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A Cohort Study of Blunt Cerebrovascular Injury Screening in Children: Are They Just Little Adults?

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Abstract

Background: Blunt cerebrovascular injuries (BCVI) are rare with nonspecific predictors, making optimal screening critical. Radiation concerns magnify these issues in children. The Eastern Association for the Surgery of Trauma (EAST) criteria, the Utah score (US) and the Denver criteria (DC) have been advocated for pediatric BCVI screening, though direct comparison is lacking. We hypothesized that current screening guidelines inaccurately identify pediatric BCVI.

Methods: This was a retrospective cohort study of pediatric trauma patients treated from 2005-2015 with radiographically confirmed BCVI. Our primary outcome was a false negative screen, defined as a patient with a BCVI who would not have triggered screening.

Results: We identified 7440 pediatric trauma admissions and 96 patients (1.3%) had 128 BCVIs. Median age was 16 (13, 17) years. A cervical-spine fracture was present in 41%. There were 83 internal carotid injuries, of which 73% were grade I or II as well as 45 vertebral injuries, of which 76% were grade I or II, $p=0.8$. More than 1 vessel was injured in 28% of patients. A cerebrovascular accident (CVA) occurred in 17 (18%); 8 were identified on admission and 9 identified thereafter. The CVA incidence was similar in those with and without aspirin use. EAST

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screening missed injuries in 17% of patients, US missed 36%, and DC missed 2%. Significantly fewer injuries would be missed using DC than either EAST or US, $p<0.01$.

Conclusions: BCVI does occur in pediatric patients and a significant proportion of patients develop a CVA. The DC appears to have the lowest false negative rate, supporting liberal screening of children for BCVI. Optimal pharmacotherapy for pediatric BCVI remains unclear despite a relative high incidence of CVA.

Keywords

blunt cerebrovascular injury; pediatric trauma; computed tomography angiogram; pediatric cerebrovascular accident; trauma

Background

Blunt cerebrovascular injuries (BCVI) are injuries to the carotid and vertebral arteries, thought to be related to a flexion / extension mechanism in the neck (1-5). Diagnosis is complicated in that approximately 66% of adult patients may be initially asymptomatic. As many as 33% of adult patients with a BCVI, however, will go on to develop a cerebrovascular accident (CVA) or other neurologic symptom related to their BCVI (3, 6). The incidence of CVA following BCVI in children is not well established (7, 8). The risk of CVA following BCVI in adult patients can be attenuated by anti-platelet and anti-coagulant therapy, from 64% to 7% for carotid and vertebral artery injuries (1, 7). While generally thought to be safe in children, limited data exist on as to the efficacy of anti-platelet and anti-coagulant therapy in children (7, 8). This lack of uniformity in treatment exists despite a similarly held understanding of the pathophysiology of BCVI in children and adults. The inability of providers to clinically diagnose these injuries prior to the evolution of a devastating complication coupled with the presence of an effective risk reduction strategy highlights the need to accurately and quickly identify pediatric patients with BCVIs.

The appropriate screening for BCVIs remains a hotly debated topic. Computed tomographic angiogram (CTA) has emerged in the recent years as the diagnostic study of choice, replacing four-vessel digital subtraction angiography as the gold standard test (9-13). While consensus regarding an appropriate approach to BCVI in adults is beginning to emerge, this is not yet present in pediatric patients and current pediatric guidelines are incompletely followed (1-5). The Eastern Association for the Surgery of Trauma (EAST) has made a Level III recommendation that pediatric patients should be screened according to the same guidelines as adults, acknowledging a paucity of pediatric-specific data (13). While a liberal pediatric screening strategy would likely improve BCVI detection rates, concerns regarding the oncogenic effects of ionizing radiation may limit widespread applicability of this strategy, in comparison to adults (14, 15). In an attempt to optimize pediatric BCVI screening, several groups have attempted to either apply adult screening guidelines to pediatric patients or derive pediatric specific scoring systems to help predict patients at increased risk for BCVI (2, 7, 16-18). The comparative efficacy of these approaches is unknown.

The objective of this study was to assess our institutional experience with pediatric BCVI and evaluate the efficacy of several screening guidelines: the current iteration of the Denver criteria (DC), EAST guidelines and the Utah Score (US) for pediatric BCVI (3, 10, 13, 16-18). The EAST and DC have been well described in the adult literature and are intended to help guide decision making for confirmatory CTA imaging (3, 13, 16). The DC have been recently updated in order to more fully account for the finding that certain high mechanism injury patterns place patients at risk for BCVI even in the absence of direct neck trauma (3). The US is a five component score derived and validated in pediatric trauma to quantify BCVI risk in pediatric patients and determine the need for screening (17, 18). We hypothesized that the commonly used adult BCVI screening criteria as well as the pediatric specific BCVI screening tools would all fail to identify a large number of pediatric patients with BCVI.

Methods

In order to answer this question, we queried our institutional trauma registry between 2005 and 2015. Our center is an urban, high volume, Level-1 adult and pediatric trauma center with a wide geographic catchment area. We included admitted trauma patients 18 years old who suffered a blunt injury or strangulation, survived at least 24 hours and who either underwent CTA or magnetic resonance angiogram (MRA) neck during their initial trauma evaluation or were diagnosed with a BCVI confirmed by CTA or MRA. We excluded patients with a penetrating mechanism as well as burn patients. Presence, location and grade of BCVI were ascertained based on the final radiographic interpretation by a board-certified radiologist (2). Data regarding patient demographics, injuries and clinical course were obtained from the institutional trauma registry and manual review of medical records.

The EAST, DC and US scoring systems were identified from published literature and retrospectively applied to the radiographic and clinical data available for each subject (3, 10, 13, 16-18). Within the pediatric specific US system, a score of 3 is the suggested threshold for obtaining imaging and associated with 39% incidence of BCVI (17, 18). During chart review, we sought to provide the most liberal interpretation of the available clinical data possible. The DC and US scores both referenced “focal neurologic” findings and we, retrospectively, scored this as positive if there was either an abnormal Glasgow Coma Score (GCS) or a localizing motor/sensory finding on admission. Similarly, we scored cervical spine injuries as positive if any injury was identified. The DC and EAST guidelines both made reference to a neurologic status incongruous with the severity of brain injury and accurately scoring this criterion was not possible with the available charting. Similarly the EAST guidelines make reference to diffuse axonal injury (DAI), which is an injury pattern that is not well captured in registry data and difficult to identify on admission CT imaging. We therefore used an admission GCS ≤ 6 as a surrogate for DAI (3, 10, 13, 16-18). The DC make reference to “scalp degloving” and this was scored as positive if a laceration requiring more than a single staple was identified (3).

The primary outcome of this study was the false negative rate (type II error) of the included clinical screening (i.e. EAST, DC or US) tests. These “screening failures” were defined as a patient who did not meet screening criteria for BCVI but was ultimately shown to have a

BCVI. False negative rates were calculated independently for the EAST, DC and US. We used a single positive item in the EAST and DC criteria and a US ≥ 3 as a screening threshold that warranted CTA confirmation (17, 18). These criteria were set to allow the most liberal application of the available tools. Further characterization of the screening tools' performance was limited by the clinically silent nature of the majority of BCVIs and the fact that the vast majority of pediatric trauma patients did not undergo a confirmatory CTA (3, 6).

A CVA was defined as radiographically proven areas of ischemia on CT or magnetic resonance imaging (MRI) study, confirmed by the final radiographic interpretation of a board certified radiologist. If a CVA was present on admission imaging, it was scored as a pre-hospital CVA; if present on follow-up imaging but not detected on admission imaging, the CVA was defined as occurring while in the hospital. Given the difficulties of associating areas of ischemia with the distribution of injured vessels, we did not categorize CVAs by a speculative relationship to the BCVI.

Data are presented as medians with 1st and 3rd quartiles; comparisons were made with Fischer's exact test and the Mann-Whitney U test, as appropriate. Statistical significance was set as $p < 0.05$. Data were analyzed with Microsoft Excel (Redmond WA) and GraphPad Quick Calcs (La Jolla CA) and STATA v 14.0 (College Station, TX). This project was reviewed and approved by the University of Washington Institutional Review Board.

Results

We identified 7440 blunt pediatric trauma admissions over the 10-year study period, of whom 558 patients underwent imaging of the neck for blunt trauma or strangulation injuries. We identified 96 patients with 128 BCVIs, a 1.3% incidence. The diagnosis of BCVI was made by CTA in 92/96 patient (96%), with the remainder made by MRA. The median age of those with radiographically proven BCVI was 16 (13, 17) years, the majority (59%) were male and most (60%) were injured following a motor vehicle crash. Median admission GCS was 3 (3, 11) and median ISS was 34 (21, 43) with a median head abbreviated injury severity score (AIS) of 4 (4, 5). In hospital mortality was 9%. A slight majority of patients (52%) had at least one spine fracture on admission imaging. The most common site was cervical spine (40%), followed by thoracic (11%), and lumbar spine (11%). A multi-level spine fracture was found in 10% of patients, TABLE 1. When patients with cervical spine injuries were examined, 21/38 patients (55%) had an injury at the level of C1, C2 or C3.

Within these 96 patients with a BCVI, we identified 128 injured vessels: 72% patients had a single vessel injured, 24% of patients injured two vessels, 3% patients injured three vessels and 1% of patients injured all four vessels. Within the cohort of 128 injured vessels, there were 83 carotid injuries (65%) and 45 vertebral injuries (35%); the injury patterns are described in TABLE 2.

A CVA was present on admission in 8/96 (8%) of patients with a BCVI; an additional 9/96 (9%) of patients developed evidence of a CVA during their hospital stay. The total CVA incidence in children diagnosed with a BCVI was 17/96 (18%), although approximately half

occurred before there was an opportunity for intervention. When patients with a CVA were examined, 5/17 (29%) had a two vessel injury and the remainder had a single vessel injury. A grade III or higher BCVI was present in 11/17 (65%). We found no significant difference between patients with and without CVAs in either the number of injured vessels or the grade of BCVI.

Aspirin was the most common therapy, used in 57/96 (59%) patients, however 34/96 (35%) patients received no anticoagulant or anti-platelet therapy, due to contraindications. In those nine children that developed CVA following admission, 67% were undergoing ASA therapy prior to the identification of their in-hospital CVA. Of the remaining 3 patients, 2 were on no anticoagulation and one patient developed a CVA following the planned occlusion of a pseudoaneurysm in the supraclinoid internal carotid artery.

We next sought to determine the false negative rate of the BCVI screening criteria. Within our cohort, the median number of positive Utah screening items was 2 (1, 3) for a median Utah score of 3 (1, 6). Importantly, 36% of patients with a radiographically proven BCVI had a Utah score of 2, excluding them from imaging (6, 9). EAST screening guidelines had a false negative rate of 17% and DC missed 2% of patients. The DC had a significantly lower false negative rate than either EAST or US, $p < 0.01$, TABLE 3. As screening failures are illustrative, we reviewed these in depth. There was only one patient who did not meet screening criteria for any of the three tools; this patient had a combination of an occipital condyle fracture and a 1st rib fracture. An additional patient presented with DAI and a GCS of 7, triggering imaging according to the Utah criteria but not according to DC or EAST.

In order to determine if there might be a combination of factors from the EAST, DC and US that would have a low false negative rate for BCVI, we next broke each composite score down by individual criteria. While no single criteria identified all patients with a BCVI, we did find that our liberal interpretation of “focal neurologic deficit” and a GCS ≥ 8 were both positive in 67% of patients with a known BCVI, FIGURE 2.

We did find that our cohort’s median age of 16 (13,17) years old was older than both the derivation (mean age 8.3, range 0.04-17years) and validation (mean age 8.6 ± 5.4 years) cohorts for the US (17, 18). It is possible that this pediatric specific score does not function appropriately in an older cohort with more mature anatomy and response to injury. In order to address this issue, we next considered only the youngest quartile of our cohort, $n=24$. The median age of our youngest quartile was 7 (4, 10) years and 4/24 (17%) had a CVA noted during their hospital stay. Within this youngest quartile, 7/24 (29%) of patients with a radiographically proven BCVI had a Utah score of 2 or less, a score that would not necessarily trigger imaging (17, 18). This suggests that even among the youngest cohort members the false negative rate of the US is still sizeable.

When we consider the clinically significant screening failures (i.e. patients who did not meet clinical screening criteria and developed a CVA), EAST screening criteria was falsely negative in 2/17 (11%) while the US was falsely negative in 1/17 (6%). The DC would have indicated screening in all patients with neurologic sequelae of their injury. This difference was not statistically significant. There were three deaths in patients with CVAs, only one of

which was clearly attributable to the cerebrovascular injury, a 15 year old with a grade V carotid injury after being struck by a car.

When compared to the published incidence of BCVI in the combined US derivation and validation cohorts, we observed a significantly higher incidence of BCVI in our cohort of patients undergoing CTA; 96/588 (16%) vs 58/645 (9%), $p < 0.001$ (17, 18). Given the identified number of BCVIs and CVAs, at the current ordering practices we would have to order six CTA necks in order to identify one BCVI and 33 CTAs to identify one patient with neurologic sequelae of their BCVI.

Discussion

In this study, we present the largest series of pediatric trauma patients with proven BCVI published to date. We demonstrate that the incidence of BCVI in children is similar to the BCVI rate in adults, higher than previously appreciated (7, 8, 13, 19-21). The incidence of CVA associated with BCVI, perhaps more importantly, is higher than anticipated and appears to be clinically relevant. These findings may lend credence to the more liberal use of imaging while screening for BCVI in children (5, 13, 16). The DC false negative rate is significantly lower than either the EAST or US in our cohort, providing the most opportunity for intervention to mitigate stroke risk. While we observed no statistically significant differences in the rate of clinically significant false negatives between the screening methodologies, the absolute numbers remains small.

A CVA can be a devastating clinical event and while the absolute numbers within this series are small, we found no significant difference in the rate of clinically significant false negatives between the screening methodologies. While underpowered to answer this question, we did not find an association between either the grade of BCVI or the number of vessels injured and the CVA rate in this cohort. These are disparate findings from the preponderance of the adult literature and while likely a result of the limited sample size, it is possible that the underlying etiology of the ischemic complications in children is different than in adults. Further investigation into this topic is warranted to elucidate the answer.

In adults, it has been recommended to screen based on recognized risk factors and to apply this same approach to pediatric patients by identifying high risk injury patterns and mechanisms of injury (13). The EAST, DC and US criteria are all attempts to organize the myriad risk factors into a clinically usable form to allow screening of high risk populations without needlessly screening low risk groups. The fact that there are patients in this study who were diagnosed with BCVI after undergoing a CTA despite not meeting any of the screening criteria highlights the idiosyncratic nature of CTA ordering by trauma care teams in the pediatric population. When the two screening failures of the DC are considered, both children had highly concerning imaging patterns that did not technically meet the established clinical screening criteria but were clear evidence of significant trauma. The injury pattern was concerning enough; however, that imaging was obtained based upon the clinical suspicion of the treating surgeon. This likely reflects practice across the country where patients with injuries not quite meeting formal screening criteria are indicated for screening based upon clinical concern. Clinical acumen can never be completely replaced by

a pre-established set of screening, although available guidelines aid, guide and sharpen trauma bay evaluation.

Prior work on this topic has focused on identification of pediatric risk factors for BCVI. In a series of 128 pediatric patients who met EAST screening criteria, 52 were eventually screened to identify 14 injuries, leading to the conclusion that risk factors in the pediatric population appear to mimic those seen in an adult population (16). In contrast, it has been shown that up to 2/3 of pediatric patients presenting with a CVA following BCVI did not have screening indications according to adult DC criteria, with the conclusion from this series of 45 patients being that there is a need for broader screening criteria with pediatric specific indications (5). These data suggest that the pediatric trauma provider needs to have a heightened level of suspicion for BCVI and there is a need for a reliable clinical scoring tool that can be reproducibly applied (7, 22). The breakdown of the predictive factors suggests that no single clinical or radiographic factor, no matter how liberally applied, will be sufficient to identify all pediatric patients with a BCVI, again supporting a liberal approach to screening.

This liberal approach to screening must be balanced against the concern about ionizing radiation in children. It has been suggested that the nearly four million CT scans obtained in children yearly potentially result in an additional 4,870 future cancers, clearly highlighting the importance of optimal patient selection for screening (14). Extrapolating this rate to our cohort suggests that the ionizing radiation associated with the 558 scans over ten years will result in an additional 0.68 cancers. While it seems biologically plausible that the oncogenic effects of radiation become less significant with increasing age of the child, this has not been rigorously tested and remains speculative. While we should always be cognizant of placing patients at additional future risk for present gain, our data suggests that with current screening practices, a BCVI is identified once every six screening CTAs with a clinically significant BCVI identified once in every 33 CTAs.

The focus of this work has been on optimizing the radiographic identification of a potentially significant traumatic injury. This must be balanced against the increased risk for future malignancy related to the increased radiation dose. This tradeoff is complicated by the fact that both events are rare: a 1.3% incidence of BCVI in our cohort (0.2% symptomatic) as compared to the risk of inciting a cancer, suggested to occur in 0.02% of pediatric patients who undergo a CT scan (14). This incidence of future cancers related to ionizing radiation is further complicated by the multiply interacting variables, including the cumulative radiation dose from all radiographic studies, the age of the child at the time of the study and their sex (14). While radiation dose can vary by the exact protocol, the imaging center and the patient's body size, the mean dose-length product (DLP) for a non-contrasted CT scan of the head was recently found to be 543 mGy-cm (15). In the US validation study, a CTA neck in pediatric trauma patients was found to have a mean DLP of 649 mGy-cm, approximately twice the radiation exposure of pediatric trauma patients who did not undergo a CTA neck (18). It is our assertion that the risks of failing to diagnose and appropriately manage a BCVI outweighs the risk of malignancy and as we continue to optimize BCVI screening tools and imaging techniques, we expect that this gap will continue to favor screening.

Given that radiographic imaging is more common in children treated at adult trauma centers than pediatric trauma centers, the US was an attempt to derive and validate a pediatric specific BCVI risk stratification tool in order to help focus imaging on high risk populations without unnecessarily irradiating young children (17, 18, 23, 24). Our study demonstrates a concerning high false negative rate for the US, far higher than in either derivation or validation cohorts (17, 18). The reason for this disparate finding is not immediately clear. While our cohort was older than the US cohorts, isolating our analysis to the youngest quartile demonstrate a similar false negative rate. The incidence of BCVI was significantly higher in our cohort than in the combined derivation and validation US cohorts. This suggests either a different population and injury pattern between centers or a systematic difference in radiologic interpretation. This wide variation in BCVI incidence and thus the ability to develop and validate scores retrospectively highlights the need for a prospective observational series as well as caution in limiting the CTA based upon the US criteria.

The challenges of selecting which patients to screen for BCVI are compounded by difficulties in selecting the optimal treatment to mitigate subsequent risk of CVA. The incidence of CVA in this cohort was 18%, a number that falls within the range of risk identified in the adult literature (20, 25-27). While our study is clearly underpowered to comment on the comparative efficacy of anti-platelet and anti-coagulant based strategies, we did not find any adverse events related to either of these. This is congruent with a prior finding of safety in a series of 52 pediatric patients with BCVI (8). The appropriate medical management of pediatric BCVIs is clearly a fertile field for research both in pediatric and adult patients and given the evidence that BCVIs may persist for a period of time following trauma, a full accounting of the risks and benefits of anti-thrombotic therapy will likely include medium and long term follow-up (13, 28).

We acknowledge that the optimal study design would be a prospective observational study with prospectively calculated screening scores and routine imaging to determine the efficacy to the screening tool. Given the rare nature of this injury, cost and ethical concerns about radiation exposure, this design was not possible. With a retrospective cohort design, we are limited by the fact that imaging was not obtained in all blunt trauma patients. We are thus unaware of clinically silent injuries and cannot calculate sensitivity, specificity or the negative and positive predictive values for the screening tools. The clinically meaningful performance metric of the screening tool, however, is the false negative rate as this is rate that trauma providers must grapple with when utilizing the available scoring criteria. As presented above, the incidence of BCVI in a pediatric population is at least 1%, with a not insignificant rate of associated CVAs. Given the low statistical risk of future malignancy, we would argue that it is worse to avoid a CTA neck due to radiation concerns and fail to appropriately treat a patient with a BCVI than to obtain the imaging, make the diagnosis of a BCVI and accept a statistically small increased risk of future malignancy. With this in mind, it is critical to identify as many patients as possible who warrant screening and thus the screening criteria with the lowest false negative rate, the DC, are the most clinically applicable.

In addition to the design, the findings of this study must be interpreted with an understanding of a number of other limitations. We used a more liberal definition of

pediatric patients than most investigators (age 18). This was intentional as while nearly mature teenagers may be imaged like adults, adult literature often limits analyses to patients 18 years old, leaving adolescents incompletely studied. Given that the adolescent population is a group at risk for motor vehicle crashes, a common mechanism for BCVI, we felt this group was critical to include. We also acknowledge that injury dynamics are likely different between a toddler and a near-adult adolescent. While previous work on pediatric BCVI has not stratified children into age cohorts, it may be that the risk factors vary based on the child's developmental stage and a unified "pediatric" screening tool is not reasonable (5, 8, 17, 18). Given the rarity of this injury, however, we did not believe it possible to focus on age or developmental subgroups and retain an adequate sample size to draw meaningful conclusions. Our institution also used a modified version of the DC as guidelines for screening in pediatric trauma since 2003, potentially biasing these retrospective findings. The clinical management and follow-up of these patients was also not standardized, resulting in nonrandom medication prescription and variable approaches to CVA diagnosis. While this is the largest cohort of pediatric BCVI in the literature, this remains a small series within a single institution with relatively rare pathology and even more rare complications. Many of the findings in this paper could be expected to change with evaluation of a larger series of children. We are additionally hampered by the lack of a low morbidity gold standard. As alluded to previously, it is likely that there is a much higher incidence of low grade BCVI (Grade I & II) than we present in this cohort as these patients are never imaged and remain clinically silent. The median admission GCS score is only 3 and this potentially is a combination of extensive training in airway management of our local medics as well as the severity of injury in these children (29-31).

In conclusion, pediatric BCVI remains a rare clinical occurrence although clinically significant sequelae of the injuries do occur with a frequency greater than previously appreciated. Three commonly used clinical screening criteria all have a sizeable false negative rate, although the most liberal criteria, the DC criteria, performed the best. These findings support the EAST recommendations to screen children according to adult guidelines and support the use of a liberal approach to clinical screening and imaging for BCVI. A prospective, multi-institutional observational trial is warranted to aid the development of a sufficiently sensitive clinical screening tool to optimize the identification of BCVI and mitigation of CVA risk.

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Screening Guidelines	
Denver Criteria	
Signs/symptoms of BCVI:	<ul style="list-style-type: none"> Arterial hemorrhage Cervical bruit Expanding cervical hematoma Focal neurologic deficit Neurologic examination incongruous with head CT Stroke on secondary CT scan
Risk factors for BCVI:	
High energy mechanism with:	<ul style="list-style-type: none"> LeFort II or III fracture Mandible fracture Cervical spine fracture patterns including: subluxation, fractures extending into the transverse foramen, fractures of C1-C3 Basilar skull fracture with carotid canal involvement Petrous bone fracture Diffuse axonal injury with GCS <6 Clothesline type injury Traumatic brain injury with thoracic injury Scalp degloving Thoracic vascular injury Blunt cardiac rupture Near hanging with anoxic brain injury
EAST Guidelines	
Neurologic abnormality not explained by diagnosed injury	
Blunt trauma + epistaxis	
GCS ≤ 8	
Petrous bone fracture	
Diffuse Axonal Injury	
C-spine fracture: C1-C3 or fracture through transverse foramen	
C-spine fracture with subluxation or rotation	
Lefort II or III fracture	
Utah Score	
Criteria	Points
GCS ≤ 8	1
Focal neurologic deficit	2
Carotid canal fracture	2
Petrous bone fracture	3
Cerebral infarct on CT	3
All factors	11

Figure 1: Scoring systems for Blunt Cerebrovascular Injury (BCVI) screening from the Eastern Association for the Surgery of Trauma (EAST) (13), Denver (3) and Utah Guidelines (17,18). GCS: Glasgow Coma Score. CT: Computed Tomography.

Positive Screening Criteria			
Denver Criteria			Number Positive (n=96)
Signs/symptoms of BCVI:			
	Arterial hemorrhage		0(0%)
	Cervical bruit		0(0%)
	Expanding cervical hematoma		0(0%)
	Focal neurologic deficit*		63(66%)
	Neurologic examination incongruous with head CT		NA**
	Stroke on secondary CT scan		8(8%)
Risk factors for BCVI:			
High energy mechanism with:			
	LeFort II or III fracture		25(26%)
	Mandible fracture		8(8%)
	Cervical spine fracture patterns including: subluxation, fractures extending into the transverse foramen, fractures of C1-C3		38 (40%)
	Basilar skull fracture with carotid canal involvement		21(22%)
	Petrous bone fracture		31(31%)
	Diffuse axonal injury with GCS <6		57(59%)
	Clothesline type injury		4(4%)
	Traumatic brain injury with thoracic injury		0(0%)
	Scalp degloving		6(6%)
	Thoracic vascular injury		0(0%)
	Blunt cardiac rupture		0(0%)
	Near hanging with anoxic brain injury		2(2%)
EAST Guidelines			
Neurologic abnormality not explained by diagnosed injury			NA**
Blunt trauma + epistaxis			0(0%)
GCS ≤ 8			64(67%)
Petrous bone fracture			31(31%)
Diffuse Axonal Injury			57(59%)
C-spine fracture: C1-C3 or fracture through transverse foramen			21(22%)
C-spine fracture with subluxation or rotation†			38(40%)
Lefort II or III fracture			25(26%)
Utah Score			
Criteria		Points	
GCS ≤ 8		1	64(67%)
Focal neurologic deficit		2	63(66%)
Carotid canal fracture		2	21(22%)
Petrous bone fracture		3	21(31%)
Cerebral infarct on CT‡		3	8(8%)
All factors		11	2(2%)

Figure 2:

Positive screening items from the Eastern Association for the Surgery of Trauma (EAST), Denver and Utah Guidelines on the screening of Blunt Cerebrovascular Injury (BCVI). GCS: Glasgow Coma Score. CT: Computed Tomography.* Interpreted most liberally to mean either a depressed GCS or localizing motor/sensory exam findings. † Applied most liberal interpretation of any Cervical spine fracture. ‡ Any infarct present on admission imaging. ** Not obtainable from medical record.

Table 1:

Admission Demographics and Injury Patterns of the BCVI Cohort

Variable	Results
Age	16 (13,17)
Male	57/96 (59%)
Admit GCS	3(3,11)
ISS	34(21,43)
Mortality	9/96 (9%)
C-spine Fracture	38/96 (40%)
T-spine Fracture	11/96 (11%)
L-spine Fracture	11/96 (11%)

ISS: Injury Severity Score, GCS: Glasgow Coma Score

Table 2:

Injury Patterns of 96 patients with 128 BCVIs.

Carotid Artery Injury		Vertebral Artery Injury		Number of Vessels Injured	
Grade I	38	Grade I	23	1 vessel injury	69
Grade II	23	Grade II	11	2 vessel injury	23
Grade III	16	Grade III	2	3 vessel injury	3
Grade IV	5	Grade IV	7	4 vessel injury	1
Grade V	1	Grade V	2	Total Patients	96
Total	83	Total	45	Total Vessels	128

Table 3:

Median score of three BCVI screening scores with screen fail rate (proven BCVI but screening not indicated from that scoring system) and clinically significant screen fail rate (BCVI with subsequent stroke not identified by screening tool).

Criteria	Median Score	Screen Fail	p	Clinically Significant Screen Fail	p
EAST	1(1,2)	16/96 (17%)	p<0.01	2/17 (12%)	p=0.48
DC	2(2,4)	2/96 (2%)	--	0/17 (0%)	--
US	3(1,6)	16/96 (17%)	p<0.01	1/17 (6%)	p=1

EAST: Eastern Association for the Surgery of Trauma, DC: Denver Criteria, US: Utah Score. p-value of EAST and US compared pair-wise to DC.