Risk Factors for Blunt Cerebrovascular Injury in a Cohort of Pediatric Patients With Cervical Seat Belt Sign

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Background: Blunt cerebrovascular injury (BVCI), injury to the carotid or vertebral arteries, may result from forces involving seatbelts. Although previous studies have not found a seat belt sign to be a significant predictor for BCVI, it is still used to screen patients for BCVI.

Objective: This study aims to determine risk factors for BCVI within a cohort of patients with seat belt signs.

Methods: We conducted a retrospective cohort study using our institutional trauma registry and included patients younger than 18 years with blunt trauma who both had a computed tomography angiography (CTA) of the neck performed and had evidence of a seat belt sign per the medical record. We reported frequencies, proportions, and measures of central tendency and conducted univariate analysis to evaluate factors associated with BCVI. We estimated the magnitude of the effect of each variable associated with the study outcome by conducting logistic regression and reporting odds ratios and 95% confidence intervals.

Results: Among all study patients, BCVI injuries were associated with Injury Severity Score higher than 15 ($P = 0.04$), cervical spinal fractures ($P = 0.007$), or basilar skull fractures ($P = 0.01$). We observed higher proportions of children with BCVI when other motorized and other blunt mechanisms were reported as the mechanisms of injury ($P = 0.002$) versus motor vehicle collision.

Conclusions: Significant risk factors for BCVI in the presence of seat belt sign are: Injury severity score greater than 15, cervical spinal fracture, basilar skull fracture, and the other motorized mechanism of injury, similar to those in all children at risk of BCVI.

Key Words: blunt cerebral vascular injury, seat belt sign, computed tomography angiography

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Blunt cerebrovascular injury (BCVI), injury to the carotid or vertebral arteries, has been attributed to 3-point seat belt restraints.[1] Patients with injuries from a seat belt often present with cervical and thoracic abrasions, also known as seat belt signs. The overall incidence of BCVI in pediatric patients ranges from 0.4% to 5.8%.[2,3] Potential sequelae of BCVI include neurological deficits, strokes, and death.[4,5] Blunt cerebrovascular injury may present asymptomatically initially, making the diagnosis difficult.[5] Due to the potential severity of this injury, it is important to determine if the seat belt sign is a true risk factor for BCVI. Limited studies have concluded that the isolated cervical seat belt sign is not a significant predictor for BCVI in both children and adults.[6–9] Yet, some guidelines still include the seat belt sign as an indicator for screening for BCVI.

Various screening methods have been developed for adult and pediatric populations.[10] The Denver criteria, Memphis criteria, and Eastern Association for Surgery of Trauma (EAST) recommend computed tomography angiography (CTA) for certain risk factors in adults that have been historically applied to children.[9,11,12] By using adult criteria, BCVI may be overlooked at a high rate in pediatric patients.[13] The McGovern and Utah scores are two pediatric screening methods developed in the last few years. Criteria for the McGovern score include the risk factors included in the Utah score consisting of Glasgow Coma Scale (GCS) of 8 or lower (1 point), focal neurological deficit (2 points), petrous bone fracture (3 points), fracture through carotid canal (2 points), and traumatic ischemia on noncontrast head CT (3 points) in addition to motor vehicle collision (MVC) as a mechanism of injury (2 points).[14] A score of ≥3 indicates high risk and imaging recommended for screening. Although both are generalizable screening tools for pediatric populations, the seat belt sign is not included as a risk factor for screening with CTA nor was it included in the analysis as a potential risk factor in the derivation studies. The McGovern score has a 92% sensitivity and 62% specificity to predict BCVI in pediatric patients.[15] Other statistically significant risk factors associated with BCVI in children include an Injury Severity Score (ISS) of 16 or higher, head infarction on imaging, a hanging mechanism, cervical spine fracture, and basilar skull fracture.[2] Still, other studies include a GCS of 8 or lower, midfacial fractures, and mandibular fractures as significant risk factors for BCVI in children.[3,6,16]

The objective of this study is to determine risk factors that are associated with BCVI in pediatric patients with a cervical seat belt sign at our level I trauma center.

METHODS

Study Design, Setting, and Patients

The Committee for the Protection of Human Subjects reviewed and approved this retrospective study and assigned an international review board number, HSC-MS-15-0311. The study included children treated at Children's Memorial Hermann Hospital in Houston, TX, the only American College of Surgeons-verified Level I combined adult and pediatric trauma center in the city. The hospital cares for approximately 6000 trauma patients ≥ 16 years and approximately 1500 trauma patients ≤ 15 years on a yearly basis. We conducted a retrospective hospital-based cohort study of our trauma registry and included children younger than 18 years who presented with blunt trauma between November 1, 2002 to December 31, 2014.[2] All patients included in this study had a CTA of the neck performed on admission to the emergency department (ED). We performed a priori subanalysis of patients who also had a cervical seat belt sign. The hospital trauma registry

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uses the National Trauma Data Standard dictionary for data collection and is a participant in the American College of Surgeons (ACS) Trauma Quality Improvement Program Benchmarking (TQIP). The registry identifies patients from the ED and in-hospital logs reporting diagnoses, comorbidities, and complications, as defined in the National Trauma Data Standard dictionary. Abstractors use standardized procedures to collect injury data about the patients, along with clinical and surgical procedures from the electronic medical record. In addition, the registry team audits 10% to 15% of their records, attend regular educational activities, and hold coding exercises to maintain acceptable standards of interrater reliability. All files are verified to be compliant with the National Trauma Data Bank and the Trauma Quality Improvement Program through robust mapping and validation tools.

Measurements and Outcomes

The outcome variable was the presence of BCVI, grades I through V, among children with seat belt sign observed after blunt trauma. Independent variables were demographic characteristics including age, sex, and race/ethnicity. Age was collected as both a continuous and categorical variable (age < 10 years or age ≥ 10 years) for all patients. Clinical parameters included the McGovern score, GCS, and the ISS. The McGovern score was calculated using the values previously described by Hebert et al[14] where researchers assigned 1 point for a GCS ≤ 8, 2 points for a positive focal neurological deficit (ie, a set of symptoms or signs in which causation can be localized to an anatomic site in the central nervous system), 2 points for a carotid canal fracture, 2 points for a mechanism of injury of MVC, 3 points for a petrous temporal bone fracture, and 3 points for a cerebral infarction on CT. The range of scores is from 0 to 13 points, with a value of ≥ 3 indicating a high risk for BCVI and screening with CTA recommended. Children in our cohort were grouped as having a GCS ≤ 8 or > 8. The ISS was recorded as both a continuous and categorical variable (ISS ≤ 15 or ISS > 15) for all patients. We included the distinct variables that composed the McGovern score as discrete risk factors. Fractures of the cervical spine, basilar skull, clavicle, thorax, rib, and scapular bones were also included. The presence of hanging mechanism (yes/no) and the mechanism of the injury, classified as MVC, other motorized accident, and other blunt trauma were also abstracted.

Data Analysis

We reported frequencies, proportions, and measures of central tendency and conducted univariate analysis to evaluate factors associated with the presence or absence of BCVI. For categorical variables evaluated with cells counts less than 6, the Fisher exact test was used. Age and ISS as continuous variables were analyzed according to the normality of their distributions, using the Student *t* test and the nonparametric Kolmogorov-Smirnov test, respectively. Due to the low number of incident cases (only 11 children with BCVI) we did not conduct multivariable analysis. However, we estimated the magnitude of the effect of each variable associated with the study outcome observed in the univariate analysis by conducting logistic regression and reporting odds ratios (ORs) and 95% confidence intervals (CIs). A 2- tailed *P* value of less than 0.05 was considered significant. All statistical analysis was performed using Stata/IC version 15.1 statistical software (StataCorp LP, College Station, Tex).

RESULTS

Eighty-six (22.93%) of the 375 children who were screened with a cervical CTA presented with a seat belt sign. A total of 11 (12.79%) of the 86 children experienced cervical vascular injuries. Table 1 demonstrates the risk factors associated with BCVI among all patients with a seat belt sign. We observed higher proportions of BCVI injuries when the ISS > 15 ($P = 0.04$) and when cervical spinal fractures ($P = 0.007$) or basilar skull fractures ($P = 0.01$) were present. We observed higher proportions of children with BCVI when other motorized and other blunt mechanisms were reported as the mechanisms of injuries ($P = 0.002$).

The magnitude of the effect of the unadjusted risk factors associated with the presence of BCVI is presented in Table 2. Compared to children with ISS ≤ 15, those with an ISS > 15 had a higher odds of presenting with BCVI (OR, 4.74; 95% CI, 1.6–19.38). Children with cervical spinal fracture were at higher risk of BCVI compared with those without cervical spine fracture (OR, 6.45; 95% CI, 1.68–24.82). The presence of a basilar skull fracture increased the odds of BCVI (OR, 8.0; 95% CI, 1.74–36.84) and only the subgroup of children whose mechanism of injury was due to other motorized mechanisms had a greater odds of BCVI compared to children with an MVC mechanism of injury (OR, 12.71; 95% CI, 2.67–60.44).

Table 3 denotes the number of risk factors, type of risk factor, respective McGovern score, injury type, and the treatment, if any, for each patient with a BCVI. Our patients presented with grades I–IV vascular injuries; none presented with a grade V lesion. We discovered that 10/11 patients (90.90%) presented with 2 or more risk factors. A single patient with a seat belt sign had no other risk factors identified. The lesions identified in this patient were considered low grade, grade I and grade II carotid artery injuries, and he was treated with aspirin transiently. Per hospital records, he did not have any further injury or evolution to stroke. Six (54.54%) of the 11 patients presented with a high-risk McGovern score. Eight (72.72%) of the 11 patients received anticoagulation, antiplatelet, or both for treatment. Of the three not treated, one was determined to be brain dead on presentation.

DISCUSSION

We discovered that an ISS >15, the presence of a cervical spinal fracture, the presence of a basilar skull fracture, and the injury mechanism of "other motorized" were significantly associated with BCVI in this cohort of children with seat belt signs. Most children in our study with seat belt sign and BCVI presented with two or more previously identified risk factors for BCVI. Rozycki and colleagues[17] similarly concluded that the seat belt sign alone was not significant to predict BCVI. They suggest that a seat belt sign along with abnormal findings (such as GCS <14 and ISS >16) may be effective to screen for BCVI in adult and pediatric patients.[17] Leeras and colleagues[6] found that children with BCVI had a higher odds of experiencing basilar skull fractures, GCS < 8, midfacial fractures, mandibular fractures, and coma. Other investigators have found a low GCS to be significantly associated with BCVI in children.[3,6,16–18] Conversely, we did not discover an association between GCS < 8 with BCVI, possibly because we had a small sample of patients presenting with BCVI in this cohort of patients with seat belt sign.

Most patients with seat belt sign in our study (75/86) did not have BCVI, and there was a single patient with a seat belt sign but no other risk factors who had grade I and II carotid injuries. He was treated transiently with aspirin and, per review of the medical record, did not appear to have a stroke or progression of the lesion. Whether this treatment was warranted and clinically beneficial is not clear. There are no evidence-based clinical guidelines for treatment regimens in children with BCVI. Dewan et al reported that aspirin was a common treatment for low-grade injuries in patients without contraindications, and clinical judgment was used to decide whether patients should receive antithrombotic therapy

TABLE 1. Demographic and Clinical Factors in Patients With Cervical Seat Belt Sign Among Those With and Without BCVI

	Seat Belt Sign and No Vascular Injury N (%)	Seat Belt Sign and Vascular Injury N (%)	P*
Total	75 (87.21)	11 (12.79)	
Age, y, mean (SD)	12.81 (5.49)	11.82 (4.71)	0.53†
Age			0.49
<10 y	26 (34.67)	2 (18.18)	
≥10 y	49 (65.33)	9 (81.82)	
Sex			0.99
Male	48 (64.00)	7 (63.64)	
Female	27 (36.00)	4 (36.36)	
White non-Hispanic			0.51
Yes	43 (57.33)	8 (72.73)	
Other	32 (42.67)	3 (27.27)	
McGovern score ≥3			0.07
Yes	18 (24.00)	6 (54.55)	
No	57 (76.00)	5 (45.45)	
GCS ≤8			0.27
Yes	16 (21.33)	4 (36.36)	
No	59 (78.67)	7 (63.64)	
ISS, median (IQR)	10 (9–18)	19 (15–34)	0.04‡
ISS			0.04
≤15	48 (64.00)	3 (27.27)	
>15	27 (36.00)	8 (72.73)	
Petrous bone fracture			0.34
Yes	2 (2.67)	1 (9.09)	
No	73 (97.33)	10 (90.91)	
Carotid canal fracture			0.34
Yes	2 (2.67)	1 (9.09)	
No	73 (97.33)	10 (90.91)	
Cerebral hemorrhage			0.49
Yes	20 (26.67)	4 (36.36)	
No	55 (73.33)	7 (63.64)	
Infarct on head observed in CT scan			0.08
Yes	2 (2.67)	2 (18.18)	
No	73 (97.33)	9 (81.82)	
Laceration			0.43
Yes	3 (4.00)	1 (9.09)	
No	72 (96.00)	10 (90.91)	
Cervical spinal fracture			< 0.01
Yes	16 (21.33)	7 (63.64)	
No	59 (78.67)	4 (36.36)	
Basilar skull fracture			0.01
Yes	5 (6.67)	4 (36.36)	
No	70 (93.33)	7 (63.64)	
Clavicular fracture			0.99
Yes	11 (14.67)	1 (9.09)	
No	64 (85.33)	10 (90.91)	
Thoracic fracture			0.14
Yes	8 (10.67)	3 (27.27)	
No	67 (89.33)	8 (72.73)	
Rib fracture			0.38
Yes	11 (14.67)	3 (27.27)	
No	64 (85.33)	8 (72.73)	
Scapula fracture			0.34
Yes	2 (2.67)	1 (9.09)	
No	73 (97.33)	10 (90.91)	
Hanging mechanism			0.17
Yes	4 (5.33)	2 (18.18)	
No	71 (94.67)	9 (81.82)	
Mechanism			< 0.01
MVC	61 (81.33)	4 (36.36)	
Other motorized	6 (8.00)	5 (45.45)	
Other blunt	8 (10.67)	2 (18.18)	

*Fisher exact test.

†Student *t* test.

‡Kolmogorov-Smirnov test.

IQR indicates interquartile range.

(anticoagulant or antiplatelet) or surgical consultation for grades II–V injuries.[18] They surmised that 3 months or longer of antithrombotic treatment was reasonable if follow-up imaging demonstrated persistent lesions but fell short on making this a definitive recommendation.[18] Ravindra et al[19] compared anticoagulation and antiplatelet therapy for BCVI management in children younger than 10 years and found no significant differences in subsequent thromboembolic events in this age group, but the data are not clear if this is true for older pediatric patients. Although there is more expansive literature on BCVI treatment in adults, pediatric data are limited. Without clear guidance on therapy, clinical judgment is used to guide management in children with BCVI.

Prior research often omits the seat belt sign in the derivation of risk factors for screening guidelines for BCVI in children. In their retrospective review of 1209 pediatric patients, Kopelman et al[20] included the cervical seat belt sign as a risk factor but could not determine its significance because of insufficient

TABLE 2. Risk Factors Associated With BCVI in Children With Cervical Seat Belt Sign

Variable	OR	95% CI	Std. Error	P
ISS				
≤15	Reference			
>15	4.74	1.16–19.38	2.17	0.03
Cervical spinal fracture				
No	Reference			
Yes	6.45	1.68–24.82	4.43	<0.01
Basilar skull fracture				
No	Reference			
Yes	8.00	1.74–36.84	6.23	<0.01
Mechanism				
MVC	Reference			
Other motorized	12.71	2.67–60.44	10.11	<0.01
Other blunt	3.81	0.60–24.26	3.60	0.16

TABLE 3. Presence of Risk Factors, McGovern Score, Types of Vascular Lesions and Treatment in Patients With BCVI and Cervical Seat Belt Sign

Patient	No. Risk Factors	McGovern Score	Type of Risk Factor	Vascular Injury Type	Treatment
1	0	0		Gd II left ICA, Grade I right ICA	Aspirin started then stopped
2	6	2	• Laceration • Penetrating injury • Facial fracture • Hanging mechanism • Basilar skull fracture • Focal neurological deficit	Gd I right common carotid	Aspirin
3	2	4	• Cervical spine fracture • Positive McGovern score	Gd I right vertebral	None
4	6	6	• ISS >15 • Facial fracture • Cervical spine fracture • Basilar skull fracture • Carotid canal fracture • Positive McGovern score	Gd II left ICA, Grade II right ICA, Gd I left vertebral	Aspirin/hep/coumadin
5	4	0	• ISS >15 • Cerebral hemorrhage • Cervical spine fracture • Basilar skull fracture	Gd III left ICA, Grade II left vertebral	Heparin drip/lovenox
6	3	3	• ISS >15 • Focal neurological deficit • Positive McGovern score	Gd IV right vertebral	Aspirin
7	7	4	• GCS ≤8 • ISS >15 • Facial fracture • Cervical spine fracture • Basilar skull fracture • Focal neurological deficit • Positive McGovern score	Gd IV left vertebral	None
8	7	2	• GCS ≤8 • ISS >15 • Cerebral hemorrhage • Head infarction • Hanging mechanism • Cervical spine fracture • Focal neurological deficit	Gd IV left vertebral, Gd III right vertebral	Non-brain death
9	3	5	• ISS >15 • Cervical spine fracture • Positive McGovern score	Gd III right ICA	Aspirin
10	3	0	• GCS ≤8 • ISS >15 • Cerebral hemorrhage	Gd III left ICA	Aspirin/coumadin
11	6	3	• GCS ≤8 • ISS >15 • Cerebral hemorrhage • Head infarction • Cervical spine fracture • Positive McGovern score	Gd IV right vertebral	Aspirin

ICA, Internal Carotid Artery.

data. Only three patients in their study presented with the seat belt sign, and only one of those had BCVI. They concluded that the EAST guidelines were an appropriate BCVI screening tool in children.[20] The EAST guidelines recommend screening for BCVI in those with near-hanging mechanism of injury with anoxic brain injury or severe cervical hyperextension/rotation or hyperflexion especially if associated with diffuse axonal injury or complex mandibular or displaced midfacial fractures and basilar or cervical spinal fractures in close proximity to the carotid or vertebral arteries.[11] In addition to these, the EAST guidelines also include as a risk factor a seat belt abrasion or other soft tissue injury of the anterior neck resulting in significant swelling or altered mental status.[11] Both the Utah and McGovern scores did not consider a seat belt sign as a risk factor in the derivation of their decision rules. In a multiyear query of the National Trauma Data Bank to assess for risk factors in children and adults with BCVI, Leraas et al[6] found that the cervical seat belt sign was more commonly identified in children with BCVI compared with adults with BCVI. However, on multivariable analysis, the seat belt sign was not associated with pediatric BCVI.[6] Based on the data we present here, we advise against using the cervical seat belt sign as an independent risk factor for radiologic screening.

There exists ambiguity on the characteristics of a true cervical seat belt sign. Varying degrees of impact which occur in motor vehicle accidents cause different types of seat belt sign presentations. A seat belt sign may consist of erythema, abrasion, or ecchymosis of the affected area. In their retrospective review of 431 patients who presented to the ED with an abdominal seat belt sign, Shreffler and colleagues[21] found that both abrasions and ecchymosis were significantly associated with intraabdominal injury as independent presentations. Furthermore, Borgialli et al[22] decided to broaden the classification of a seat belt sign to include erythema in addition to an abrasion or ecchymosis. They subsequently found that more pediatric patients experienced intraabdominal injury through this classification of the seat belt sign than those who did not have one.[22] The abdominal seat belt sign's correlation with intra-abdominal injury may not be a fair comparison of a seat belt sign of the neck predicting BCVI. Children may have some anatomical protection from stroke as the presence of a complete Circle of Willis is greater in children than in adults, resulting in a greater capacity for collateral blood flow in the presence of a large vessel occlusion.[23]

Overall, the seat belt sign's use in BCVI predictability is limited by the lack of prospective studies on the topic. We conclude based on the literature and our own findings that the cervical seat belt sign alone is less likely to be predictive of BCVI in children and not a significant risk factor. The seat belt sign in the presence of other high risk factors seems to have a higher predictive value for pediatric BCVI.

Limitations

Inherent limitations of retrospective designed studies are present in our study. Our study is limited by the small sample size because we only investigated patients who were sent for imaging with a positive cervical seat belt sign, and we were not able to determine independent predictors of the outcome based on a multivariate analysis. However, our previous study looked at the whole cohort of patients screened for BCVI.[2] The long span of data collection of 12 years could also present with differences in screening patterns for BCVI in pediatric patients throughout the years. Due to the retrospective design of our study, physical examination findings may not always be accurately documented in our study, which limited an analysis of the specific cervical seat belt sign presentation in our patients.

We found several significant risk factors for BCVI in the presence of seat belt sign and calculated their magnitude of association, but the calculated CIs for these associations were considerably wide indicating less rigor in our calculated OR. Our study only looked at patients who underwent CTA imaging. Thus, the incidence of the seat belt sign could be underreported. The possibility exists of different interpretations of the seat belt sign among physicians in the ED and throughout the 12 years. We included abrasion and ecchymosis in our analysis. A prospective study would be needed to differentiate the degree of a cervical seat belt sign and whether it truly meets criteria established a priori.

CONCLUSIONS

Significant risk factors for BCVI in the presence of seat belt sign are ISS higher than 15, cervical spinal fracture, basilar skull fracture, and the other motorized mechanism of injury, similar to those in all children at risk of BCVI.

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