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ORIGINAL ARTICLE CLINICAL STUDIES

Multi-Center Validation of the McGovern Pediatric Blunt Cerebrovascular Injury Screening Score

Sidish S. Venkataraman,[1,**] Joseph P. Herbert,[2,**] Vijay M. Ravindra,[3] Bangning N. Yu,[4] Robert J. Bollo,[3] Charles S. Cox, Jr,[4] Stephen R. Gannon,[5] David D. Limbrick, Jr.,[6] Robert P. Naftel,[5] Irma T. Ugalde,[7] Brian K. Yorkgitis,[8] Howard L. Weiner,[9] and Manish N. Shah[4,10,*]

Abstract

Blunt cerebrovascular injury (BCVI) is defined as blunt trauma to the head and neck leading to damage to the vertebral and/or carotid arteries; debate exists regarding which children are considered at high risk for BCVI and in need of angiographic/vessel imaging. We previously proposed a screening tool, the McGovern score, to identify pediatric trauma patients at high risk for BCVI, and we aim to validate the McGovern score by pooling data from multiple pediatric trauma centers. This is a multi-center, hospital-based, cohort study from all prospectively registered pediatric (<16 years of age) trauma patients who presented to the emergency department (ED) between 2003 and 2017 at six Level 1 pediatric trauma centers. The registry was retrospectively queried for patients who received a computed tomography angiogram (CTA) as a screening method for BCVI. Age, length of follow-up, mechanism of injury (MOI), arrival Glasgow Coma Scale (GCS) score, and focal neurological deficit were recorded. Radiological variables queried were the presence of a carotid canal fracture, petrous temporal bone fracture, and CT presence of infarction. Patients with BCVI were queried for mode of treatment, type of intracranial injury, artery damaged, and BCVI injury grade. The McGovern score was calculated for all patients who underwent CTA across all data groups. A total of 1012 patients underwent CTA; 72 of these patients were found to have BCVI, 51 of which were in the validation cohort. Across all data groups, the McGovern score has a >80% sensitivity (SN) and >98% negative predictive value (NPV). The McGovern score for pediatric BCVI is an effective, generalizable screening tool.

Keywords: blunt cerebrovascular injury; computed tomography angiogram; McGovern score; pediatric trauma; radiation risk screening

[1]Department of Neurosurgery, Wake Forest Medical School, Winston-Salem, North Carolina, USA.
[2]Department of Neurosurgery, University of Missouri-Columbia, Columbia, Missouri, USA.
[3]Department of Neurosurgery, University of Utah, Salt Lake City, Utah, USA.
[4]Department of Pediatric Surgery, [7]Department of Emergency Medicine, [10]Department of Neurosurgery, McGovern Medical School at UTHealth, Houston, Texas, USA.
[5]Department of Neurosurgery, Vanderbilt University, Nashville, Tennessee, USA.
[6]Department of Neurosurgery, Washington University School of Medicine, St. Louis, Missouri, USA.
[8]Department of Pediatric Surgery, University of Florida, Jacksonville, Jacksonville, Florida, USA.
[9]Department of Neurosurgery, Baylor College of Medicine, Houston, Texas, USA.
**The first two authors contributed equally.

*Address correspondence to: *Manish N. Shah, MD, Departments of Pediatric Surgery and Neurosurgery, McGovern Medical School at UTHealth, 6431 Fannin, Houston, TX 77030, USA E-mail:* Manish.n.shah@uth.tmc.edu

Introduction

Blunt cerebrovascular injury (BCVI) is defined as blunt trauma to the head and neck leading to damage to the vertebral and/or carotid arteries. The incidence, risk factors, and management of BCVI have been well described in the adult population, but further investigation in children is needed. The radiation dose for a typical computed tomography angiogram (CTA) of the head and neck is substantial and therefore appropriate screening tools are especially important in the pediatric population. For this reason, there has been a flurry of research in recent years regarding BCVI in children, with an emphasis on developing a screening tool geared toward identifying which pediatric trauma patients are at high risk for developing BCVI and in need of vessel imaging.[1–6]

There is debate regarding the appropriate evaluation and treatment of BCVI in the pediatric population, and because the risk factors for pediatric BCVI have not been clearly described, which pediatric patients are considered to be at high risk and in need of angiographic/vessel imaging (CTA, etc.) is largely based on clinical and institutional treatment patterns. Some have suggested that the risk factors for the pediatric population may be similar to those seen in adults[7]; however, when validated adult BCVI screening scores such as the Denver[8] and modified Memphis criteria[9] have been applied to pediatric patients, less than 30% of symptomatic children with BCVI were appropriately screened.[10–11] Further, great caution must be observed when advocating for the implementation of adult screening criteria in the pediatric trauma population, as these criteria endorse a very liberal angiographic screening protocol that could expose pediatric patients to unnecessary radiation resulting in eventual cancer development.[12]

Recently, Ravindra and colleagues sought to retrospectively design a score specifically tailored toward identifying high-risk BCVI patients in a large pediatric trauma cohort.[5] This was the first study, to our knowledge, that designed a score based entirely on a pediatric cohort. The score, titled the Utah score, was based on the presence or absence of radiographic variables seen on CT and other assessments obtained upon admission to the emergency department (ED): Glasgow Coma Scale (GCS) score, focal neurologic deficit, carotid canal fracture, petrous temporal bone fracture, and cerebral infarction (Table 1). These variables were chosen based on previously published adult screening criteria, as factors the investigators believed to identify high risk for BCVI in the pediatric trauma population as well. However, upon validating this score, they found that they had missed 40.9% (9/22) of patients who were later found to have BCVI and were incorrectly classified as at low risk per their criteria.[5] This study marked a pivotal transition from trying to mold adult screening criteria to a pediatric population to building a score designed to identify children at high risk with a focus on eliminating unnecessary radiation exposure.

Table 1. Utah and McGovern Score Criteria

Variable	*No. of points*
Utah score	
GCS score ≤8	1
Focal neurological deficit	2
Carotid canal fracture	2
Petrous temporal bone fracture	3
Cerebral infarction on CT	3
McGovern score	
GCS score ≤8	1
Focal neurological deficit	2
Carotid canal fracture	2
MOI	2
Petrous temporal bone fracture	3
Cerebral infarction on CT	3

A score ≥3 points on both scales signifies high risk for BCVI and indicates that the patient should undergo angiography.

CT, computed tomography; GCS, Glasgow Coma Scale; MOI, mechanism of injury.

Our institution evaluated the previously proposed BCVI screening criteria (Utah, Denver, modified Memphis, and EAST) using a pediatric (<16 years of age) trauma database ($n = 12{,}614$) of patients seen in the ED, at an American College of Surgeons verified Level 1 pediatric trauma center, between 2005 and 2015.[13] When the Utah score was applied to our pediatric trauma cohort, the Utah score missed 10 out of 21 (47.6%) patients with BCVI (Table 2). To improve the sensitivity (SN) of these scores, we built upon the Utah score by incorporating mechanism of injury (MOI) into the screening criteria, thus creating the McGovern score (Table 1).

The McGovern score is unique in that patients involved in a high-speed collision were classified as higher risk. MOI was considered because multiple institutions,

Table 2. Comparison of the Utah Score and McGovern Score

	Utah score		
	BCVI	*No BCVI*	
Utah test +	11	42	PPV: 22.4%
Utah test –	10	441	NPV: 97.6%
	Sensitivity: 52.4%	Specificity: 91.3%	
	McGovern score		
	BCVI	*No BCVI*	
McGovern test +	17	105	PPV: 9.4%
McGovern test –	4	262	NPV: 98.6%
	Sensitivity: 81.0%	Specificity: 71.4%	

Compares the Utah and McGovern scores when applied to the Children's Memorial Hermann Hospital (CMHH) cohort. Utah + test refers to patients who would have been considered at high risk for BCVI by the Utah score and CTA would have been recommended. McGovern score + refers to patients who would be considered at high risk for BCVI by the McGovern score.

BCVI, blunt cerebrovascular injury; CTA, computed tomography angiography; PPV, positive predictive value; NPV, negative predictive value.

including our own, consistently demonstrated that the majority of the patients diagnosed with pediatric BCVI were involved in a motor vehicle collision or automobile-pedestrian incident.[14] In our pediatric trauma cohort, the introduction of MOI into the criteria greatly improved the screening score's SN. With the incorporation of MOI, the McGovern score identified 17 out of 21 of our pediatric BCVI patients (81%; as compared with the Utah score's 52.4%) while continuing to have a good specificity (SP; 71.4%). Importantly, it also identified all pediatric patients in our cohort who would later have a focal neurological deficit or cerebral vascular accident that was not present on admission. Further, the only patients missed by our score suffered from low-grade vascular injuries and were managed with observation or antiplatelet therapy alone.[13]

There is a lack of standardization in the treatment of pediatric BCVI, with treatment protocols largely based on clinical gestalt and varying widely by trauma center.[15–21] In our previous study for example, all but one BCVI patient was managed with observation or antiplatelet therapy. Treatment of that one patient with anticoagulation was due to concurrent deep venous thrombosis and not due to vascular injury. With conservative management, none of our patients had deficits attributable to their vascular injury on follow-up. Due to the lack of consistency and variation between the pediatric and adult population, it is imperative that a standardized method for screening and treating pediatric BCVI be developed.

In this study we aimed to validate the McGovern score by pooling data from multiple pediatric trauma centers to standardize screening criteria for the evaluation of BCVI in the pediatric trauma population. Currently, there is no consistent methodology for evaluating pediatric BCVI and consequently, no reliable determination of pediatric BCVI incidence or treatment. Additionally, given the rarity of pediatric BCVI, pooling institutional data will provide for a more accurate evaluation of pediatric BCVI risk factors, and with a bigger sample size, allow for a more accurate evaluation of treatment options (observation, antiplatelet therapy, anticoagulation, endovascular stenting, or open surgery) for pediatric BCVI as stratified by severity of injury. We hypothesized that the McGovern score would accurately predict BCVI in a multi-center patient population.

Methods

This was a multi-center retrospective cohort study designed with the goals of evaluating the performance of the McGovern score, and describing and comparing BCVI incidence and management at multiple Level 1 pediatric trauma centers across the country. For each institution, approval was obtained from the institutional review board. All institutions signed a dual-data transfer agreement and all information shared between the institutions was de-identified. The RedCAP data collection tool was utilized to collect and share data between institutions.

Patient population

This multi-center, retrospective, hospital-based, cohort study involved data collected from six Level 1 pediatric trauma centers. A trauma registry was compiled at each institution containing all pediatric trauma patients who presented to the ED between 2003 and 2017. The trauma registries used as inclusion criteria the National Trauma Data Standard (NTDS) Data Dictionary, which includes presence of *International Classification of Diseases*, 9th Revision (ICD9)/ICD10 codable injury presenting within 14 days of the injury (and excludes patients whose injuries were only isolated superficial, such as abrasions and soft-tissue contusions). In addition, patients had to meet one of the following criteria: admitted patients (observation or inpatient), dead on arrival/died in the ED, transferred out of the ED for higher level of care, or transferred in from an acute care ED/hospital regardless of whether they were discharged from the ED or admitted to the hospital.

This trauma registry was then queried for patients who received a CTA as a screening method for BCVI. Any patients with penetrating injuries (i.e., gunshot or stab wounds) to the head or neck were excluded from this study.

Data collection

Among the patients who underwent CTA ($n = 1012$), patient age, arrival date, length of follow-up, and MOI were recorded. The MOI was categorized as either blunt high energy (motor vehicle accident, automobile-pedestrian accident, bicycle accident, or fall >1 story), or low energy (fall <1 story, struck with object, etc.). The clinical information recorded for each patient who underwent CTA included GCS score on arrival and the presence or absence of a focal neurological deficit. The obtained radiological variables included the presence or absence of a carotid canal fracture, petrous temporal bone fracture, and cerebral infarction as determined on CT scanning. Patients who underwent CTA were then individually evaluated. Records of those found to have BCVI ($n = 72$) were queried for mode of treatment, type of intracranial injury, artery damaged, and BCVI injury grade, in addition to the aforementioned clinical and radiological variables. Additionally, Le Fort fractures, cervical spine fractures, cervical spine subluxation, and neck soft-tissue injuries (e.g., seatbelt sign, hanging, hematoma) were noted in the BCVI cohort.

The mode of treatment was characterized as observation, antiplatelet therapy, anticoagulation therapy, endovascular stenting, or open surgery. The type of

intracranial injury was characterized as epidural, subdural, subarachnoid, or contusion. The artery damaged was characterized as intracranial carotid, extracranial carotid, intracranial vertebral, or extracranial vertebral. Lastly, the BCVI injury grade was classified according to the Biffl grading scale[1–2] as follows: a grade 1 injury involved intimal irregularity with <25% narrowing; grade 2 injury involved dissection of a vessel or the presence of an intramural hematoma with >25% narrowing; grade 3 injury involved the presence of pseudoaneurysm; grade 4 injury was characterized by complete occlusion; and a grade 5 injury involved the transection of the vessel with extravasation.

Statistical analysis

The data collected were summarized using the means and standard deviations for continuous variables and counts and frequencies for categorical variables. The recorded categorical variables were compared using Fisher's exact test or chi-square test.

To assess the McGovern score's ability to predict BCVI incidence in this study's multi-center cohort, the McGovern score was calculated for all patients who underwent CTA ($n=1012$). The variables involved in the McGovern score included the Utah score variables with the addition of MOI: GCS score ≤8, focal neurological deficit, carotid canal fracture as seen on CT, petrous temporal bone fracture as seen on CT, and cerebral infarction as seen on CT as well as a high-speed MOI. Each of the variables was weighted as 1, 2, 2, 3, 3, and 2 points, respectively (Table 1). A cumulative score of 3 classified patients as high risk according to the McGovern score and merited the need for vessel imaging (CTA) to confirm or rule out a diagnosis of BCVI. Once these six variables were evaluated in the imaging cohort ($n=1012$), patients were categorized into a 2×2 table (positive/negative McGovern test vs. the presence/absence of BCVI) and the SN, SP, positive predictive value (PPV), and negative predictive value (NPV)were then calculated and the results were compared for the patient population at Children's Memorial Hermann Hospital (CMHH) as compared with those at other institutions (Table 3). Additionally, in the cohort of patients with BCVI ($n=72$), MOI, injury severity, and injury location were included (Table 4). Lastly, those patients with BCVI were evaluated for treatment (observation, antiplatelet agent, anticoagulation, endovascular intervention, or open surgery) relative to severity/grade of injury (Table 5). Results obtained from CMHH were compared with the results obtained from the other institutions. All statistical testing was performed with the R software package (v3.1.2) (MASS).

It should also be noted that in our previous publication (Herbert and associates[13]), receiver operator curves (ROCs) were generated to evaluate the SN and SP of

Table 3. Calculation of the Validity of the McGovern Score

Data set	No. of patients: BCVI	No. of patients: No BCVI	PPV/NPV	Sensitivity/ Specificity
Children's Memorial Hermann Hospital				
Positive McGovern test	17	105	13.9%/98.5%	81.0%/71.4%
Negative McGovern test	4	262		
Not Including Hermann Data Set				
Positive McGovern test	47	206	18.6%/98.9%	92.2%/64.0%
Negative McGovern test	4	367		
All Data Sets				
Positive McGovern test	64	311	17.1%/98.7%	88.9%/66.9%
Negative McGovern test	8	629		

Summarizes the PPV, NPV, sensitivity, and specificity for three different data sets. The first data set, Children's Memorial Hermann Hospital (CMHH), includes only the data set of those patients who presented to CMHH, that is, this initial data set upon which the McGovern score was based. The second data set, Not Including the Hermann data set, includes all other patients included in this study, that is, those from Primary Children's Hospital, Vanderbilt Children's Hospital, Texas Children's Hospital, St. Louis Children's Hospital, and the University of Florida in Jacksonville—excluding CMHH. The third data set, All Data Sets, includes all patients evaluated from all hospitals combining data sets 1 and 2.

BCVI, blunt cerebrovascular injury; NPV, negative predictive value; PPV, positive predictive value.

Table 4. Clinical and Imaging Characteristics in Patients Diagnosed With BCVI

Variables	CMHH values (%)	All other institutions (%)	P-value
Patient characteristics			
Cohort size	21	51	
Mean age (SD)	10.4 (5.0)	9.0 (5.2)	
Male	12 (57.1)	32 (62.7)	0.79
Mechanism of injury			
Motor vehicle accident	11 (52.4)	18 (35.3)	0.36
Automobile-Pedestrian	5 (23.8)	10 (19.6)	
Fall	2 (9.5)	6 (11.8)	
Other	3 (14.3)	17 (33.3)	
Intracranial injury			
Epidural hematoma	1 (4.8)	8 (15.7)	0.11
Subdural hematoma	7 (33.3)	14 (27.5)	
Subarachnoid hemorrhage	11 (52.4)	13 (25.4)	
Contusion	4 (19.0)	18 (35.3)	
Injury grade			
1	4 (19.0)	30 (58.8)	0.30
2	7 (33.3)	12 (23.5)	
3	5 (23.8)	5 (9.8)	
4	4 (19.0)	3 (5.9)	
5	1 (4.8)	1 (2.0)	

Compares imaging and clinical characteristics of the 21 patients diagnosed with BCVI in the Children's Memorial Hermann Hospital (CMHH) cohort with the remaining 51 patients diagnosed with BCVI from the other institutions included in this study.

BCVI, blunt cerebrovascular injury; SD, standard deviation.

Table 5. BCVI Treatment Based on Injury Grade

	CMHH: Grade of vascular injury[a]				
Treatment	*Grade 1*	*Grade 2*	*Grade 3*	*Grade 4*	*Grade 5*
Observation	2	2	2	1	1
Antiplatelet therapy	1	5	3	3	0
Anticoagulant therapy	1[b]	0	0	0	0
Endovascular	0	0	0	0	0
Open surgery	0	0	0	0	0
	Other institutions: Grade of vascular injury[a]				
Treatment	*Grade 1*	*Grade 2*	*Grade 3*	*Grade 4*	*Grade 5*
Observation	19	4	1	1	0
Antiplatelet therapy	8	5	1	0	0
Anticoagulant therapy	3	2	1	2	0
Endovascular	0	1	1	0	1
Open surgery	0	0	1	0	0

[a]The grade of vascular injury was determined using the Biffl grading scale.

[b]This patient was managed with anticoagulation therapy for deep venous sinus thrombosis and not BCVI.

Values are presented as the number of patients.

Summarizes the treatment received by each patient in the cohort of patients diagnosed with BCVI for each grade of vascular injury at Children's Memorial Hermann Hospital (CMHH) compared with the other institutions combined. At CMHH, in grade 1 injuries, blood thinners were contraindicated in 4 patients (treated with observation) and 1 patient was started on ASA for venous sinus thrombosis. In grade 2 injuries, blood thinners were contraindicated in 4 patients (treated with observation) and 1 patient was anticoagulated for concurrent venous sinus thrombosis. In grade 3 injuries, blood thinners were contraindicated in 1 patient. In grade 5 injuries, blood thinners were contraindicated in 1 patient due to concurrent, large intracranial hemorrhage.

ASA, aspirin; BCVI, blunt cerebrovascular injury.

the McGovern score at varying thresholds as well as to determine which discrimination point would be most appropriate. The most predictive threshold was determined by calculating the area under the curve. A sample ROC was published in our previous publication.[13] Based on this statistical analysis, we assigned MOI a point value of 2 and determined a threshold of 3 as high risk for BCVI, warranting angiographic imaging (such as CTA). We kept a dichotomous score (high or low risk) to facilitate ease of use and more streamlined clinical decision-making.

Results

Patient population characteristics

In total, 1012 pediatric trauma patients were identified who underwent angiographic screening with CTA: 388 patients from Children's Memorial Hermann Hospital (CMHH), 308 patients from Vanderbilt Children's Hospital (VCH), 223 patients from Primary Children's Hospital (PCH), 42 patients from St. Louis Children's Hospital (SLCH), 46 patients from Texas Children's Hospital (TCH), and 5 patients from University of Florida Jacksonville (UFJ). Of those who underwent angiographic imaging, 72 patients were identified as having BCVI: 21 from CMHH, 34 from PCH, 6 from VCH, 4 from SLCH, 6 from TCH, and 1 from UFJ. CTA was performed in all patients within 24 h of admission, often in the ED. Mean age of patients found to have BCVI was 9.0 years as compared with 10.4 years in the CMHH cohort, although this difference was not statistically significant (Table 4). In this cohort of patients, 18 (35.3%), were involved in a motor vehicle accident, 10 (19.6%) were involved in an automobile-pedestrian accident, 6 (11.8%) were involved in a fall, and 17 (33.3%) were injured due to some other cause of trauma (Table 4).

Additionally, 33 patients (64.7%) had one or more intracranial injuries (similar to the CMHH cohort in which 66.7% of patients had an intracranial injury), including 8 with an epidural hematoma, 14 with subdural hematomas, 13 with subarachnoid hemorrhage, and 18 with cerebral contusions. Eight (15.7%) as compared with 6 (28.6%) in the CMHH cohort had a stroke seen on imaging ($p = 0.22$).

Of the 51 patients in the external cohort who sustained a BCVI, 30 (58.8%) suffered a grade 1 vessel injury, 12 (23.5%) sustained a grade 2 vessel injury, 5 (9.8%) suffered a grade 3 vessel injury, 3 (5.9%) suffered a grade 4 vessel injury, and 1 (2.0%) suffered a grade 5 vessel injury. This is significantly different ($p = 0.012$) than the distribution of injury grades seen in the CMHH cohort in which there were 4 (19.0%) grade 1 injuries, 7 (33.3%) grade 2 injuries, 5 (23.8%) grade 3 injuries, 4 (19.0%) grade 4 injuries, and 1 (4.8%) grade 5 injury, respectively (Table 4). Of those with arterial injuries, 25 of 51 patients (49.0%) received no treatment (observation alone) as compared with 8 of 21 (38%) patients in the CMHH cohort. At all institutions in this cohort, of those who did receive treatment, the majority of grade 1–3 vessel injuries were treated with antiplatelet therapy.

In the CMHH cohort, grade 4 injuries were treated primarily with antiplatelet agents and the only grade 5 injury was treated with observation (due to concomitant intracranial hemorrhage). In the external cohort ($n = 51$), 1 grade 4 injury was treated with observation alone due to devastating concomitant intracranial hemorrhage and the remaining 2 grade 4 injuries were treated with anticoagulation. The only grade 5 injury was treated with endovascular intervention (Table 5). It should be noted, however, that of the grade 1 injuries, antiplatelet/anticoagulant agents were contraindicated in 4 patients, of the grade 2 injuries, all 4 patients who were observed had concomitant intracranial hemorrhage and 1 underwent anticoagulation due to concomitant venous sinus thrombosis, and of the grade 3 injuries, the treatment of the patient with observation was due to concomitant intracranial hemorrhage (Table 5).

Assessment of McGovern score

Table 3 summarizes the application of the McGovern test in three different cohorts: CMHH, Not Including

Hermann Data Set (includes the other institutions but excludes CMHH), and All Data Sets (includes CMHH and the other institutions). A 2×2 matrix was created comparing a positive McGovern test (classified as a score ≥3) with a negative McGovern test in patients with and without BCVI. Table 3 demonstrates the PPV and NPV as well as SN and SP for all three data sets. Note that the PPV, NPV, SN, and SP were similar for all three. Additionally, across all data groups, the McGovern score has a >80% SN and >98% NPV (Table 3).

Discussion

Predicting BCVI in children

Over the last decade, numerous studies have been published in an effort to determine which pediatric trauma patients are at high risk for BCVI and in need of angiographic imaging. In the adult population, many institutions have adopted a fairly liberal screening criteria; however, applying this to the pediatric population raises concern for unnecessary radiation exposure. Further, the pathophysiology of BCVI in children is thought to be different as a result of less calcified, more elastic arteries and ligaments, and there is mounting evidence that many children present with delayed neurological decline/stroke as compared with the adult population. Weber and colleagues looked at more than 8000 pediatric trauma patients between 2002 and 2015 from hospitals in Germany, Austria, and Switzerland and identified 42 children with BCVI (prevalence of 0.5%), with 30 patients having carotid injuries and 12 having vertebral injuries.[22] Importantly, they noted the risk for thromboembolic events and in-hospital mortality to be 8.3% and 38.1%, respectively, both significantly higher than the incidence in pediatric trauma patients without BCVI, stressing the importance of identifying this injury.[22]

Initially, there had been attempts to apply the previously published adult screening criteria (Denver, modified Memphis, EAST) to the pediatric population, but these faired poorly.[10] The Utah score built on these adult screening scores and emerged as a specific pediatric BCVI screening tool. It was designed using the pediatric trauma cohort at PCH in the hope of creating a pediatric BCVI screening tool specifically designed for children. The designers selected risk factors that they observed in their pediatric cohort, namely GCS score ≤8, focal neurological deficit, carotid canal fracture as seen on CT, petrous temporal bone fracture as seen on CT, and cerebral infarction as seen on CT. Each of the variables was weighted as 1, 2, 2, 3, and 3 to create a dichotomous score with a cutoff of 3 points being high risk and warranting a CTA (Table 1).

The development of the Utah score marked a paradigm shift in which clinicians were recognizing that pediatric BCVI risk factors differed from adults. However, the Utah score missed many pediatric trauma patients in Utah's validation cohort, with only a 59% SN.[4] When the Utah score was applied to the CMHH cohort, the SN was again poor at only 52% and missed 2 patients who went on to have strokes secondary to BCVI (Table 2). The challenge was that of the 21 BCVI patients in the CMHH cohort, 7 (33%), upon initial presentation, had no focal neurological deficit and no fractures or soft-tissue signs that could be appreciated on initial imaging, making a high risk for BCVI in these patients difficult to identify. Nearly all of these patients were missed by the Utah score and previous adult screening scores.

Thus, we sought to improve the SN of existing BCVI screening criteria in the pediatric trauma population by incorporating MOI as an independent risk factor for BCVI. This variable was utilized because many prior studies had noted that high-velocity injuries (and motor vehicle collisions in particular) were common underlying MOIs.[22] By incorporating MOI, the SN of the score was dramatically improved. Further, the McGovern score correctly identified two patients who would have delayed neurological decline/stroke that was missed by the other screening criteria, and all four patients who were missed by the McGovern score were managed conservatively.

These findings highlight the huge advantage the McGovern score offers over the previous screening criteria with potential to alter management and treatment recommendations for pediatric trauma patients. However, this study was limited by being a single institution study.

The purpose of this study was to validate the McGovern score at multiple, large, pediatric trauma centers across the country. Pediatric trauma patients from six different institutions were evaluated. The results of use of the McGovern score in these institutions are summarized in Table 3. The McGovern score maintained an excellent 92.2% SN and 64.0% SP. Incorporating MOI into the screening criteria increases the SN and identifies patients missed by other screening criteria. Our data strongly support the McGovern score as being an effective, generalizable, and sensitive screening tool for pediatric BCVI across a variety of trauma centers in the United States.

MRA versus CTA

It is important to note that only CTA neck was used to evaluate BCVI in this study. Although our institution also included patients who obtained magnetic resonance angiography (MRA) and digital subtraction angiography (DSA) to evaluate for BCVI, this was not done at the other institutions involved in this study, and so patients with BCVI identified with MRA or DSA alone were not included in this study. In our institution, 40 patients who had MRA were excluded from analysis in the present study. None of these patients had BCVI identified. No

head-to-head comparison of the SN and SP of MRA and CTA for BCVI has been published to our knowledge. The lack of radiation exposure associated with MRA makes it an attractive alternative to CTA for use as a screening tool; however, more research is needed to compare these imaging modalities.

BCVI risk factors

The primary improvement of the McGovern score over previously published scores was the emphasis on the importance of MOI. Applied to our institution, the McGovern score had a SN of 81% and SP of 71.3%, much higher than the Utah score alone ($\sim$50% SN). Additionally, when the McGovern score was applied to the other five institutions, the SN was 89% and SP was 67%, making the McGovern score a sensitive indicator of pediatric BCVI (Table 3). Of note, the McGovern score is sensitive in the external data set even when the distribution of BCVI grades was significantly different (Table 3), suggesting generalizability of the score.

The inclusion of MOI in a pediatric BCVI screening score mirrors the experience of the improvement represented by the Canadian C-Spine (cervical-spine) Rule (CCR), which includes MOI, over the previous National Emergency X-Radiography Utilization Study (NEXUS) Low-Risk Criteria (NLC), which did not.[23]

BCVI treatment

BCVI treatment in the pediatric population is not well established and varies based on institution as demonstrated by the variety of treatment strategies employed by the six institutions in this study (Table 5). Our data overall suggest that the majority of grade 1 injuries are treated with observation alone, higher-grade injuries (grades 2–4) with antiplatelet/anticoagulant therapy as able, and grade 5 injuries ($n=1$) with endovascular intervention. Future prospective studies will help determine the optimal treatment strategy for these injuries, which, although rare, can lead to significant neurological sequelae.

Limitations

As with all retrospective cohort studies, our present study is limited by the availability and accuracy of the medical record. The primary limitation of this study lies in the difficulty of retrospectively applying a screening score to a patient population with a rare injury with a high degree of heterogeneity of clinical decision-making regarding screening criteria. The true incidence of BCVI among the pediatric trauma patients of the participating institutions is thus unknown, as only patients who underwent CTA for screening were included.

Conclusions

To our knowledge, this study represents the largest retrospective study of pediatric BCVI patients to date. It supports the McGovern score as being an effective, generalizable, and sensitive screening tool for pediatric BCVI across a variety of trauma centers in the United States. Further validation of the McGovern score in a prospective patient cohort is needed.

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Authors' Contributions

All authors contributed substantively and approve of the conception of the study, data collection, data analysis, and critical review of the manuscript. MNS provided material support for the study.

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Author Disclosure Statement

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