3 for 3-6 months is recommended.
4. Grade III injuries (pseudoaneurysm) rarely resolve with observation or heparinization and invasive therapy (surgery or angio-interventional) should be considered. *N.B.* carotid stents placed without subsequent anti-platelet therapy have been noted to have a high rate of thrombosis in this population.7

5. In patients with an early neurologic deficit and an accessible carotid lesion operative or interventional repair should be considered to restore flow.

6. In children who have suffered an ischemic neurologic event, aggressive management of resulting intracranial hypertension up to and including resection of ischemic brain tissue has improved outcome as compared to adults and should be considered for supportive management.

**Question addressed:** For how long should antithrombotic therapy be administered?

No recommendations can be made for this question.

**Question addressed:** How should one monitor the response to therapy?

**Level 1:** No Level 1 recommendation can be made.

**Level 2:**
1. Follow-up angiography is recommended in Grade I-III injuries. In order to reduce the incidence of angiography-related complications this should be performed after 7 days post injury.

**Level 3:** There are no Level 3 guidelines for this question.

**Scientific Foundation:**

**Screening and Diagnosis**

Symptomatic patients that undergo FVCA for the indications of unexplained neurologic symptoms or arterial epistaxis the diagnosis of BCVI is made in a significant percentage of cases (38-100%) and is clearly recommended as a reason to pursue the diagnosis.8, 9, 10

Screening asymptomatic patients at risk for BCVI is more controversial. Multiple studies have indicated that patients with BCVI often present hours to days prior to the onset of symptoms.11, 12, 13 Failure to identify and treat these injuries can result in significant mortality and morbidity.14 It is clear that screening for BCVI by essentially any modality can diagnosis BCVI prior to the onset of symptoms at rates up to 10 times higher than previously identified.15 On the basis of this data a number of individuals recommend screening blunt trauma patients at risk for BCVI using 4-vessel cerebral angiography as the diagnostic modality.16, 17, 18, 19 There is some countervailing opinion.

In a database review of thirty-five thousand patients Mayberry determined that only 17 were diagnosed with BCI of which 11 became symptomatic. Of these only 2
were asymptomatic for over 2 hours post admission, and of these 2, only 1 met criteria for screening. Based on this data Mayberry et al concluded that screening was futile in light of the inability to diagnose the injury prior to the development of symptoms. The majority of the available data does not support this finding. The preponderance of the evidence supports the recommendation that patients at risk for BCVI can be identified and diagnosed prior to the onset of symptoms with the application of an appropriate screening modality.

**Criteria for screening/Risk factors**

The mechanism of BCVI seems to be associated with cervical hyperextension and rotation, hyperflexion, or direct blow. The factors that are most closely associated with the finding of BCVI are direct evidence of neurologic deficits as noted above. In asymptomatic patients a number of factors have been associated with increased risk of BCVI. Biffl and colleagues performed linear regression analysis of a liberally screened patient population (N =249)and found that there were four independent risk factors for BCAI. These were: 1) GCS<6, 2) Petrous fracture, 3) Diffuse axonal injury, and 4) LeFort II or III fracture. Patients who had one risk factor had a risk of 41% for BCAI. This risk increased to 93% in the presence of all 4 factors. The only risk factor for BVAI was presence of cervical spine fracture. However 20% of patients diagnosed with BCVI selected for screening by the criteria in Table 1 did not have the independent risk factors identified by regression analysis indicating that broad selection criteria are necessary to prevent missed injuries. Cothren retrospectively reviewed patients with BVAI and found that complex cervical spine fractures involving subluxation, fracture into the foramen transversarium, or C1 to C3 fractures were closely associated with this injury. In a prospective review of screening with DFVCA Cothren et al utilized criteria similar to that proposed by Biffl and modified to incorporate those specific cervical spine fracture patterns shown to increase risk of BVAI to select patients for evaluation (Table 2). Seven hundred and twenty-seven patients (4.6%) of all blunt trauma patients were studied and 244 were diagnosed with BCVI for a screening yield of 34%. An isolated cervical seat belt sign without other risk factors and normal physical exam has failed to be identified as an independent risk factor in two retrospective studies and should not be utilized as the sole criteria to stratify patients for screening.
### Table 1

<table>
<thead>
<tr>
<th>Injury mechanism</th>
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<tr>
<td>• Severe cervical hyperextension/rotation or hyperflexion, particularly if associated with</td>
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<tr>
<td>o Displaced midface or complex mandibular fracture</td>
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<tr>
<td>o Closed head injury consistent with diffuse axonal injury</td>
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<tr>
<td>• Near hanging resulting in anoxic brain injury</td>
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<tr>
<td>Physical signs</td>
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<tr>
<td>• Seat belt abrasion or other soft tissue injury of the anterior neck resulting in significant swelling or altered mental status</td>
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<tr>
<td>Fracture in proximity to internal carotid or vertebral artery</td>
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<tr>
<td>• Basilar skull fracture involving the carotid canal</td>
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<tr>
<td>• Cervical vertebral body fracture</td>
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### Table 2

<table>
<thead>
<tr>
<th>Signs/symptoms of BCVI</th>
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<tr>
<td>• Arterial hemorrhage</td>
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<tr>
<td>• Cervical bruit</td>
</tr>
<tr>
<td>• Expanding cervical hematoma</td>
</tr>
<tr>
<td>• Focal neurological deficit</td>
</tr>
<tr>
<td>• Neurologic examination incongruous with CAT scan findings</td>
</tr>
<tr>
<td>• Ischemic stroke on secondary CAT scan</td>
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<tr>
<td>Risk factors for BCVI</td>
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<tr>
<td>• High-energy transfer mechanism with</td>
</tr>
<tr>
<td>o Lefort II or III fracture</td>
</tr>
<tr>
<td>o Cervical spine fracture patterns: subluxation, fractures extending into the transverse foramen, fractures of C1-C3</td>
</tr>
<tr>
<td>o Basilar skull fracture with carotid canal involvement</td>
</tr>
<tr>
<td>o Diffuse axonal injury with GCS ≤6</td>
</tr>
<tr>
<td>o Near hanging with anoxic brain injury</td>
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</table>

Denver Modification of Screening Criteria for BCVI adapted from Cothren et al\(^5\)\(^9\) (with permission)
Screening Modality

Duplex Sonography

Multiple studies have shown that duplex sonography is not sensitive enough for screening for BCVI with an overall sensitivity from as low as 38.5% to as high as 86% (the latter for carotid injuries alone). Duplex US cannot be recommended as a screening modality for BCVI.

Angiography

Arguments have been made that DFVCA, in an appropriate group is safe, sensitive, and cost effective. Biff et al report a 27\% rate of positive screening angiogram when asymptomatic patients were screened according to the criteria in Table 1. Cothren utilized DFVCA in 727 asymptomatic patients that met screening criteria (Table 2) in which he found 244 patients with injury (34\% screening yield). In patients who were initially asymptomatic and could not have antithrombotic therapy there was a 21\% (10/48) rate of ischemic neurologic event (INE) whereas in those treated with either heparin, low molecular weight heparin, or antiplatelet agents only one of 187 had an INE. Using this internal data Cothren estimated that the identification and treatment of asymptomatic BCVI in these 187 patients prevented 32 strokes. This comes at an expense (charge data) of $6500 per angiogram for a total of approx. $154 000 per stroke avoided. Cothren concludes that this is cost-effective and screening with DFVCA should be pursued. The argument against the utilization of DFVCA (aside from that against screening per se) is that it is expensive (approx $1500), carries an inherent risk of stroke (1-2\%) and is impractical to apply at many institutions.

Magnetic Resonance Angiography

In so far as MRA is non-invasive and requires no contrast administration MRA/MRI has been gaining popularity as an alternative to DFVCA for the diagnosis of BCVI. Although a number of studies describe the use of MRA to identify BCVI at this time the few direct studies that do exist indicate that sensitivity and specificity is significantly lower than that of DFVCA. In a (albeit small) direct comparison of MRA vs. angiography Miller et al found a sensitivity of 50\% for CAI and 47\% for VAI. Levy also reported a significantly lower sensitivity for MRI and MRA than angiography for the diagnosis of BCVI. It seems that, based on this data MRA cannot be recommended as the sole modality for the screening of BCVI.

Computed Tomographic Angiography

Early CT angiography with 1 to 4 slice scanners is not sensitive enough to qualify as an adequate screening modality for BCVI. In a prospective study of CTA on a single slice scanner vs. DFVCA Biff et al report a sensitivity and specificity of 68\% and 67\% respectively. Similarly Miller et al compared 4-slice CTA vs. DFVCA and showed that CTA performed poorly with a sensitivity of 47\% for CAI and 53\% for VAI. Sensitivity and specificity seems to improve in direct relationship to improvements in technology, however. In a prospective study which included images obtained from single, four and eight-slice scanners Bub reports improvement in image quality and concomitant improvement in sensitivity and specificity as the number of detectors increases. The overall results for the mixed population (reported as ranges from different observers) was
83-92% sensitivity and 88-92% specificity for the carotid artery and 50-60% sensitivity and 90-97% specificity for the vertebral artery. Berne et al screened patients with 4-slice and, later, 16-slice scanner CTA in a study in which only positive CTA studies underwent confirmatory angiography showing an overall sensitivity (for symptomatic BCVI) and specificity of 100% and 94% respectively. Interestingly the incidence of BCVI detected went up from 0.6% with the earlier machine to 1.05% with the newer device, approaching historic incidence of BCVI as diagnosed by DFVCA and the comparative specificity improved from 90.8% to 98.7%. In a follow-up study Berne et al screened patients for BCVI solely with a 16-slice scanner. In this prospective study Berne showed that the detected incidence of BCVI goes up threefold when changing from a 4-slice scanner to a 16-slice scanner with a resulting incidence of 1.2% which is similar to that found by screening with DFVCA. In a similar study in which only positive 16-slice CTA studies were followed by DFVCA, Biffl et al reversed an earlier recommendation that CTA was not adequate for screening for BCVI reporting a sensitivity of 100% for symptomatic BCVI. Schneidereit and colleagues report similar findings and give a diagnosed incidence for BCVI of 1.4% using a 16-slice scanner. Although these studies are interesting obviously a true sensitivity can only be obtained via direct comparison between CTA and DFVCA. At this time only one study has directly compared 16-slice CTA vs. angiography for screening for BCVI. Eastman et al performed 162 CTAs followed by 146 confirmatory DFVA studies (12 patients refused consent, 4 were discharged, and 6 died of non-neurologic causes prior to the study being obtained). Twenty carotid injuries and 26 vertebral artery injuries were identified with one false negative CTA (a grade I vertebral artery injury) for a screened population incidence of 28.4% and an overall incidence of 1.25%. The overall sensitivity, specificity, positive predictive value, negative predictive value, and accuracy were 97.7%, 100% 100%, 99.3%, and 99.3% respectively.

Blunt cerebrovascular injuries in children: There is a relative paucity of information on the screening, diagnosis, and management of BCVI in children and what is available primarily consists of isolated case reports and small case series. In one review of the National Pediatric Trauma Registry (NPTR) Lew and colleagues found an overall incidence of 0.03%, which is lower than that of the adult trauma population and speculated that it may be due to the increased elasticity of the younger children’s blood vessels. They did note that another possibility was that the difference was secondary to decreased detection in children and the retrospective nature of the study. Children under six years of age seemed to be at higher risk, making up 73% of patients with BCVI whereas they made up only 36% of the registry patients. Chest trauma (in particular clavicle fracture) and severe head injury (basilar skull fracture, intracranial hemorrhage) were associated with a higher risk of BCVI in the pediatric population. In a case review of 5 patients with BCI Duke and Partington recommend initial treatment of the arterial injury to be the same as in adults. Where recommendations differ is that they go on to recommend aggressive management of intracranial hypertension in children up to and including resection of infarcted tissue due to improved outcome in pediatric patients in contradistinction to the dismal outcome of post-ischemic intracranial hypertension in adults.
Treatment of BCVI

Surgery – a number of studies from the 80’s and 90’s have concluded that if individuals have minimal or no symptoms and an accessible carotid lesion they do well with operative intervention and therefore recommend repair of any more than minor intimal irregularities. However most of these studies also note that if patient present with profound neurologic deficit, revascularization does not improve outcome. In all studies that have compared ligation v. repair, those patients that do not have a profound deficit do much better with repair. Karlin for example found a 7.8% mortality in patients undergoing repair v. 50% in those undergoing ligation and that, furthermore, those patients who did not have a deficit prior to surgery did not develop one if revascularized. Finally a vast majority of these studies including Richardson indicate that if the patient presents with a dense neurologic deficit, neither operation nor anticoagulation improves outcome. All of these studies however were of Class III quality.

Anticoagulation – there have been a number of studies attempting to evaluate the impact of antithrombotic agents on the progression or development of sequelae of BCVI. As is not unexpected the results have been somewhat contradictory but the weight of the evidence seems to support the administration of antithrombotic agents to those patients with BCVI who do not have contraindications for such. A series of retrospective studies found that administration of antithrombotic agents reduces the rate of neurologic sequelae after BCVI. Fabian also indicated that mortality also improves with heparinization in this population. Although there has not been a direct, controlled comparison of heparinization vs. antiplatelet agents (aspirin or clopidigrel) in the prevention of CVA after BCVI, a number of studies performed subgroup analysis in an attempt to address this question. In one of these studies Biffl compared those patients treated with ASA v. heparin and found a trend towards reduction in CVA for those treated with heparin (1% v. 9% p=0.07) however in studies by Wahl, Cothren, and a second study by Biffl failed to demonstrate a difference in outcome between the two modalities. In these previously mentioned studies both Cothren and Biffl still recommend heparinization as first line therapy for those patients without contraindications, reserving antiplatelet agents for those not deemed to be candidates for anticoagulation.

Serious bleeding complications can accompany aggressive anticoagulation regimens. In a mixed population of patients with both blunt and penetrating carotid injury Nanda found that, in patients with a pre-existing intra-cerebral hemorrhage, anticoagulation resulted in worsening in 2/3. Extradural hemorrhage is another frequent complication of systemic heparinization in polytrauma patients. For example in a previously mentioned study Biffl noted that bleeding which required either transfusion or cessation of heparin was encountered in 54% of patients prompting him to recommend a conservative protocol for the initiation and maintenance of the heparin infusion and tight control of aPTT to within 40-50 seconds in a later study.

Angiointerventional therapy – There have been several preliminary, Class III studies that have indicated the safety and feasibility of catheter directed therapy to include embolization of pseudoaneurysms and stenting of intimal injuries. A more recent Class II study by Cothren indicated that the carotid artery occlusion rate in patients who underwent stenting is much higher than that of patients with BCAI who
were treated with antithrombotic agents alone. This resulted in a rate of complications (3 CVA and one subclavian artery dissection) of 21% in stented patients v. 5% in non-stented patients (no one who was received anticoagulation suffered a CVA). The author goes on to add that the reason for this may be that patients who had undergone stenting were then treated with heparin and not anti-platelet agents and recommends a study to evaluate this.

Monitoring response to therapy – In a Class II study, Biffl75 found that follow-up angiography changes management in 61% of BCVI, particularly in that Grade 1 and 2 injuries often go on to complete healing or to form a pseudoaneurysm within 7-10 days. The author went on to note that the complication rate of angiography was significantly higher if the follow-up procedure was performed within 7 days and recommends that at least that amount of time be allowed to lapse prior to follow-up angiography.

**Future Directions.**

**Screening** – Blunt cerebrovascular injury is a rare entity (though not as rare as formerly thought), which requires a high index of suspicion to identify prior to the onset of symptoms. The clinical and cost-effectiveness of a screening program depends on both disease-specific, test specific, and organizational issues as well as the utility (or futility) of the treatment modalities available. Further prospective investigation is necessary to further refine the screening criteria so as to maximize the disease incidence in the screened population which will increase accuracy and decrease costs.

**Treatment** – the optimum modality for the treatment of BCVI is as yet undetermined. Prospective studies will be necessary to compare invasive intervention v. anticoagulation. Furthermore the optimal anticoagulation regimen is as yet unknown in terms of agent (anti-platelet v. heparinoid v. warfarin) as well as the duration and endpoint of therapy. Clearly there is room for further study in this regard. In light of the relative rarity of the disease entity, systematic, multi-institutional studies will be required to answer this question.

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32 cost data, unpublished, Memorial Health University Medical Center, Savannah, GA
45 Berne JD, Reuland KS, Villarreal DH, McGovern TM, Rowe SA, Norwood SH. Sixteen-slice multidetector computed tomographic angiography improves the accuracy of screening for blunt cerebrovascular injury. *J Trauma*. 2006;60:1204-1210
47 Biffl WL, Egglin T, Benedetto B, Gibbs F, Cioffi WG. Sixteen-slice computed tomographic angiography is a reliable noninvasive screening test for clinically significant blunt cerebrovascular injuries. *J Trauma*. 2006;60:745-752
<table>
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<tr>
<th>First Author</th>
<th>Year</th>
<th>Reference</th>
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</table>
Findings:

1. Blunt cerebrovascular injury (BCVI) is uncommon (0.48% of all blunt trauma admissions) but lethal (59% mortality), particularly when diagnosis is delayed.

2. Most deaths (80%) are directly attributable to BCVI and not to associated injuries.

3. Chest injury, rib fractures, and basilar skull fracture were significant predictors of BCVI.

4. Closed head injury, basilar skull fracture, and hematoma or bruise to neck were significant predictors of BCVI.

Recommendations:

1. Aggressive screening based on mechanism of injury, associated injuries, and physical findings is justified to minimize morbidity and mortality.

2. Head and chest injuries may serve as markers for BCVI.

3. Findings are utilized to minimize morbidity and mortality associated with BCVI.

4. Head CT was performed initially and then 16 slice CTAs were followed by helical CTA using a four-slice scanner initially and with closure CTA using a four-slice scanner initially.

Design: Prospective screening to identify BCVI with helical CTA using a four-slice scanner initially and with closure CTA using a four-slice scanner initially.

Findings:

1. Incidence of BCVI diagnosed with CTA was 0.6%.

2. A combination of 4 and 16-slice CTA was used.
<table>
<thead>
<tr>
<th>Study</th>
<th>Year</th>
<th>Design</th>
<th>Findings</th>
<th>Recommendations</th>
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<tbody>
<tr>
<td>Berne JD 2006</td>
<td>2006</td>
<td>Prospective screening protocol initiated based on injury criteria which led to CTA using a 16-slice scanner. Positive, equivocal, and suspicious studies were followed up with FVCA. Patients with negative studies were followed clinically. This is a subset of an earlier group that was then compared to CTA with a 4-slice scanner.</td>
<td>1. Incidence of BCVI diagnosed with 16-slice CTA was 1.2% (same as historic controls screened with FVCA) as compared to 0.38% with 4-slice CTA. 2. No patient with an initial negative CTA went on to develop symptoms. 3. Mortality improved from 59% to 29% with screening. 4. Screening for BCVI is indicated as it can decrease BCVI-related mortality.</td>
<td>3. Diagnostic screening with 16-slice CTA accurately identifies all clinically significant BCVI. 4. Screening for BCVI is indicated as it can decrease BCVI-related mortality.</td>
</tr>
<tr>
<td>Biffl WL 1998</td>
<td>1998</td>
<td>Retrospective registry review of 15,331 blunt trauma patients. Compared unscreened population (prior to 1996) to screened population (after 1996).</td>
<td>1. Incidence of BCVI prior to screening was 0.38% of which 72% were asymptomatic. 2. Incidence of BCVI post-screening was 0.86%. 3. Screening strategy did not improve survival. 4. Screening is impractical at most institutions.</td>
<td>1. Diagnostic screening with CTA accurately identifies all clinically significant BCVI. 2. FVCA is impractical as a screening mechanism. 3. FVCA misses all clinically significant BCVI.</td>
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</table>
There is a trend to neurologic improvement in symptomatic BCI patients treated with heparin.

Hemorrhagic complications of anticoagulation are common in the trauma population.

**Recommendations:**

1. Aggressive screening for BCI based on injury patterns is warranted.
2. Early institution of heparin therapy is indicated (with a target aPTT of 40-50).
3. Follow-up angiography should be withheld until at least 7 days post injury.
4. Heparin should be withheld (with a target APTT of 40-50).

**Findings:**

### II

- **Grade II injuries**
  - 10% healing rate with heparin.
  - 3% risk of stroke if untreated.
  - 70% progressed to higher grade.

### III

- **Grade III injuries**
  - 8% healed with heparin initially.
  - One occluded.
  - 33% stroke rate if untreated.
  - 8% healed with heparin initially.
  - 11% stroke rate if untreated.
  - 70% progressed to higher grade.

**Design:** Initially retrospective review followed by prospective protocol.

<table>
<thead>
<tr>
<th>Grade</th>
<th>Healing Rate</th>
<th>Stroke Rate</th>
<th>Progression Rate</th>
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<tbody>
<tr>
<td>II</td>
<td>10%</td>
<td>3%</td>
<td>70%</td>
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<tr>
<td>III</td>
<td>8%</td>
<td>33%</td>
<td>11%</td>
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If GI or II progressed to III, none healed.

5. Grade IV injuries:
   a. None healed with medication alone.
   b. 44% stroke rate if untreated.

6. Grade V (transection) - 100% mortality

Recommendations:
1. Repeat angiogram at or after 10 days to evaluate for evolving or healed lesion.
2. Grade II injuries should be treated with heparin anticoagulation.
3. Grade III injuries:
   a. Surgical repair is front-line therapy in accessible lesions.
   b. Stenting for BCAI is risky in the acutely injured artery and should be delayed 7 days.
   c. Endovascular stents placed in traumatized arteries should be treated adjunctively with full systemic anticoagulation.
4. Grade IV injury - treat with heparin anticoagulation to prevent stroke.

3. Signs
   a. Seat-belt abrasion or other soft tissue injury of the anterior neck resulting in significant swelling or altered mental status

4. Fracture in proximity to internal carotid or vertebral artery
   a. Basilar skull fracture involving the carotid canal
   b. Cervical vertebra fracture

Findings:
1. Incidence of BCVI in screened population was 34%
2. In patients screened for symptoms incidence was 70%.
3. In asymptomatic patients incidence was 27%.
4. Linear regression analysis identified these risk factors for BCVI:
   a. GCS ≤ 6
   b. Petrous bone fracture
   c. Diffuse axonal injury
   d. LeFort I or II fractures
   e. Cervical spine fractures (specifically for BVAI)

Recommendation:
1. Screening angiography based on the above criteria is indicated to identify BCVI.

Reference:
Cervical spine injury is independently associated with BCVI.

**Recommendations:**

1. Screening for BCVI is indicated and should include all those with cervical injury, unilateral headache, and posterior neck pain when sudden, severe, and unlike previous pain.

2. Arteriography is the gold standard for diagnosis of BCVI.

3. Anticoagulation improves neurologic outcome.

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**Design:** Retrospective review of a prospective study conducted at a single tertiary care trauma center.

**Findings:**

- 7/23 false negatives and 8/23 false positives (sensitivity 68%, specificity 67%, PPV 65%, NPV 70%)
- MRA had 1/11 false negatives and 4/7 false positives (sensitivity 67%, specificity 70%, PPV 43%, NPV 69%)

**Recommendations:**

1. Angiography remains the gold standard for screening and diagnosis of BCVI at the time of this publication.

2. If DFVCA is unavailable CTA or MRA should be used to screen for BCVI in patients with a history of sudden, severe, and unlike previous pain.

---

**Design:** A retrospective review of a prospectively collected database.

**Findings:**

- Incidence of BCVI is found to be 1.55%

---

**Design:** A retrospective review of patients with BCVI at a single tertiary care trauma center.

**Findings:**

- Anticoagulation improves neurologic outcome.

**Recommendations:**

1. Screening for BCVI is indicated and should be performed in patients with cervical spine injury.

---
In patients diagnosed with BCAI, follow-up angiography showed healing of grade I injuries in 57% in 7-10 days and 8% grade II injuries (allowed cessation of Rx). However, 8% grade I and 43% grade II injuries progressed to pseudoaneurysm.

Grade III and IV injuries rarely changed in early follow-up (93% and 82% unchanged respectively).

23% of BCAI and 20% BVAI developed an INE and risk of INE increased with grade of injury. Trends towards improvement of neurologic outcome in both heparin vs. ASA (stroke rate was 1% on heparin and 9% on ASA, p=0.07) and heparin vs. no therapy but not statistically significant.

There was a complication rate of 22% with anticoagulation. 20/22 bleeds were on aggressive therapeutic protocol (bolus dose followed by PTT of 60-80), while 2/53 patients (46%) on a non-aggressive heparin protocol developed INE. Subsequently, a less aggressive protocol resulted in only a 4% incidence of INE.

Recommendations:

1. Follow-up angiography is recommended at 7-10 days because findings that will require a change in management are likely.

2. Anticoagulation is recommended for the treatment of BCVI in those patients without contraindication. A non-aggressive heparin protocol is suggested.

3. Grade IV injuries are unlikely to improve without intervention.

Design: Prospective evaluation of 16-slice CTA in a non-invasive screening role. A positive CTA was confirmed with DFVCA. Patients with a negative CTA were followed clinically.
<table>
<thead>
<tr>
<th>Findings</th>
<th>Recommendations</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. No patient with a negative CTA developed neurologic signs of BCVI.</td>
<td>16-slice CTA is a reliable noninvasive screening test for clinically significant BCVI.</td>
</tr>
</tbody>
</table>
| 2. False positive rate of 1.2% with CTA. | **Findings:**
| 3. Most liberal screening protocol continues to miss clinically significant BCVI. | **Findings:**
| 4. Duplex US missed 1/3 injuries in which a normal head CT. | 3. No injury was detected based on the multiaxial review of images obtained by either a 4 and 8 slice CT. | 2. When evaluating data obtained by pooling images obtained by either a 4 and 8 slice CT. |

**Recommendations:**
- Imaging sensitivity will likely improve with newer generation technology.
- Angiography continues to have higher sensitivity and specificity when compared to 4 and 8-slice CTA.
- Imaging sensitivity will likely improve with newer generation technology.

**Findings:**
- When evaluating data obtained by pooling images obtained by either a 4 and 8 slice CT. |

**Recommendations:**
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**Findings:**
- When evaluating data obtained by pooling images obtained by either a 4 and 8 slice CT. |

**Recommendations:**
- Imaging sensitivity will likely improve with newer generation technology.
- Imaging sensitivity will likely improve with newer generation technology.

**Findings:**
- When evaluating data obtained by pooling images obtained by either a 4 and 8 slice CT. 
1. Screening of asymptomatic patients is not justified.

2. Duplex scanning is not useful for the diagnosis of BCVI.

3. The optimal method of management for complex lesions is poorly defined.


5. The spectrum of blunt injury to the carotid artery: a multi-center perspective.


Design: Prospective review of 49 patients (60 injuries) from 11 institutions.

Findings:

1. Neurologic symptoms may develop after blunt carotid injury in a delayed fashion.

2. Injuries with complete arterial thrombosis are associated with high mortality and poor neurologic outcome in proportion to the initial degree of neurologic impairment.

3. Sensitivity of Duplex US is 86%.

4. Injury specific mortality was 19.4%.

Recommendations:

1. Surgical repair is indicated for the treatment of pseudoaneurysms in accessible locations.

2. Systemic anticoagulation is the primary method of treatment for arterial dissections in the absence of a pseudoaneurysm or complete thrombosis.

3. The optimal method of management for arterial thrombosis remains poorly defined.


5. The spectrum of blunt injury to the carotid artery: a multi-center perspective.

<table>
<thead>
<tr>
<th>Author</th>
<th>Year</th>
<th>Design</th>
<th>Findings</th>
<th>Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coldwell DM</td>
<td>2000</td>
<td>Case series of 14 patients with blunt carotid pseudoaneurysms treated with metallic endoprostheses and anticoagulation.</td>
<td>1. No patients developed neurologic symptoms. 2. 12/14 patients showed complete healing at 2 month follow-up.</td>
<td>Endovascular stenting with metallic endoprostheses followed by anticoagulation is safe and effective in the treatment of carotid pseudoaneurysm.</td>
</tr>
<tr>
<td>Colella JJ</td>
<td>1996</td>
<td>Retrospective database review which identified 20 patients with BCAI.</td>
<td>1. 10/12 patients treated with heparin survived and had normal neurologic function. 2. 2 patients died while on heparin, one from infarct progression and one from hemorrhage. 3. 2 patients treated with antiplatelet therapy (aspirin, 325mg/day) and survived without deficit.</td>
<td>Patients without contraindication to heparin should be heparinized, however “with careful patient selection, a delay in the initiation of heparin therapy, no therapy, or aspirin should be considered.”</td>
</tr>
<tr>
<td>—</td>
<td>2000</td>
<td>Case series of 14 patients with blunt carotid pseudoaneurysms treated with metallic endoprostheses and anticoagulation.</td>
<td>Treatment of posttraumatic internal carotid arterial pseudoaneurysm resulted in complete healing with minimal neurologic symptoms.</td>
<td></td>
</tr>
</tbody>
</table>
| Design: Prospectively collected database of patients with CAI treated with antithrombotic agents alone. Post-stenting patients were placed on therapeutic warfarin. Stent patients received follow-up angiography. Patients treated with antithrombotic agents alone were followed clinically.

**Findings:**

1. 45% of patients who underwent carotid stenting had documented occlusion v. 5% of patients receiving antithrombotic agents alone. However, only 2/23 received post-stent antiplatelet agents (18 received heparin to warfarin, 3 received nothing).

2. There was a 21% procedure-related complication rate associated with stenting.

3. Of 27 asymptomatic patients with BCVI treated with anticoagulation, none developed an INE. (19%) developed an INE who did not receive anticoagulation secondary to their INE.

**Recommendations:**

1. Asymptomatic patients with BCVI and no contraindication to anticoagulation should be anticoagulated to reduce the incidence of INE.

2. Anticoagulation is the gold standard therapy for BCVI. Risks exceed benefits.
selective cases and antithrombotic agent therapy remains the cornerstone of treatment for posttraumatic pseudoaneurysms.

Cothren CC 2005  Screening for blunt cerebrovascular injury is cost effective

**Design:** Retrospective review, multi-institutional

**Findings:**
1. Extrapolating from previously published data for BCVI, with anticoagulation, it is estimated that this prevented 32 ischemic neurologic events (INE).
2. Further extrapolating based on previously obtained data in which the mortality of patients with and without INE was 18% and 7% respectively, the authors estimate that this prevented 3.2 lives.
3. Extrapolating from previously reported charges of $6,500 per angiogram, the authors report a charge of $146,672 per INE avoided or $1,476,719 per life saved.
4. This prevented 3.2 lives.

**Recommendations:**
1. Screening of selected at-risk patients for BCVI with angiography is cost effective.
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3. Based on charges of $6,500 per angiogram, the authors report a charge of $146,672 per INE avoided or $1,476,719 per life saved.
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4. This prevented 3.2 lives.
Combination of head injury + facial fractures or head injury + C-spine injury had an increased risk of BCI.

Recommendations:
1. Duplex scan appears to be a useful screening test in patients at increased risk for BCD.
2. A positive duplex scan should be followed by angiography of the aortic arch with selective studies of the carotid arteries.

Note:
- Based on the small number of symptomatic patients, a cervical seat belt sign should not serve as a sole indicator for evaluation of the carotid artery in the absence of other pertinent signs or symptoms.
- A cervical seat belt sign should be followed by a Dairama C scan to rule out BCI.

Findings:
- One patient was found to have a BCI by duplex scan (incidence of 0.76%). This patient had presented with lateralizing signs.
- No initially asymptomatic patient (50 patients) was found to have a BCI by duplex scan.

Recommendations:
1. No patient was anticoagulated because they all were identified after the development of BCI.
2. A cervical seat belt sign should not serve as a sole indicator for evaluation of the carotid artery in the absence of other pertinent signs or symptoms.

Note:
- Based on the small number of asymptomatic patients (50) and an estimated 1.5% incidence of BCVI in a screened asymptomatic population, it is likely that no injuries were present in the asymptomatic group.
### 1. Recommendations:
- The use of endovascular stents may provide a safe and effective alternative to surgery and medical therapy for the management of BCIs.
- In light of the better outcomes of children with elevations in ICP following ischemic stroke as compared to adults, aggressive ICP management including resection of infarcted tissue is indicated should intractable intracranial hypertension develop.

### Findings:
- Five of the patients had healing on repeat angiography at 2 months. The sixth had healing at 7 months.
- There was no stenosis or thrombosis of the stents in this series (follow up 2-7 months).
- Two patients had complications. One required anticoagulation to be discontinued and this patient was changed to aspirin with no anticoagulation. The other patient was discharged on aspirin and warfarin.

### Recommendations:
- The use of endovascular stents may provide a safe and effective alternative to surgery and medical therapy for the treatment of BCIs.

### Design:
- Case series of 6 patients who were treated with stenting for worsening pseudoaneurysm on repeat angiography. Stents were anticoagulated with heparin followed by coumadin for 8 weeks followed by aspirin for 1 additional month.

### Findings:
- By aspirin for 1 additional month, there was no stenosis or thrombosis of the stents. Two patients had complications, one of whom required discontinuation of anticoagulation.

### Recommendations:
- The use of endovascular stents may provide a safe and effective alternative to surgery and medical therapy for the treatment of BCIs.
Findings:
1. 46 BCVI's were identified in 43 patients (20 negative CTA were followed with angiography).

**Note:** This is the only study in which both positive and negative CTA were followed with angiography.

Recommendations:
1. Suggested a prospective, randomized, multiinstitutional trial of heparin vs. antiplatelet therapy.
2. Despite findings above, recommended anticoagulation with heparin followed by warfarin for 3-6 months followed by lifelong aspirin in patients with CTA negative for BCVI. 16 patients were screened for BCVI with 15-screen CTA.

**Design:** Prospective, blinded observational study.

**Eastman, AL 2005**

**Computed Tomographic Angiography for the Diagnosis of Blunt Cervical Vascular Injury:** Is it ready for primetime? A prospective, observational study.

| Patients | 162 patients screened with CTA. 16 did not receive arteriogram secondary to refusal of consent (12) or early discharge (4). 6 patients died from non-neurologic causes prior to arteriogram. 162 patients were screened with CTA. 162 patients were screened for BCVI with 15-screen CTA. Patients were screened for BCVI with CTA. 15-screen CTA.
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<tr>
<td>16-channel, multislice CTA is an effective and sensitive diagnostic test modality for the detection of BCEVI.</td>
<td></td>
</tr>
<tr>
<td><strong>Recommendations:</strong></td>
<td>Specifi city for BVAI was 100%. Sensitivity of CTA for BVAI was 96.1%. Specifi city for BCEVI was 100%. Sensitivity of CTA for BCEVI was 100%. Respectively.</td>
</tr>
<tr>
<td>2. PPv of NPA and accuracy of 16-slice CTA for BCEVI over all the sensitivity, specificity, specifi city of 1.25% and an incidence of 28.4% in the BCEVI, 26 BVAI for an overall incidence of 28.4% in the screened population.</td>
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<td>A retrospective review of a trauma registry which identified 67 patients with 87 BCAIs over 11 years.</td>
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</tr>
<tr>
<td><strong>Recommendations:</strong></td>
<td>1. Heparin anticoagulation was associated with better neurologic outcome and higher survival than no treatment.</td>
</tr>
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</table>

16 or the 21 deaths were directly related to strokes due to BCEVI. 3. 16 of the 21 deaths were directly related to strokes due to BCEVI. 2. 77 patients received heparin. 8 no therapy. 6 were neurologic exam inconsistent with CTH. 1. Most common indication for anticoagulation therapy. Ann Surg. 1996;223:513-525

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<tr>
<th>preventative_thromboembolism</th>
<th>BVAI (cervical stroke secondary to vertebral artery injury)</th>
<th>II</th>
<th>Friesen D</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Findings:</strong></td>
<td>Inaccessible lesions can be safely treated.</td>
<td>1995</td>
<td>Friesen D</td>
</tr>
<tr>
<td>2. Patients with BVAI with a neck deviation and risk of multiple vessel injury.</td>
<td></td>
<td>1988, 1989</td>
<td>Friesen D</td>
</tr>
<tr>
<td>1. Complete FVEA is recommended because of risk.</td>
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<tr>
<td><strong>Recommendations:</strong></td>
<td>Vascular injury after acute cervical spine trauma.</td>
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<tr>
<td>Preventive angiography and MRA of cervical spine: No contraindication when all patients with cervical injury underwent MRA in non-rando</td>
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<tr>
<th>facial_and_abdominal_neurologic_deficit</th>
<th>Symptomatic indirect trauma to the cervical artery was assessed.</th>
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<th>Friesen D</th>
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<td>1. Facial and abdominal neurologic deficits.</td>
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<tr>
<td>3. 40% of patients had new one infarct.</td>
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<tr>
<td>2. 80% of patients developed symptoms in delayed post-amission.</td>
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<td>1. All patients diagnosed after the development of symptoms.</td>
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<td>2. Patients with BCVI with a fixed deficit and inaccessible lesions can be safely treated with heparin.</td>
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<td>1988, 1995</td>
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<tr>
<td>1. The presence of focal neurologic deficits suggested possible carotid artery injury.</td>
<td></td>
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</table>
4. Only one patient had treatment directed at the BVAI (heparin).

Recommendations:

1. MR imaging should be utilized to screen for vascular injury in the acutely injured cervical spine.

Findings:


II

1. Patients with cervical spine injury:

Recommendations:

1. Angioembolization is useful in the treatment of symptomatic V/A dissections and pseudoaneurysms. No neurologic outcomes are reported.

Findings:


III

1. Excellent technical success is reported but no neurologic outcomes are reported.

Findings:

1. Excellent technical success is reported but no neurologic outcomes are reported.

Recommendations:

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1. Patients with cervical spine injury:

Recommendations:

1. MR imaging should be utilized to screen for vascular injury in the acutely injured cervical spine.

Findings:


Design: Prospective protocol in which all patients with cervical spine injury were studied. No confirmatory angiography was performed.

1. Excellent technical success is reported but no neurologic outcomes are reported.

Findings:


Design: Prospective protocol in which all patients with cervical spine injury were studied. No confirmatory angiography was performed.

Recommendations:

1. MR imaging should be utilized to screen for the BVAI (heparin).

Design: Retrospective review of 18 patients over 22 years.

Findings:
1. Development of symptoms was usually delayed for a period ranging from 4 hours to 1 month.
2. Bilateral lesions were common (50%).
3. Bilateral lesions were common (50%)

Recommendations:
1. When a carotid lesion is suspected bilateral angiography should be performed.


Design: Retrospective review of 18 patients over 22 years.

Findings:
1. Incidence of incidental CAI is 3.7%.
2. 1/2 patients who underwent observation alone died.
3. No patient treated medicinally (4 given heparin followed by warfarin, 1 treated with aspirin) had infarction or hemorrhagic complication.

Recommendations:
1. MRI/MRA screening of the head and neck should be included for patients who fit the profile for occult carotid injury.
2. Medical therapy provides excellent results.
3. MRI/CTA should be included with cranial CT scan for patients with head injury.


Design: Prospective collection data utilizing liberal screening criteria for the detection of symptomatic blunt carotid and vertebral artery injuries in head injured patients. Patients were subsequently treated medically.

Findings:
<table>
<thead>
<tr>
<th>Findings:</th>
<th>III</th>
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<tbody>
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<td>1. Fracture of foramen transversarium</td>
<td></td>
</tr>
<tr>
<td>2. CVA, TIA</td>
<td></td>
</tr>
<tr>
<td>3. Massive epistaxis</td>
<td></td>
</tr>
<tr>
<td>4. Severe flexion/extension injury of the C-spine</td>
<td></td>
</tr>
<tr>
<td>5. Massive facial fracture</td>
<td></td>
</tr>
<tr>
<td>6. Neck hematoma</td>
<td></td>
</tr>
<tr>
<td>7. Massive facial hematoma</td>
<td></td>
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<tbody>
<tr>
<td>1. Liberal screening is justified.</td>
<td>Kraus RR</td>
</tr>
<tr>
<td>2. They will continue to anticoagulate with heparin followed by warfarin in patients without contraindication. (Expert opinion)</td>
<td>Kraus RR</td>
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<tr>
<td>3. In patients with contraindications they recommend aspirin or aspirin and warfarin. (Expert opinion)</td>
<td>Kraus RR</td>
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**Findings:**

| 1. Of the 48 patients screened, 21 (44%) had BCVI (19 BCAI and 10 BVAI). |
| 2. Overall incidence was 1.1%. |
| 3. Of 1941 total blunt trauma victims 5 patients developed delayed symptoms and had been missed by screening criteria. |
| 4. No difference in outcome was documented. |
| 5. 43% of BCVI's were diagnosed prior to the development of neurologic symptoms. |
| 6. 100% of patients with severe facial hematoma had BCVI. |
| 7. Unexplained neurologic exam: 33% |
| 8. Basilar skull fracture: 42% |
| 9. Unexplained hemiparesis: 44% |
| 10. Transverse sinus: 60% |

**Recommendations:**

1. Liberal screening is justified.
2. They will continue to anticoagulate with heparin followed by warfarin in patients without contraindication. (Expert opinion)
3. In patients with contraindications they recommend aspirin. (Expert opinion)
**Findings:**

1. Limited, although favorable experience with Duplex scan.

**Recommendations:**

1. Anticoagulation is recommended for the treatment of BCAI in patients without contraindications.

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**Design:** Review of the National Pediatric Trauma Registry and thorough review of the adult literature.

**Findings:**

1. MRA is a reliable noninvasive method for diagnosis and follow-up of BCVI in 18 patients.

**Recommendations:**

1. MRA is a reliable noninvasive method for use in the diagnosis and follow-up of BCVI in 18 patients.

2. Conventional MRI is not as sensitive as MRA in the assessment of TAV.

3. Conventional angiography is recommended as an alternative.

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**Design:** Review of the National Pediatric Trauma Registry and thorough review of the adult literature.

**Findings:**

1. There is an increased incidence of BCVI in children with chest trauma, combined head and chest trauma, basilar skull fractures, intracranial hemorrhage, and clavicle fractures.

2. Children and adults are similarly susceptible to the adverse sequelae of BCVI.

**Recommendations:**

1. Anticoagulation is recommended for the treatment of BCAI in patients without contraindications.

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**Design:** Prospective protocol in which MRA was evaluated in angiographically confirmed BCVI in 18 patients.

**Findings:**

1. MRA found to be superior to MRI with sensitivity of 95% and specificity of 99% overall.

2. For vertebral injuries specifically MRA was only 60% sensitive.

**Recommendations:**

1. MRA is a reliable noninvasive method for use in the diagnosis and follow-up of BCVI.

2. Conventional angiography is recommended in the assessment of VAI.

3. Conventional MRI is not as sensitive as MRS for the evaluation of BCVI.
Incidence of BCVI was found to be 0.03% (15/57,659). 40% (6) had neurologic complication.

Recommendations:
1. Screen, diagnose, and treat children for BCVI similarly to adults.

Louw JA

Findings:
1. 4 patients were found incidentally when screening for other injuries.
2. 2 patients were treated operatively; one was treated surgically.
3. One patient was treated with angioplasty.
4. All had one patent vertebral artery.

Recommendations:
1. Vertebral artery angiography is indicated in all patients with neurological deficit above the level of potential spinal cord injury.
2. Vertebral artery angiography should be considered in all patients with cervical facet dislocations.
3. Evaluation of the vertebral arteries should be routine in all patients with neurological deficits above the level of potential spinal cord injury.

Martin RF

Findings:
1. 71.4% of 5 had bilateral occlusions.
2. 2 patients with unilateral dislocation were evaluated for BVAs.
3. 3 patients were treated operatively, two with asymptomatic occlusion of the common carotid artery, and one with recurrent transient ischemic attack (TIA).
4. All had complete neurologic recovery or remained asymptomatic.
5. Only one patient was treated with heparin and did not develop symptoms.

Recommendations:
1. Occlusion of the vertebral artery in cervical spine dislocation should be evaluated for BVAs.
2. All patients with cervical spine injury should be evaluated for BVAs.
3. NCVA is similar to adults.

Acknowledgements:
1. Scenario diagnosis and treatment for BCVI.
Recommendations:

1. Angiography is recommended for screening in patients being screened for possible aortic injuries.
2. Angiography is recommended if neurological exam does not correlate with intracranial findings.
3. Surgery is recommended for those with accessible lesions. (Expert opinion)
4. Anticoagulation (unless contraindicated) is recommended for small intimal lesions. (Expert opinion)

Findings:

1. Of 30 patients, 27 (90%) were identified in 22 patients for an overall incidence of 0.07%.

Design: Retrospective review of 22 patients identified over 8 years.

References:


### Recommendations

<table>
<thead>
<tr>
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<tbody>
<tr>
<td><strong>III</strong></td>
<td><strong>Design:</strong> Retrospective review.</td>
</tr>
<tr>
<td><strong>Findings:</strong></td>
<td>Stroke rates vary with injury type in untreated patients: a. dissection 14%, b. occlusion 90%, c. pseudoaneurysm 50%, d. carotid-cavernous fistula 67%.</td>
</tr>
<tr>
<td><strong>Recommendations:</strong></td>
<td>Limited screening resources should focus on risk factors for occult extracranial injury: namely, low GCS and significant thoracic trauma as ECAI is more likely to benefit from identification prior to the onset of symptoms.</td>
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<td>Design</td>
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<tr>
<td>Prospective observational study.</td>
<td>Decreased sensitivity to 3.3%, including early deaths as having BEVI.</td>
</tr>
<tr>
<td>Prospective screening for blunt CVI.</td>
<td>CT with 4 slice scanner had a sensitivity of 99.4% and specificity of 98.6%. (Worst case)</td>
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</table>

**Findings:**

1. Accuracy of Doppler US for detection of carotid artery stenosis was only 38.5% if you exclude deaths where only 19.2% of patients were identified. |

**Recommendations:**

1. CT and MRA are inadequate for screening; conventional angiography remains the standard for diagnosis. |

2. Aggressive screening for BCVI is indicated prior to the development of symptoms. |

3. Treatment of patients with asymptomatic BCVI is indicated to prevent progression to INE. |
### Recommendations:

1. Duplex US is not useful in the diagnosis of BCVI.

2. CT angiography with 4 slice scanner is useful in the diagnosis of BCVI.

### Findings:

**Patients with BCVI**

- A retrospective chart review looking at

### Design:

**Retrospective review of 33 patients with BCVI**

**Findings:**

1. Incidence of BCVI was found to be 0.24%.

### Recommendations:

1. BCVI patients with ICH should not be treated with heparin anticoagulation.

### Findings:

1. 2/4 patients with ICH treated with heparin had worsening of the ICH.

### Design:

**Case series of quadriplegic patients with cervical spine injuries all at C4-C6 with subluxation on C-spine films. Conclusion lateral subluxation puts you at high risk of VA I. In 27 patients found to have VA injury over 12 years all were seen to have lateral subluxation with some element of broad vertebral displacement.

### Recommendations:

1. Spinal stabilization is recommended early.

2. The artery may need ligation or embolization.

### Findings:

1. In 12 patients found to have VA injury over 12 years all were seen to have lateral subluxation with some element of broad vertebral displacement.

### Design:

**A retrospective chart review looking at patients with BCI.**

### Findings:

1. Incidence of BCAI was found to be 0.24%.

2. Head + chest injuries increase risk of BCAI by 14X.

### Recommendations:

1. BCAI patients with ICH should not be treated with heparin anticoagulation.

2. BCVI patients with ICH should not be treated with heparin anticoagulation.

### Findings:

1. 2/4 patients with ICH treated with heparin had worsening of the ICH.

### Design:

**Retrospective review of 33 patients with BCVI**

1. 2/4 patients with ICH treated with heparin had worsening of the ICH.

### Recommendations:

1. Duplex US is not useful in the diagnosis of BCVI.

2. CT angiography with 4 slice scanner is useful in the diagnosis of BCVI.
### Findings

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<td>III</td>
<td>1988</td>
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### Recommendations

1. Repair of injured vessel is safe and effective in patients with carotid injuries in whom prograde flow continues and there is only mild neurological deficit present.

2. Repair is not indicated if there is complete occlusion, severe neurological deficit and altered consciousness.

3. Patients with BCAI not detected by blunt trauma. Any type of anticoagulation has been shown to be safe and effective in reducing neurological morbidity and mortality, especially those with symptomatic disease.

4. Patients who underwent anticoagulation of carotid artery injuries caused by blunt trauma. Any type of anticoagulation has been shown to be safe and effective in reducing neurological morbidity and mortality, especially those with symptomatic disease.

### Patients who underwent anticoagulation of carotid artery injuries caused by blunt trauma.

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### Findings

1. Patients who underwent anticoagulation of carotid artery injuries caused by blunt trauma. Any type of anticoagulation has been shown to be safe and effective in reducing neurological morbidity and mortality, especially those with symptomatic disease.

2. Patients who underwent anticoagulation of carotid artery injuries caused by blunt trauma. Any type of anticoagulation has been shown to be safe and effective in reducing neurological morbidity and mortality, especially those with symptomatic disease.

3. Patients who underwent anticoagulation of carotid artery injuries caused by blunt trauma. Any type of anticoagulation has been shown to be safe and effective in reducing neurological morbidity and mortality, especially those with symptomatic disease.
### Findings

1. The use of CT A increased the detection of BCAI from 0.06% to 0.19%.
2. Duplex Ultrasound missed 2/3 injuries in which it was used to screen for BCAI.
3. Patients with asymptomatic BCAI should be anticoagulated to prevent INE.
4. Anticoagulation was associated with improved neurologic outcome.

### Recommendations

1. All patients undergoing evaluation for blunt aortic injury should be screened for BCAI.
2. Anticoagulation is recommended as the most effective therapeutic modality.

### Findings

1. The use of CTA increased the detection of BCAI from 0.06% to 0.19%.
2. Duplex Ultrasound missed 2/3 injuries in which it was used to screen for BCAI.
3. Patients with asymptomatic BCAI should be anticoagulated to prevent INE.
4. Anticoagulation was associated with improved neurologic outcome.

### Recommendations

1. All patients undergoing evaluation for blunt aortic injury should be screened for BCAI.
2. Anticoagulation is recommended as the most effective therapeutic modality.
1. The incidence of BCVI as detected by 8-slice CTA was 1.1% (as confirmed by DFA) or 1.3% when combined, with 4 patients undergoing positive CTA and negative DFA and 0 patients with negative CTA and positive DFA.

**Findings:**
- BCAI presented without neurologic deficit.
- There was a 16% complication rate (2/12 patients) related to anticoagulation.
- No patient with negative CTA developed stroke.
- No patients went on to complete stroke in the post-CTA group.

**Recommendations:**
1. The inclusion of CTA in the admission work-up for patients at risk for BCAI is safe and effectively increases the frequency of diagnosis of this injury.

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**Design:**
Prospective, non-randomized study of a CTA screening protocol utilizing an 8-slice CT scanner.

**Findings:**
- The presence of cervical or thoracic seat belt seen should prompt diagnostic evaluation.
- The presence of cervical or thoracic seat belt seen should raise the suspicion for the presence of occult vascular injury and in the presence of an abnormal physical exam the possible injury should be considered.
- The incidence of BCVI as detected by 8-slice CTA was 1.1% (as confirmed by DFA) or 1.3% when combined, with 4 patients undergoing positive CTA and negative DFA and 0 patients with negative CTA and positive DFA.

**Recommendations:**
1. Cervical or thoracic seat belt seen is associated with a 3% risk of BCVI.

---

**Design:**
Prospective, non-randomized study of 131 patients with seat-belt signs after blunt trauma.

**Findings:**
- The prevalence of occult vascular injury and in the presence of an abnormal physical exam the possible injury should be considered.
- The incidence of BCVI as detected by 8-slice CTA was 1.1% (as confirmed by DFA) or 1.3% when combined, with 4 patients undergoing positive CTA and negative DFA and 0 patients with negative CTA and positive DFA.

**Recommendations:**
1. Cervical or thoracic seat belt seen is associated with a 3% risk of BCVI.

---

**Design:**
Prospective, non-randomized study of 131 patients with seat-belt signs after blunt trauma.

**Findings:**
- The incidence of BCVI as detected by 8-slice CTA was 1.1% (as confirmed by DFA) or 1.3% when combined, with 4 patients undergoing positive CTA and negative DFA and 0 patients with negative CTA and positive DFA.

**Recommendations:**
1. Cervical or thoracic seat belt seen is associated with a 3% risk of BCVI.
1.4% based on CTA alone (including those 4 patients treated based on the CTA alone).

2. The incidence of delayed stroke rate and injury-specific mortality went down from 67% to 0% and 38% to 0% from pre to post-screening period.

3. Of the 23 confirmatory angiograms, 8 were found to be falsely positive.

4. The only significant predictor of BCVI by linear regression analysis was cervical spine injury.

Recommendations:
1. Liberal screening utilizing 8-slice CTA is recommended to identify BCVI prior to neurologic event.


Design: Retrospective registry review of 22 patients diagnosed with BCAI. 7 of which were treated with heparin and 7 treated with antiplatelet agents.

Findings:
1. There was no difference in neurologic outcome between groups.
2. Heparin-treated patients had significantly higher bleeding risk (4 patients had bleeding complications vs. none on antiplatelet agents).

Recommendations:
3. Use antiplatelet therapy in patients who are at high risk for bleeding complications and/or have concomitant torso injuries or intracranial injuries.


Design: Prospective non-randomized review of a screening protocol utilizing MRI/MRA for the detection of vertebral artery injury after cervical spine injury.

Findings:
1. The incidence of delayed stroke rate and injury-specific mortality went down from 67% to 0% and 38% to 0% from pre to post-screening period.

Recommendations:
1. Liberal screening utilizing 8-slice CTA is recommended to identify BCVI prior to neurologic event.

Design: Prospective non-randomized review of a screening protocol utilizing MRI/MRA for the detection of vertebral artery injury after cervical spine injury.
Findings:

1. Of 38 patients with cervical spine injury there were 4 vertebral artery injuries identified.
2. All BVAI were associated with fracture through the ipsilateral foramen transversarium.
3. All patients found to have BVAI were treated initially with antiplatelet agents and 2 were systemically anticoagulated.
4. No patient developed INE.

Recommendations:

1. Patients with cervical spine injury, particularly fracture through the foramen transversarium are at high risk for BVAI and should undergo diagnostic evaluation for this injury.


Findings:

1. In this population the incidence of BVAI was found to be 46%.
2. No patient had neurologic dysfunction secondary to the BVAI.
3. Patients with non-occlusive injury (3) were secondary to the BVAI and went on to heal on this therapy. 1 patient had an enlarging pseudoaneurysm and was treated with anticoagulation. 2 went on to heal on this therapy. 3 patients with non-occlusive injury (3) were treated with anticoagulation. 2 went on to heal on this therapy. 1 patient had a pseudoaneurysm and was treated with anticoagulation.

Recommendations:

1. Vertebral angiography should be considered before surgical reduction & stabilization in patients sustaining significant subluxation.
Recommendations: 

1. The presence of CC fracture had a 
   Retrospective review of patients found to 
   Have cervical canal (CC) fracture who subsequently 
   underwent cervical angiography within 7 days. 

Findings: 

1. Of the 8 patients with fracture into the vertebral 
   foramen, 7 had BVCAI. 
2. 2 of these 7 had clinical evidence of vertebral 
   artery injury, with the vertebral fracture in 8/10 patients. 

Recommendations: 

1. The incidence of BVCAI in patients with vertebral 
   fractures was 88%, in light of the low incidence of symptomatic 
   injury, the authors recommend reserving angiography for patients with 
   symptoms of vertebral-basilar artery stroke.
2. No difference in outcome between those 4 of 
   whom underwent angiography versus those 4 of 
   whom were managed without angiography was noted.
3. Association of internal carotid artery injury with carotid 
   canal fractures in patients with head injury and a 
   Retrospective review of patients found to 
   have carotid canal (CC) fracture who subsequently 
   underwent cerebral angiography within 7 days. 

Findings: 

1. The presence of CC fracture had a sensitivity, 
   specificity, PPV, and NPV of 60%, 67%, 35%, and 85%, 
   respectively, for the detection of BCAI. 
2. This was not significantly better than other 
   CT findings typically associated with BCAI, which had a 
   sensitivity, specificity, PPV, and NPV of 69%, 79%, 35%, and 85%, 
   respectively.

Recommendations: 

1. Their injury is significant. 
2. Transverse process fractures of the cervical vertebrae are
   particularly when a comminuted fracture of lateral mass of transverse process is present. (more than 1 cm or fracture involving the
1. CC fracture is not useful as a single risk factor for the identification of BCAI.