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ABSTRACT

BACKGROUND AND PURPOSE: Screening for blunt cerebrovascular injury in patients after motor vehicle collision (MVC) solely based on the presence of cervical seat belt sign has been debated in the literature without consensus. Our aim was to assess the value of emergent neurovascular imaging in patients after an MVC who present with a seat belt sign through a large-scale multi-institutional study.

MATERIALS AND METHODS: The electronic medical records of patients admitted to the emergency department with CTA/MRAs performed with an indication of seat belt injury of the neck were retrospectively reviewed at 5 participating institutions. Logistic regression analysis was used to determine the association among age, sex, and additional trauma-related findings with blunt cerebrovascular injury.

RESULTS: Five hundred thirty-five adult and 32 pediatric patients from June 2003 until March 2020 were identified. CTA findings were positive in 12/567 (2.1%) patients for the presence of blunt cerebrovascular injury of the vertebral ($n = 8$) or internal carotid artery ($n = 4$) in the setting of acute trauma with the seat belt sign. Nine of 12 patients had symptoms, signs, or risk factors for cervical blunt cerebrovascular injury other than the seat belt sign. The remaining 3 patients (3/567, 0.5%) had Biffl grades I–II vascular injury with no neurologic sequelae. The presence of at least 1 additional traumatic finding or the development of a new neurologic deficit was significantly associated with the presence of blunt cerebrovascular injury among adult patients, with a risk ratio of 11.7 ($P = .001$). No children had blunt cerebrovascular injury.

CONCLUSIONS: The risk of vascular injury in the presence of the cervical seat belt sign is small, and most patients diagnosed with blunt cerebrovascular injury have other associated findings. Therefore, CTA based solely on this sign has limited value (3/567 = a 0.5% positivity rate). We suggest that in the absence of other clinical findings, the seat belt sign does not independently justify neck CTA in patients after trauma.

ABBREVIATIONS: BCVI = blunt cerebrovascular injury; FND = focal neurologic deficit; GCS = Glasgow Coma Scale; LOC = loss of consciousness; MVC = motor vehicle collision

Motor vehicle collision (MVC) is a major cause of blunt cerebrovascular injury (BCVI).[1] Historically, the incidence of BCVI was reported to be as low as 0.1%–0.67% among patients with blunt trauma.[2,3] However, implementation of more rigorous screening protocols in trauma centers has revealed a 10-fold higher rate of BCVI, as high as 2.7%, among severely injured patients.[4-6] Although uncommon, the neurologic sequelae of BCVI are potentially serious. Many patients do not manifest stroke symptoms until hours to days after the injury,[7] and when not treated in a timely fashion, up to 80% develop permanent neurologic sequelae with an estimated 40% mortality rate.[3,8,9] Thus, screening CTA or MRA for BCVI has become commonplace in

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The authors declare that they had full access to all the data in this study and they take complete responsibility for the integrity of the data and the accuracy of the data analysis.

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the management of patients after an MVC.[10,11] However, the selection of which patients to screen has been a controversial topic during the past 4 decades.[6]

Various screening algorithms, including the modified Memphis and Denver criteria or the Western Trauma Association algorithm, may be used as guidelines (Online Supplemental Data). These guidelines, developed on the basis of observational studies and expert opinion, have adopted a liberal approach to imaging patients with possible BCVI.[7,12,13] Although this approach helps avoid missing occult injuries, it may lead to unnecessary imaging, discovery of incidental findings, increased radiation exposure, and low-value health care expenditures.[14-17] Many believe that advanced imaging studies are being overused in many medical centers, in part, due to a "defensive medicine" mentality. It is estimated that up to 50% of ordered studies lead to no improvement in patient welfare.[15,18]

One of the controversial indications for BCVI is the physical sign of neck abrasion or contusion caused by a seat belt, the so-called cervical seat belt sign. Screening for BCVI solely based on the presence of this sign has been debated in the literature without consensus.[19-22] The existing guidelines also recommend contradictory approaches regarding the use of the seat belt sign as a sole indicator to stratify patients for screening (Online Supplemental Data). Despite some single-center studies suggesting that discoloration of the skin from the seat belt is not a reliable indicator of risk to the cervical vessels,[23-25] many trauma centers persist in ordering emergent CTAs to exclude BCVI in patients with this finding because of continued debate as to the validity of the seat belt sign as an indicator of vascular injury. To address this controversy, we aimed to assess the value of emergent neurovascular imaging in patients with a seat belt sign after an MVC through a large-scale multi-institutional study that would identify the situations in which the seat belt sign may be predictive of cervical vascular injury. We hypothesized that cervical CTA performed solely on the basis of a seat belt sign has limited value.

MATERIALS AND METHODS

The acquisition of patient data for this study was Health Insurance Portability and Accountability Act–compliant. This retrospective study protocol was approved by the institutional review board at each institution separately, and informed consent was not required.

Study Population

Local radiology information systems or electronic medical records were searched in all institutions for patients who underwent CTA and/or MRA of the neck after an MVC, in which "seat," "belt," "seat belt," "seat-belt," "seatbelt," "lap," "lap belt," "lap-belt," or "lapbelt" injury of the neck was stated in the indication, body, or impression of the radiology report. The start and end points of the study were not strictly predefined but were decided separately for each institution on the basis of access to the electronic records of the patients, the period during which each institution had adopted the guidelines to screen for BCVI using a cervical seat belt sign, and the number of cases available in that time period. We were interested in separately investigating the association between the cervical seat belt sign and BCVI in adults and pediatric (younger than 18 years of age) patients. Therefore, no age limit was set for the inclusion criteria.

Data Collection

Clinical data and imaging reports for all patients were gathered from the participating centers. Scans with positive findings were identified on the basis of the imaging reports and then confirmed by subspecialty trained neuroradiologists at each center. The neurology notes were reviewed for patients with negative findings to confidently rule out the diagnosis of a BCVI in those patients. Clinical variables included age, sex, a subjective report of on-scene loss of consciousness (LOC), the initial Glasgow Coma Scale (GCS) score, physical examination, neurologic findings as per the neurology report, and associated trauma-related injuries to the head, neck, and chest. Treatment, hospital course, outcome, and other proposed indications for screening of the BCVI as outlined in the Online Supplemental Data were further retrieved for patients with confirmed BCVI. The side of the seat belt sign was gathered from their medical records for patients with positive findings on a scan and was compared with the evident soft-tissue injury, if present, on imaging. The vascular injury scale proposed by Biffl et al[26] was adopted to grade the severity of BCVI: intimal irregularity or dissection with $<25\%$ narrowing (grade I), dissection or intramural hematoma with $>25\%$ narrowing (grade II), pseudoaneurysm (grade III), vessel occlusion (grade IV), and transection with extravasation (grade V).

Statistical Analysis

Data from independent participating institutions were pooled. Descriptive statistics were used to summarize the baseline data. Non-normality of the distribution of age and the GCS score was determined by the Shapiro-Wilk test. Demographic and clinical features were compared between patients with and without BCVI using the Fisher exact test for categorical and the Mann-Whitney *U* test for continuous variables. Univariate analysis was performed with exact logistic regression to determine the association among age, sex, and the presence of at least 1 additional trauma-related finding with BCVI. Because the sample size of patients with BCVI was small, we could not perform multivariate analysis to determine the association between each single traumatic finding with BCVI. STATA 16.0 software (StataCorp) was used for statistical analysis. The level of significance was set to $<.05$.

RESULTS

Study Group Description

Data were collected from 5 independent medical/trauma centers. In total, 567 consecutive patients underwent screening angiography for BCVI in the setting of an MVC with the seat belt sign. In this population, there were 535 adult (67.6% women; mean age, 42.2 [SD, 18.4] years) and 32 pediatric (younger than 18 years of age) (56.2% female; mean age, 13.0 [SD, 4.0] years) patients. The demographic and clinical profiles of included patients are summarized in Table 1 (details from each center are given in the Online Supplemental Data). The imaging studies were performed between June 2003 and March 2020. CTA ($n = 526$) or MRA ($n = 41$) was performed within 24 hours of admission, following detection of a cervical seat belt abrasion.

Table 1: Clinical and imaging characteristics of patients with cervical seat belt sign

Characteristics	
No. (% female)	
Adult	535 (67.6)
Pediatric	32 (56.2)
Total	567 (67.0)
Age (mean) [SD] (range) (yr)	
Adult	42.2 [SD, 18.4], (18–91)
Pediatric	13.0 [SD, 4.0], (6–17)
Mean GCS [SD] (No.)	14.9 [SD, 0.8], (519)
On-scene LOC (No.) (%)	
No	400 (70.5)
Yes	65 (11.5)
Unclear or amnesic to the event	51 (9.0)
Clinical data not available	51 (9.0)
Neurologic deficit (No.) (%)	
New FND	6 (1.1)
New FND inconsistent with head CT/MR imaging	3 (0.5)
Clinical data not available	41 (7.2)
Associated traumatic findings (No.)	
Fractures	
Skull	2
Midface (maxilla, mandible)	5
Cervical vertebrae (only C1–3)	20 (6)
First rib or clavicle	20
Upper ribs (2–4)	35
Lower ribs (5–12)	10
Sternum	30
Upper thoracic vertebra	10
Cervical ligamentous injury	3
Scalp/neck hematoma	7/7
Thoracic vascular injuries	1
Intracranial hemorrhage	13
No additional finding per patient (%)	450 (79.4)
At least 1 additional finding[a] (%)	117 (20.6)
No. of patients with BCV (%)	12 (2.1)

[a] Including a new FND, a GCS score of <8, or any of the above-listed associated traumatic findings to the head, neck, or chest.

Patient Symptoms

All patients had GCS scores of 15 or 14, except 7 patients with a GCS score between 7 and 13 and 1 patient with a GCS score of 3 at initial evaluation. Sixty-five patients (11.5%) reported an episode of LOC at the time of the MVC; a history of LOC was unclear for 51 patients (9.0%). Six patients were reported to have a focal neurologic deficit (FND) on physical examination. This was associated with closed head injury and intracranial hemorrhage in 3 patients and episodes of temporary unresponsiveness due to low blood pressure in 1 patient. Another patient presented with temporary facial nerve palsy. FNDs were manifest at the first emergency department encounter, except for 1 patient who presented after 2 days with subjective deterioration of pre-existing visual symptoms due to amblyopia.

Non-BCVI Injuries

Head, neck, and chest traumatic injuries, other than the seat belt sign, included cervical spinal fracture or ligamentous injury ($n = 23$), thoracic skeletal injuries ($n = 105$), thoracic vascular injury ($n = 1$), fracture of the skull or midface ($n = 7$), and intracranial hemorrhage ($n = 13$). No patients had a stroke. The overall mortality rate was zero during the hospital admission and at follow-up of at least 1 month (Online Supplemental Data). In total, 117 patients had at least 1 injury other than the seat belt sign to the head, neck, or chest, were reported to have a GCS score of <8, or developed new FNDs. The remaining 450 patients had only a cervical seat belt sign, with a GCS score of >8 without any other traumatic findings, signs, or symptoms of BCVI.

Patients Diagnosed with BCVI: Characteristics

Figure 1 shows the flow chart of a subgroup of patients based on the diagnosis of BCVI and the presence of additional traumatic findings other than the cervical seat belt sign. There were 12/567 patients (2.1%) with a seat belt sign who had BCVI discovered on initial cervical CTA and confirmed on review by an expert neuroradiologist (Fig 2). The Online Supplemental Data show clinical profiles and imaging findings for each patient with positive BCVI findings on CTA of the neck. The side of the seat belt sign was contralateral to the site of the BCVI in 5/12 patients. BCVI was detected in the internal carotid ($n = 4$) or vertebral artery ($n = 8$) with a Biffl grade I ($n = 6$), II ($n = 4$), or IV ($n = 2$).

One patient had initially negative cervical CTA findings confirmed on review by an expert neuroradiologist. The patient presented 2 days later with subjective exacerbation of pre-existing visual symptoms due to a history of amblyopia. The neurologic examination was limited due to the amblyopia. Repeat CTA and ultrasonography of the neck were compatible with grade I traumatic dissection of the proximal left internal carotid artery. The patient was discharged on anticoagulation, and the symptoms were resolved on 1-month follow-up.

Another patient had multiple neurologic deficits that were attributed to the coexisting brain injury. No other patient diagnosed with BCVI showed any neurologic sequelae during the hospital course or available follow-ups. No patients showed clinically overt signs of vascular trauma, including pulsatile bleeding, expanding hematoma, palpable thrill, cervical bruit, or stroke.

Patients with BCVI: Treatment and Follow-up

No vascular intervention was performed for any patients. Those with BCVI were all discharged on antiplatelet or anticoagulation therapy after neurologic consultation, except 1 patient who was merely observed for a cervical vascular injury. In 4 patients, the grade I BCVI resolved on follow-up vascular imaging (up to 2 months). Other vascular injuries were stable at 1- to 3-month follow-up in 4 patients with grade I, II, or IV vascular injury. Four patients with grade I or II BCVI did not have any follow-up imaging (Online Supplemental Data). Patients with BCVI were more likely to present with a new FND ($P = .007$), intracranial hemorrhage ($P = .03$), cervical vertebral fracture ($P < .001$), or sternal fracture ($P = .02$) (Table 2).

Patients with BCVI: Comparison of an Isolated Seat Belt Sign with a Seat Belt Sign with Additional Traumatic Injuries

Of a total of 12 patients diagnosed with BCVI, 9 had additional clinical or imaging evidence of cervicothoracic trauma. In

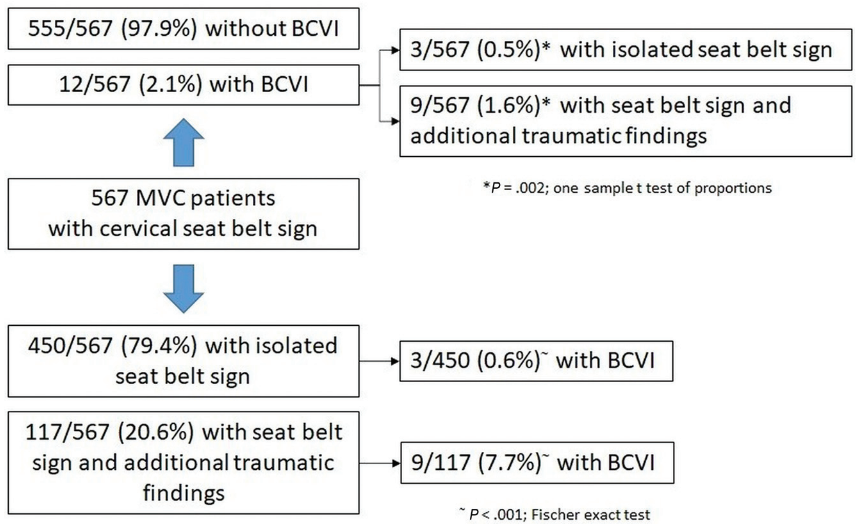

FIG 1. Flow chart of patients showing the incidence rate of BCVI among 2 subgroups of patients after an MVC based on the presence of additional traumatic findings other than the cervical seat belt sign.

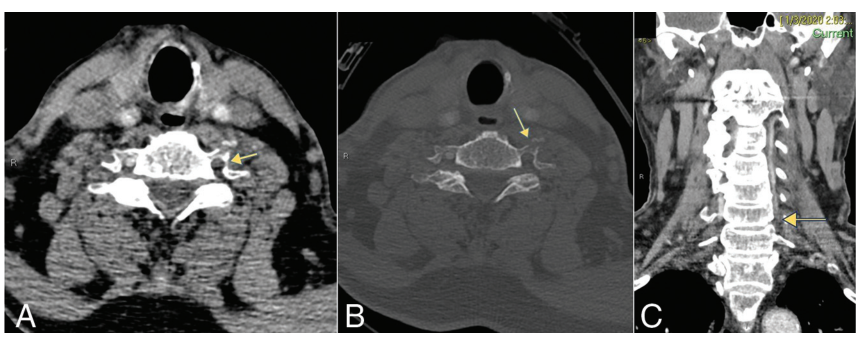

FIG 2. CTA of a 71-year-old male patient shows absent vascular opacification (*arrow*) in an occlusive dissection of the left vertebral artery (*A*). There is a mildly displaced fracture of the left transverse process/foramen of C5 (*arrow*) evident on the corresponding bone window (*B*). The coronal reconstructed image demonstrates occlusion of the V1 and proximal V2 segments and the absence of flow below the C6 vertebral level (grade IV) (*arrow*) (*C*), with a reconstituted left vertebral artery above from collaterals.

another 3 patients with BCVI, there were no traumatic findings or BCVI risk factors other than the seat belt sign during the initial presentation, hospital course, or additional follow-ups. These 3 patients had grade I or II BCVI. The incidence of BCVI among patients without traumatic findings other than a seat belt injury (0.6%, $n = 3/450$) was significantly lower than in patients with BCVI and at least 1 additional traumatic finding (7.7%, 9/117) ($P < .001$) (Fig 1). The presence of at least 1 additional traumatic finding (including fractures in the skull, midface, cervical or upper thoracic vertebrae, ribs, or sternum; cervical spinal ligamentous injury; intracranial hemorrhage; or closed head injury) or development of a new FND was significantly associated with the presence of BCVI among adult patients, with a risk ratio of 11.7 ($P = .001$). Age and sex were not associated with the presence of BCVI in adult patients on univariate logistic regression analysis ($P = .77$ and .68, respectively).

DISCUSSION

In this multi-institutional study, we found that the incidence of BCVI in the setting of an isolated cervical seat belt sign after MVC was 0.5% (3/567), which is less than in previous reports of the incidence of BCVI among severely injured patients.[4-6] Additionally, the presence of at least 1 additional traumatic finding to the head, neck, or upper chest, including skeletal injury, closed head injury, or a new FND, was significantly associated with BCVI in our study population, with a relative risk of 11.7. Currently, CTA or MRA is being ordered in many emergency departments or trauma centers for patients with a cervical seat belt sign. However, our results indicate that the seat belt sign alone has a low predictive value for BCVI and should not be considered as an independent indicator for radiologic screening. Exceptions to this rule may be applied to patients with known vascular fragility risk factors including fibromuscular dysplasia or connective tissue disorders such as Marfan or Loeys-Dietz syndrome.[27]

Existing literature on the use of this sign in isolation is scant and contradictory. Following several early reports of catastrophic BCVI in patients with a seat belt sign, this finding has appeared in some guidelines as a reliable marker to screen for BCVI (Online Supplemental Data). A review of a national trauma databank from 2008 to 2014 with 2,174,244 adult patients with blunt trauma revealed 5970 (0.27%) patients with BCVI and 859/5970 (14.4%) patients with a seat belt sign. Multivariate analysis confirmed the association of the seat belt sign with BCVI in adult patients,[28] leading to an impression that neurovascular imaging is warranted. However, this report did not address the predictive value of this sign by itself or the impact of other signs of cervicothoracic trauma; therefore, it only obfuscated the assessment of the seat belt sign as an indication for screening.

More recent studies have argued against the cervical seat belt sign as an independent factor warranting BCVI screening for adult and pediatric patients. DiPerna et al[21] retrospectively reviewed 131 consecutive patients with a cervical seat belt sign. Only 1 patient with neurologic deficits and multiple associated injuries was diagnosed with BCVI. Similarly, in a prospective study of another 131 patients with a cervicothoracic seat belt sign, the authors found 4 positive reports of BCVI. Rozycki et al[22] demonstrated that the seat belt sign in combination with other abnormal findings such as a GCS score of <14, first rib or clavicle

Table 2: Comparison of adult patients without BCVI versus patients with BCVI (18 years of age or older)

	Without BCVI (*n* = 523)	With BCVI (*n* = 12)	*P* Value
Female/male	355:168	7:5	.53
Age (mean) [SD] (yr)	42.1 [SD, 18.4]	43.6 [SD, 20.7]	.86[a]
GCS (mean) [SD]	14.9 [SD, 0.8] (GCS: 3 = 1 patient GCS: 7 = 1 patient Others: >8)	14.8 [SD, 0.6] (GCS: 13 = 1 patient Others =15)	.55[a]
On-scene LOC (No/yes/unclear)	370/56/48	8/4/0	.06
Neurologic deficit			
New FND	4 (0.7%)	2 (16.7%)	.007
New FND inconsistent with head CT/MR imaging	2 (0.4%)	1 (8.3%)	.07
At least 1 additional traumatic head/neck/chest injury			
All	103 (19.7%)	9 (75%)	<.001
All except scalp/neck hematoma	82 (15.7%)	7 (58.3%)	.001
Head injury			
Intracranial hemorrhage	11 (2.1%)	2 (16.7%)	.031
Skull fracture/hematoma	2 (0.4)/7 (1.3%)	0	
Midface fracture	5 (0.9%)	0	
Cervical injury			
Cervical spine fracture	15 (2.9%)	4 (33.3%)	<.001
C1–3 fracture	5 (1.0%)	1 (8.3%)	.12
Spinal ligamentous injury	2 (0.4%)	0	
Neck hematoma	7 (1.3%)		
Thoracic injury			
First rib/clavicle fracture	19 (3.6%)	1 (8.3%)	.37
Upper rib fracture	43 (8.2%)	2 (16.7%)	.26
Any rib fracture	53 (10.1%)	3 (25%)	.12
Sternal fracture	27 (5.2%)	3 (25%)	.02
Vertebral fracture	8 (1.5%)	0	
Vascular injury	1 (0.2%)		

[a] The Mann-Whitney test was used for those marked with a, and Fischer exact test, for the rest.

fracture, or an injury severity score of >16 was associated with a higher risk of BCVI. Therefore, a larger multi-institutional study was warranted for resolution of this controversy. Our study shows that the incidence of BCVI in the presence of an isolated seat belt sign is negligible (3/567; 0.5%). The 3 patients with an isolated seat belt sign were diagnosed with mild BCVI (grades I–II). A higher grade IV BCVI was detected in 2 patients who also had associated cervical vertebral fractures. In addition, the presence of vascular injury on the side opposite the seat belt sign (4/12 in our cohort) serves as an indicator of the severity of the MVC and/or the presence of a to-and-fro acceleration-deceleration injury, placing all vessels, ipsilateral or contralateral, at risk.[29] On the basis of these lines of evidence, we suggest that this sign should initiate a careful evaluation for other factors related to BCVI via a thorough physical examination and standard trauma imaging rather than a reflexive order of neck CTA. By doing so, a CTA could have been safely avoided in at least 450/567 (79.4%) patients without any associated trauma-related cervicothoracic finding, new neurologic deficits, or a reported GCS score of <8 among our cohort.

Although the number of pediatric patients identified through searching imaging data bases of participating sites was small ($n = 32$), there were no BCVIs detected in the included children. Three retrospective studies on pediatric patients have also recommended against the use of the seat belt sign as a sole indicator of BCVI screening in this population.[23,25,28]

Limitations

There are several limitations to this study that stem from its retrospective design. The clinical information of 40 patients was not retrievable because of missing data in the transition from paper to electronic medical records. Because the details of the kinematics and the severity of the MVC injury as well as the type of seat belt were not available for almost all of the patients, such information could not be assessed in our study. However, our reported incidence of BCVI (12/567; 2.1%) was nearly as high as in previous reports of its incidence among severely injured patients.[4-6] Patients were identified on the basis of the language of imaging reports/orders, which may have led to the exclusion of some patients after an MVC with a seat belt injury who underwent neurovascular imaging. The CTA/MRA protocols were not standardized across the institutions and may have varied within the same institution, given the wide date range. Because we intended to assess the predictive value of seat belt injury for BCVI, we did not include all patients after an MVC and thus could not study all risk factors for BCVI. Finally, all except 1 patient with BCVI received treatment. Although the number of patients with an isolated seat belt sign and BCVI was small and they experienced only mild vascular injury, neurovascular imaging resulted in a change in their management. Therefore, we cannot exclude the possibility that a very small number of patients could have experienced an adverse outcome (ie, an embolic stroke) in follow-up as a result of not performing CTA/MRA of the neck (because they would not have received antiplatelet therapy in that case). Future studies with a case-control design are warranted to investigate this possibility.

CONCLUSIONS

In a multi-institutional study, we found that the incidence of BCVI in patients with an isolated seat belt sign was negligible (0.5%). Thus, we recommend elimination of this indication for CTA in the absence of other clinical findings. While the seat belt sign should not trigger reflexive imaging, it should prompt a careful neurologic examination and evaluation for associated injuries that could increase the risk for BCVI.

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