Universal screening for blunt cerebrovascular injury

Jonathan A. Black, MD, Peter J. Abraham, MD, Mackenzie N. Abraham, MD, Daniel B. Cox, MD, Russell L. Griffin, PhD, John B. Holcomb, MD, Parker J. Hu, MD, Jeffrey D. Kerby, MD, PhD, Elizabeth J. Liptrap, MD, Bart Thaci, MD, Mark R. Harrigan, MD, *and* **Jan O. Jansen, MBBS, PhD***, Birmingham, Alabama*

CONTINUING MEDICAL EDUCATION CREDIT INFORMATION

Accreditation

The American College of Surgeons is accredited by the Accreditation Council for Continuing Medical Education (ACCME) to provide continuing medical education for physicians.

AMA PRA Category 1 Credits™

The American College of Surgeons designates this journal-based CME activity for a maximum of 1 *AMA PRA Category 1 Credit*™. Physicians should claim only the credit commensurate with the extent of their participation in the activity.

Of the *AMA PRA Category 1 Credit*™ listed above, a maximum of 1 credit meets the requirements for self-assessment.

Objectives

After reading the featured articles published in the *Journal of Trauma and Acute Care Surgery*, participants should be able to demonstrate increased understanding of the material specific to the article. Objectives for each article are featured at the beginning of each article and online. Test questions are at the end of the article, with a critique and specific location in the article referencing the question topic.

Disclosure Information

In accordance with the ACCME Accreditation Criteria, the American College of Surgeons must ensure that anyone in a position to control the content of the educational activity (planners and speakers/authors) has disclosed all relevant financial relationships with any commercial interest. For additional information, please visit the ACCME website (see below for definitions).

Commercial Interest: The ACCME defines a "commercial interest" as any entity producing, marketing, re-selling, or distributing health care goods or services used on or consumed by patients. Providers of clinical services directly to patients are NOT included in this definition.

Financial Relationships: Relationships in which the individual benefits by receiving a salary, royalty, intellectual property rights, consulting fee, honoraria, ownership interest (e.g., stocks, stock options or other ownership interest, excluding diversified mutual funds), or other financial benefit. Financial benefits are usually associated with roles such as employment, management position, independent contractor (including contracted research), consulting, speaking and teaching, membership on advisory committees or review panels, board membership, and other activities from which remuneration is received, or expected. ACCME considers relationships of the person involved in the CME activity to include financial relationships of a spouse or partner.

Conflict of Interest: Circumstances create a conflict of interest when an individual has an opportunity to affect CME content about products or services of a commercial interest with which he/she has a financial relationship.

The ACCME also requires that ACS manage any reported conflict and eliminate the potential for bias during the session. Any conflicts noted below have been managed to our satisfaction. The disclosure information is intended to identify any commercial relationships and allow learners to form their own judgments. However, if you perceive a bias during the educational activity, please report it on the evaluation.

Authors/Contributors
John B. Holcomb- Spectrum, Cellphire, Arsenal, Deciso Health, QinFlow, Zibrio, UT Health, Safeguard; Consultant, Co-Founder, BoD, Inventor. Jonathan A. Black, Peter J. Abraham, Mackenzie N. Abraham, Daniel B. Cox, Russell L. Griffin, Parker J. Hu, Jeffrey D. Kerby, Elizabeth J. Liptrap, Bart Thaci, Mark R. Harrigan, and Jan O. Jansen- No Disclosures.

Planning Committee / Editorial Committee	Nothing to Disclose	Disclosure		
		Company	Role	Received
Ernest E. Moore, Editor		*Haemonetics*	*PI*	*Shared U.S. Patents*
		Instrumentation Laboratory	*PI*	*Research Support*
		Stago, Humacyte, Prytime, Genentech	*PI*	*Research Support*
		ThromboTherapeutics	*Co-founder*	*Stock*
Associate Editors David B. Hoyt, Ronald V. Maier, and Steven Shackford	X			
Editorial Staff and Angela Sauaia	X			

Claiming Credit

To claim credit, please visit the AAST website at http://www.aast.org/ and click on the "e-Learning/MOC" tab. You must read the article, successfully complete the post-test and evaluation. Your CME certificate will be available immediately upon receiving a passing score of 75% or higher on the post-test. Post-tests receiving a score of below 75% will require a retake of the test to receive credit.

Credits can only be claimed online

Cost

For AAST members and Journal of Trauma and Acute Care Surgery subscribers there is no charge to participate in this activity. For those who are not a member or subscriber, the cost for each credit is $25.

Questions

If you have any questions, please contact AAST at 800-789-4006. Paper test and evaluations will not be accepted.

BACKGROUND: Blunt cerebrovascular injury (BCVI) can result in thromboembolic stroke. Many trauma centers selectively screen patients with cervical computed tomographic angiography (CTA) based on clinical criteria. In 2016, our institution adopted universal screening for BCVI for all blunt trauma patients. The aim of this study was to accurately determine the incidence of BCVI and to evaluate the diagnostic performance of the Denver criteria (DC), expanded Denver criteria (eDC), and Memphis criteria (MC) in selecting patients for screening.

METHODS: Retrospective cohort study of adult (≥16 years) blunt trauma patients who presented to the Level I trauma center at University of Alabama at Birmingham. We reviewed all CTA reports and selected CTA images to obtain the true incidence rate of BCVI. We then evaluated the diagnostic performance of the DC, eDC, and MC.

RESULTS: A total of 6,800 patients who had suffered blunt trauma were evaluated, of whom 6,287 (92.5%) had a neck CTA. Of these, 480 (7.6%) patients had CTA evidence of BCVI. The eDC identified the most BCVI cases (sensitivity 74.7%) but had the lowest positive predictive value (14.6%). The DC and MC had slightly greater positive predictive values (19.6% and 20.6%, respectively) and had the highest diagnostic ability in terms of likelihood ratio (2.8 and 2.9) but had low sensitivity (57.5% and 47.3%). Consequently, if relying on the traditional screening criteria, the DC, eDC, and MC would have respectively resulted in 42.5%, 25.3%, and 52.7% of patients with BCVI identified by universal screening not receiving a neck CTA to screen for BCVI.

CONCLUSION: Blunt cerebrovascular injury is even more common than previously thought. The diagnostic performance of selective clinical screening criteria is poor. Consideration should be given to the implementation of universal screening for BCVI using neck CTA in all blunt trauma patients. (*J Trauma Acute Care Surg.* 2021;90: 224–231. Copyright © 2020 American Association for the Surgery of Trauma.)

LEVEL OF EVIDENCE: Diagnostic, level III.

KEY WORDS: Blunt; trauma; cerebrovascular injury; universal screening.

Blunt cerebrovascular injury (BCVI) has been reported in 1% to 3% of patients admitted after blunt trauma and carries a risk of thromboembolic stroke.[1–8] Early diagnosis of BCVI and treatment with antithrombotic medications may reduce the stroke risk.[9] Prior to the advent of multislice computed tomography (CT) scanners, digital subtraction angiography (DSA) was used to diagnose (or rule out) BCVI. Digital subtraction angiography is resource-intensive and associated with risks, and therefore several groups developed sets of clinical screening criteria to select patients who were at high risk for BCVI to undergo DSA. The Denver criteria (DC)[10] and Memphis criteria (MC)[11] consist of lists of injuries, as well as clinical signs, which are known to be associated with BCVI (Table 1). However, the selective use of imaging techniques underestimates the true incidence of a disease, and further study by both groups resulted in ever expanding criteria for screening after demonstrating that up to 20% of patients with BCVI did not meet the initial criteria.[12,13] Expanded indications for screening and improvements in CT technology have resulted in an increase in the perceived incidence of BCVI.

Computed tomographic angiography (CTA) of the neck is now widely accepted as the primary modality for the diagnosis of BCVI.[14] However, the true incidence of BCVI continues to be a matter of debate. In 2016, we changed our institutional policy for the investigation of suspected BCVI from selective to universal screening such that all patients who had suffered blunt trauma underwent a CTA of the neck in addition to CT scans of the head, cervical spine, chest, abdomen, and pelvis. This change was instituted following the failure to diagnose BCVI in two patients who did not meet clinical screening criteria and subsequently suffered strokes. Our widespread use of CTA provides an opportunity to determine the true incidence of BCVI and to evaluate the diagnostic performance of commonly used clinical screening criteria. We hypothesized that universal evaluation with CTA neck would result in a higher incidence of BCVI than reported in the literature and a lower diagnostic performance of clinical screening criteria.

Submitted: August 10, 2020, Revised: October 7, 2020, Accepted: October 22, 2020, Published online: November 2, 2020.
From the Division of Acute Care Surgery, Department of Surgery, (J.A.B, D.B.C., J.B.H., P.J.H., J.D.K., J.O.J.); Department of Surgery (P.J.A., M.N.A.), School of Public Health (R.L.G.), Department of Neurosurgery (E.J.L., M.R.H.), and Department of Radiology (B.T.), University of Alabama at Birmingham, Birmingham, Alabama.
This article will be presented 79th Annual Meeting of the American Association for the Surgery of Trauma, September 8 to 18, 2020.
Supplemental digital content is available for this article. Direct URL citations appear in the printed text, and links to the digital files are provided in the HTML text of this article on the journal's Web site (www.jtrauma.com).
Address for reprints: Jonathan A. Black, MD, Division of Acute Care Surgery, Department of Surgery, University of Alabama at Birmingham, Boshell Building, 1808 7th Ave S, Birmingham, AL 35233; email: jonathanblack@uabmc.edu.

DOI: 10.1097/TA.0000000000003010

METHODS

Design, Setting, and Data Sources

This is a retrospective cohort study. The University of Alabama at Birmingham (UAB) hospital is an American College of Surgeons verified Level I trauma center in Central Alabama that evaluates over 5,000 trauma patients per year. The hospital has a dedicated neurovascular service staffed by neurovascular trained neurosurgeons. Adult (≥16 years) patients who presented following blunt injury between August 2017 and August 2019 were included. Data were from obtained from the UAB trauma registry and from reviews of CT scan reports and CT images (see below). The study was approved by our institutional review board.

CT Scanner and Imaging Protocol

The emergency department at UAB Hospital is equipped with a Philips iCT 256-slice CT scanner (Koninklijke Philips N. V., Amsterdam). Contrast volume is administered based on patient weight, with patients under 200 lbs receiving 120 mL of

TABLE 1. BCVI Screening Criteria for Denver, eDC, MC, and mMC

DC	eDC	MC	mMC
Carotid artery hemorrhage Cervical bruit Cervical trauma plus altered mental status Lateralizing neurologic deficit (hemiparesis, transient ischemic attack, amaurosis fugax, Horner's syndrome) Neurologic deficit incongruous with CT Cerebral infarction on CT Severe cervical hyperextension injury Severe cervical flexion and rotation injury Significant cervical soft tissue injury of the anterior neck Cervical spine fracture Displaced midface fracture Mandible fracture Basilar skull fracture involving the sphenoid, mastoid, petrous or foramen lacerum	Potential arterial hemorrhage from the neck/nose/mouth Cervical bruit in patient <50 y Expanding cervical hematoma Focal neurological deficit: TIA, hemiparesis, vertebrobasilar symptoms, Horner's syndrome Neurologic examination inconsistent with head CT Stroke on MRI or CT Displaced mid-face fracture (Lefort II or III) Mandible fracture Complex skull fracture, basilar skull fracture, occipital condyle fracture Closed head injury with diffuse axonal injury and GCS score <6 Cervical subluxation or ligamentous injury, transverse foramen fracture, anybody fracture, any fracture C1–C3 Near hanging with anoxic brain injury Clothesline type injury or seat belt abrasion with significant swelling, pain or altered mental status Traumatic brain injury with thoracic injuries Scalp degloving Thoracic vascular injuries Blunt cardiac rupture	Cervical spine fracture Neurologic examination not explained by brain imaging Horner's syndrome Lefort II or III facial fractures Skull base fracture involving the foramen lacerum Neck soft tissue injury (e.g., seatbelt injury or hanging)	Cervical spine fracture Neurologic examination not explained by brain imaging Horner's syndrome Lefort II or III facial fractures Basilar skull fracture Neck soft tissue injury (e.g., seatbelt injury or hanging) Potential head or skull injury: loss of consciousness, altered mental status, periorbital ecchymosis, supramastoid ecchymosis Potential cervical spine fracture or soft tissue neck injury: paralysis with cervical spine level, cervical step off, tenderness to palpation, soft tissue injury "seat belt" mark Potential Le Fort facial fracture: midface instability, marked external deformity

GCS, Glasgow Coma Scale.

IV contrast and patients 200 lbs and greater receiving 140 mL of IV contrast. All images are reviewed and interpreted by an attending radiologist.

Review of CT Angiograms

All CTA reports were reviewed (by two of the investigators, J.A.B. and P.J.A.), and categorized as clearly identifying the presence of a BCVI ("positive scan"), clearly excluding a BCVI ("negative scan"), or equivocal. An internal validation was performed by the neuroendovascular surgeons (M.R.H. and E.J.L.) who executed a blinded review of randomly selected positive and negative scans to evaluate the accuracy and precision of the review process. A total of 40 patients, 20 positive and 20 negative for BCVI, were reviewed, and agreement between the two groups was 100%. The CTA images of all equivocal reports were then jointly reviewed by the two neuroendovascular surgeons and an endovascular neurosurgery fellow (B.T.) to arbitrate whether a BCVI was present or not. Patients with confirmed BCVI were further evaluated to determine the number of vessels injured and the highest grade of injury using the Biffl classification.[15] Data were collated in a Microsoft Excel (Microsoft, Redmond, WA) spreadsheet.

Analysis

The incidence of BCVI was calculated as the proportion of patients with CTAs that showed a BCVI out of all patients who underwent CTA. To evaluate the diagnostic performance of the clinical screening criteria, we searched our trauma registry for Abbreviated Injury Scale (AIS) codes that corresponded to the injuries included in each of the four sets of clinical screening criteria: the original clinical screening criteria from the groups in DC (6) and MC (7), as well as updated criteria published by both groups, which we designated as the expanded DC (eDC) (8) and the modified MC (mMC) (9). Table S1 (http://links.lww.com/TA/B836) in the Supplementary Appendix lists the AIS codes for injuries specified in the screening criteria. Patients recorded as having the injuries listed were deemed to be clinical-screen positive. Many of the signs and symptoms that are included in the DC, MC, eDC, and mMC (also shown in Table S1, http://links.lww.com/TA/B836) do not have a corresponding injury code, and therefore, our analysis of the criteria represents an evaluation of the objective data recorded in the trauma registry. The diagnostic performance of the DC, MC, eDC, and mMC were expressed in terms of the proportion of patients who were clinical-screen positive, the false negative and false positive rate, the sensitivity (ability of the clinical screening criteria to correctly identify patients with BCVI), specificity (ability of the screening criteria to correctly identify patients without BCVI), positive predictive value (PPV, a measure of screening accuracy and the probability that a patient who meets the clinical screening criteria has BCVI), negative predictive value (NPV) (the probability that a patient who does not meet the clinical screening criteria truly does not have BCVI), and the likelihood ratio (LR) positive (the likelihood that a given screening test result would be expected in a patient with BCVI, compared with the likelihood that the same result would be expected in a patient without the injury). Because the MC and mMC differ only by the addition subjective criteria intended to capture patients with potential injuries to the head, neck and face, and the AIS codes

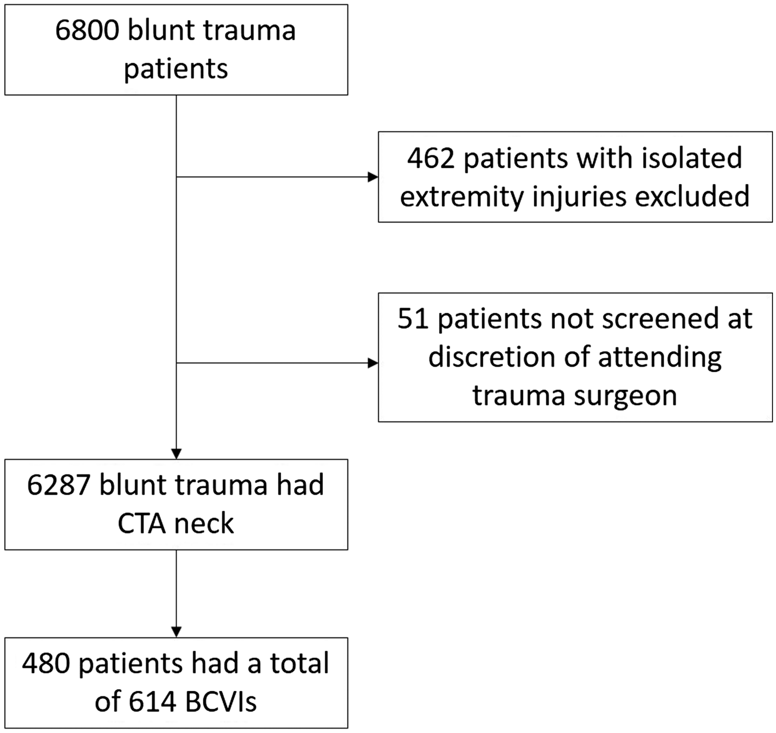

Figure 1. Derivation of study cohort.

for both sets of criteria are the same, we only report the data once. The analysis was performed using SAS v9.4.

RESULTS

A total of 6,800 patients with blunt trauma were seen in the emergency department over the study period. Of those, 6,287 (92.5%) had a neck CTA and 480 (7.6%) showed evidence of BCVI. There were 5,841 eligible for entry into the trauma registry and included in this analysis. Of the 513 patients that did not receive a screening neck CTA, the majority had isolated extremity trauma. The derivation of the study cohort is shown in Figure 1.

Characteristics of Study Population

Patients with BCVI had a mean age of 47.3 ± 19.9 years and a median Injury Severity Score of 17 (interquartile range, 11–27). The most common causes of injury were motor vehicle collisions (MVCs) (63.6%), falls (19.3%), motorcycle collisions (7.9%), and pedestrian being struck by vehicles (4.9%). A total of 251 (52.3%) patients had a carotid artery injury, and 258 (53.8%) had a vertebral artery injury. In total, there were 317 carotid artery injuries and 297 vertebral artery injuries. The distribution by Biffl grade is shown in Table 2. Grade 1 injuries were the most common (54.9% of carotid artery injuries, 44.8% of vertebral artery injuries). Grade 2 injuries accounted for around one quarter of injuries. Table 3 shows the distribution by highest grade of injury for all 480 patients. In 44.2% of patients, the highest grade of injury was a Biffl Grade 1 and in 40.2% a Biffl Grade 2. More patients had injury to bilateral carotid arteries (69 [14.4%]) than bilateral vertebral arteries (40 [8.3%]). The majority of patients had an injury to one vessel (75.4%) or two vessels (21.9%).

TABLE 2. Distribution of Injuries, by Biffl Grade, All Injuries (n = 614)

Biffl Grade		Carotid Artery Injuries n (%)	Vertebral Artery Injuries n (%)
1	Luminal irregularity or dissection <25% luminal narrowing	174 (54.9)	133 (44.8)
2	Dissection or intramural hematoma ≥25% luminal narrowing	92 (29.0)	79 (26.6)
3	Pseudoaneurysm	38 (12.0)	13 (4.4)
4	Vessel occlusion	13 (4.1)	71 (23.9)
5	Transection with free extravasation	0 (0.0)	1 (0.3)
All		317	297

Diagnostic Performance of Clinical Screening Criteria

Table 4 shows how the various clinical screening criteria performed in our blunt trauma population when compared with

TABLE 3. Distribution by Highest Grade of Injury, by Biffl Grade, Any Vessel, All Patients (n = 480)

Biffl Grade		Patients n (%)
1	Luminal irregularity or dissection <25% luminal narrowing	212 (44.2)
2	Dissection or intramural hematoma ≥25% luminal narrowing	145 (30.2)
3	Pseudoaneurysm	46 (9.6)
4	Vessel occlusion	76 (15.8)
5	Transection with free extravasation	1 (0.2)

TABLE 4. Diagnostic Performance of Clinical Screening Criteria (n = 5,841)

Criteria	DC	eDC	MC
No. (and %) patients meeting criteria	1,122 (19.2%)	2,066 (35.4%)	864 (14.8%)
No. patients with BCVI	271	352	223
False negative rate	42.5%	25.3%	52.7%
False positive rate	20.9%	38.5%	16.1%
Sensitivity	57.5%	74.7%	47.3%
Specificity	79.1%	61.5%	83.9%
PPV	19.6%	14.6%	20.6%
NPV	95.5%	96.5%	94.7%
LR positive	2.8	1.9	2.9

universal screening. The eDC identified the most BCVI cases (sensitivity 74.7%) but had the lowest PPV (14.6%). The DC and MC had slightly greater PPVs (19.6% and 20.6%, respectively) and had the highest diagnostic ability in terms of LR (LR+, 2.8 and 2.9), but had lower sensitivity (57.5% and 47.3%, respectively) than the eDC. Consequently, if relying on the traditional screening criteria, the DC, eDC, and MC would have, respectively, resulted in up to 42.5%, 25.3%, and 52.7% of patients with BCVI identified by universal screening not receiving a neck CTA to screen for BCVI.

DISCUSSION

Blunt cerebrovascular injuries are important because they carry with them a risk of stroke. Some of these strokes may be preventable—but only if BCVIs are identified and appropriate prevention strategies are instigated.

Our study shows that the incidence of BCVI, as determined by universal screening of all blunt multiple-trauma patients with CTA of the neck, is 7.6%, which is more than twice the rate previously reported.[4,6,8] This finding is not related to the detection of increasing numbers of clinically insignificant lesions. The proportions of patients with Grades 1 to 4 injuries in our cohort were 44.2%, 30.2%, 9.6%, and 15.8%, respectively, which is similar to the findings of the Denver and Memphis groups.[4,14] The discrepancy between our results and those reported previously, therefore, is most likely because of patients who do not meet the criteria currently used to select patients for investigation. Our evaluation of the diagnostic performance of the commonly used clinical screening criteria, using the results of universal screening as the "gold standard," confirms these findings. Reliance on clinical screening criteria will result in patients with blunt cerebrovascular injuries remaining undiagnosed, with potentially serious consequences.

In the National Trauma Data Bank 2016 Annual Report published by the American College of Surgeons,[16] falls comprised 44.2% of blunt traumatic injuries, followed by MVCs at 26.0%. Our blunt trauma population was 63.6% MVC followed by falls at 19.3%. Despite this difference, we believe our findings still have broad applicability. This study found a high incidence of BCVI in all types of blunt trauma, and our lowest incidence category, blunt strike, had a BCVI rate of 3.5%, which is still higher than any previously reported study.

Multislice CT scanners are now widely available, simplifying the process of evaluating the cerebrovascular injury. Furthermore, the addition of a cervical CTA to other routine blunt trauma CT scans does not increase the amount of contrast agent and thus adds little risk to the patient.[17] However, the trauma community has been slow to embrace universal screening for BCVI, and U.S. and international guidelines continue to recommend selective evaluation.[1,18,19] To our knowledge, only one other institution, Virginia Commonwealth University (VCU), has published data after adopting universal screening for BCVI.[20] In the VCU study, the incidence of BCVI detection with universal screening was 2.7%—lower than that reported by institutions which have not adopted universal screening. The VCU patients had a median Injury Severity Score virtually identical to ours, so the populations appear to be similar. It is therefore unclear why the incidence of BCVI in the VCU population is so low, since increased screening usually leads to increased detection. Despite this difference, the VCU authors call for universal screening and appropriately note that with an ever-expanding list of BCVI risk factors, it is questionable whether practitioners in busy trauma centers can consistently remember and apply the screening guidelines. We assert that if the guidelines are too complicated to be followed in busy trauma centers, they need to be simplified for everyone. We believe that the time has come to adopt universal screening as the standard of care for the evaluation of patients who have suffered blunt multiple trauma.

Our study has limitations. The most important is its retrospective, single-center design. Although all CTA reports and many of the CTA images were reviewed, the study relied on accurate trauma registry data, particularly for the evaluation of diagnostic performance. We used a "crosswalk" to create lists of AIS codes that represent the injuries included in the DC and MC. There are no such codes for the more subjective criteria, which could partly explain the low performance of the clinical screening criteria. In addition, although we aim to obtain cervical CTAs on all blunt trauma patients, 7.5% of patients entered into our trauma registry did not receive a CTA of the neck. On review of these patients, most had low-energy traumatic mechanisms resulting in isolated extremity trauma. Not requesting cervical CTAs in these patients, therefore, seems appropriate.

CONCLUSION

Despite these limitations, our study adds to the body of literature on BCVI. Our results demonstrate that when all patients undergo cervical CTA, BCVI is even more common than previously thought. When evaluated against this gold standard, the diagnostic performance of clinical screening criteria is poor. Consideration should be given to the implementation of universal screening for BCVI using cervical CTA in all blunt trauma patients.

AUTHORSHIP

J.A.B. participated in the literature search, study design, data collection, data analysis, data interpretation, writing, and critical revision. P.J.A. participated in the data collection, data analysis, data interpretation, and writing. M.N.A. participated in the data collection, data analysis, data interpretation, and writing. D.B.C. participated in the study design, data analysis, data interpretation, writing, and critical revision. R.L.G.

participated in the study design, data collection, data analysis, and data interpretation. J.B.H. participated in the literature search, writing, and critical revision. P.J.H. participated in the literature search, data interpretation, writing, and critical revision. J.D.K. participated in the study design, writing, and critical revision. E.J.L. participated in the study design, data collection, data interpretation, writing, and critical revision. B.T. participated in the data collection and data interpretation. M.R.H. participated in the literature search, study design, data collection, data analysis, data interpretation, writing, and critical revision. J.O.J. participated in the literature search, study design, data collection, data analysis, data interpretation, writing, and critical revision.

DISCLOSURE

The authors declare no funding or conflicts of interest.

REFERENCES

1. Kim DY, Biffl W, Bokhari F, et al. Evaluation and management of blunt cerebrovascular injury: a practice management guideline from the Eastern Association for the Surgery of Trauma. *J Trauma Acute Care Surg*. 2020;88(6): 875–887.
2. Müther M, Sporns PB, Hanning U, Düsing H, Hartensuer R, Raschke M, Schwake M, Stummer W, Glasgow S. Diagnostic accuracy of different clinical screening criteria for blunt cerebrovascular injuries compared with liberal state of the art computed tomography angiography in major trauma. *J Trauma Acute Care Surg*. 2020;88:789–795.
3. Sinnathamby M, Rao SV, Weber DG. Increased detection of blunt carotid and vertebral artery injury after implementation of diagnostic imaging pathway in level 1 trauma centre in Western Australia. *Injury*. 2017;48(9):1917–1921.
4. Geddes AE, Burlew CC, Wagenaar AE, Biffl WL, Johnson JL, Pieracci FM, Campion EM, Moore EE. Expanded screening criteria for blunt cerebrovascular injury: a bigger impact than anticipated. *Am J Surg*. 2016;212(6):1167–1174.
5. Berne JD, Reuland KS, Villarreal DH, McGovern TM, Rowe SA, Norwood SH. Sixteen-slice multi-detector computed tomographic angiography improves the accuracy of screening for blunt cerebrovascular injury. *J Trauma*. 2006;60(6):1204–1209; discussion 1209-10.
6. Sumislawski JJ, Moore HB, Moore EE, et al. Not all in your head (and neck): stroke after blunt cerebrovascular injury is associated with systemic hypercoagulability. *J Trauma Acute Care Surg*. 2019;87(5):1082–1087.
7. Jacobson LE, Ziemba-Davis M, Herrera AJ. The limitations of using risk factors to screen for blunt cerebrovascular injuries: the harder you look, the more you find. *World J Emerg Surg*. 2015;10:46.
8. Bonatti M, Vezzali N, Ferro F, Manfredi R, Oberhofer N, Bonatti G. Blunt cerebrovascular injury: diagnosis at whole-body MDCT for multi-trauma. *Insights Imaging*. 2013;4(3):347–355.
9. Cothren CC, Biffl WL, Moore EE, Kashuk JL, Johnson JL. Treatment for blunt cerebrovascular injuries: equivalence of anticoagulation and antiplatelet agents. *Arch Surg*. 2009;144(7):685–690.
10. Biffl WL, Moore EE, Offner PJ, Brega KE, Franciose RJ, Elliott JP, Burch JM. Optimizing screening for blunt cerebrovascular injuries. *Am J Surg*. 1999;178(6):517–522.
11. Miller PR, Fabian TC, Croce MA, Cagiannos C, Williams JS, Vang M, Qaisi WG, Felker RE, Timmons SD. Prospective screening for blunt cerebrovascular injuries: analysis of diagnostic modalities and outcomes. *Ann Surg*. 2002;236(3):386–393; discussion 393-5.
12. Burlew CC, Biffl WL, Moore EE, Barnett CC, Johnson JL, Bensard DD. Blunt cerebrovascular injuries: redefining screening criteria in the era of noninvasive diagnosis. *J Trauma Acute Care Surg*. 2012;72(2):330–335; discussion 336-7, quiz 539.
13. Emmett KP, Fabian TC, DiCocco JM, Zarzaur BL, Croce MA. Improving the screening criteria for blunt cerebrovascular injury: the appropriate role for computed tomography angiography. *J Trauma*. 2011;70(5):1058–1063; discussion 1063-5.
14. Paulus EM, Fabian TC, Savage SA, Zarzaur BL, Botta V, Dutton W, Croce MA. Blunt cerebrovascular injury screening with 64-channel multidetector computed tomography: more slices finally cut it. *J Trauma Acute Care Surg*. 2014;76(2):279–283; discussion 284-5.
15. Biffl WL, Moore EE, Offner PJ, Brega KE, Franciose RJ, Burch JM. Blunt carotid arterial injuries: implications of a new grading scale. *J Trauma*. 1999;47(5):845–853.
16. National Trauma Data Bank. 2016 Annual Report: American College of Surgeons; 2016. Available from: https://www.facs.org/-/media/files/quality-programs/trauma/ntdb/ntdb-annual-report-2016.ashx. Accessed Oct 1, 2020.
17. Rogers FB, Baker EF, Osler TM, Shackford SR, Wald SL, Vieco P. Computed tomographic angiography as a screening modality for blunt cervical arterial injuries: preliminary results. *J Trauma*. 1999;46(3):380–385.
18. Brommeland T, Helseth E, Aarhus M, Moen KG, Dyrskog S, Bergholt B, Olivecrona Z, Jeppesen E. Best practice guidelines for blunt cerebrovascular injury (BCVI). *Scand J Trauma Resusc Emerg Med*. 2018;26(1):90.
19. Biffl WL, Cothren CC, Moore EE, Kozar R, Cocanour C, Davis JW, McIntyre RC Jr., West MA, Moore FA. Western Trauma Association critical decisions in trauma: screening for and treatment of blunt cerebrovascular injuries. *J Trauma*. 2009;67(6):1150–1153.
20. Leichtle SW, Banerjee D, Schrader R, Torres B, Jayaraman S, Rodas E, Broering B, Aboutanos MB. Blunt cerebrovascular injury: the CASE for universal screening. *J Trauma Acute Care Surg*. 2020;89(5):880–886.

DISCUSSION

WALTER L. BIFFL, M.D. (San Diego, California): Thank you, Dr. Burlew. And I'd like to thank the AAST for the privilege of the podium and the opportunity to discuss this paper.

Since the introduction of screening for blunt cerebrovascular injuries in the mid-1990s the "who," "how," and "why" have been debated. At this point the "why," to prevent strokes, and the "how," with CTA, have been pretty well accepted. But the question of "who" continues to be discussed.

Numerous studies continue to try to identify the highest-risk injury patterns to focus screening efforts. On the other hand, studies like the recent EAST Practice Management Guideline by Dr. Kim and colleagues concluded that even lower-risk injuries warrant consideration for screening.

We've known for over 20 years that "the more you look, the more you find." But where do you draw the line?

At the AAST meeting ten years ago Cook and colleagues presented an analysis of NTDB data concluding that to identify all BCVI using a model based on a pattern of injuries, "an unrealistic 96 percent of the cohort would require screening."

In this paper the authors make an argument for doing just that, screening 93 percent of their patients. The authors found an unprecedented number of injuries and reported that the most liberal screening criteria they reviewed, the Expanded Denver Criteria, missed a quarter of the injuries.

I have a couple of questions about the yield of this screening as well as the consequences of universal whole body CT.

You found injuries in 7.6 percent of patients, way beyond anything previously reported. If you had only screened based upon the Expanded Denver Criteria you'd have found 360 (indistinguishable), still have over 5 percent of your blunt trauma admissions.

At this year's WTA meeting there was a similar paper from Virginia Commonwealth performing universal screening. The incidence of BCVI in their paper was only 2.7 percent, about a third of yours.

Why do you think yours was so much higher? Do you think there was a high false-negative rate at other institutions? A higher false-positive rate in your center?

I noticed 44 percent of yours are Grade 1 injuries. How many of those were healed or resolved on follow-up imaging? Or maybe it's your patient population.

And to paraphrase Dr. Feliciano when he discussed Dr. Fabian's landmark paper in 1996, the only alternative hypothesis would be that the carotid arteries of the residents of Birmingham are particularly stiff. Please comment on the incidence in your series.

In the VCU paper 51 percent of patients met screening criteria and they had 83 percent of the injuries. The other 17 percent didn't meet screening criteria but every single one of them was in a motor vehicle crash. How many of your six-thousand-plus patients met the Expanded Denver Criteria?

And you had nearly two-thirds of your patients involved in motor vehicle crashes. Is that a risk factor? And how generalizable are these findings given that in the NTDB only a quarter of patients are motor vehicle crash victims?

I'd also like to ask the authors to comment on the whole body CT scanning – you did make mention of this – adding the CTA head and neck onto that. As you know, whole body CT is debated on its merits and the additional contrast and radiation are considered potential harms.

You mentioned that there is no additional contrast given for this. What about the additional radiation given that they've already had a non-com head and neck? And what's the added cost to the patient?

I'd like to congratulate the authors on their work and look forward to following the evolution of this practice.

JONATHAN A. BLACK M.D. (Birmingham, Alabama): So thank you, Dr. Biffl, for taking the time to review our paper. Let me just take your questions in the order they were given.

Starting with the question about the work VCU had done, I will say that we certainly read VCU's paper with great interest. And we've asked ourselves a lot of the same questions you are asking.

Let me start by saying I don't think the carotid arteries in Birmingham are any stiffer than anywhere else, although we did ask ourselves that.

I will note that our injury severity score was similar to theirs, almost identical so I don't think the patient populations are that different. But honestly we were a little surprised by their numbers.

As you said, and, you know, as is typical in medicine, the more you screen, the more you find. That's true in breast cancer or colon cancer. That's true in venous thromboembolic disease. We think it's probably true in BCVI.

But their incidence of 2.7 percent is lower even than the data that your group in Denver published when you examined your expanded screening criteria. I think you guys had 2.99 percent. So, honestly, we thought their number would be a little bit higher. And we're at a little bit of a loss to explain the difference.

There are some subtle things. They used 128-slice scanners. We used a 256-slice scanner. That may help us pick up a couple extra subtle findings although, as I note, we're not just finding a lot of Grade 1 injuries so I don't think that explains all of it.

And then you asked about follow-up imaging. We don't routinely obtain follow-up imaging. Typically when we establish a diagnosis we will confirm it with our neurosurgery colleagues and then we will just treat. So, unfortunately, I don't have follow-up numbers.

Moving on to your second question, 41.8 percent of our patients met the Expanded Denver Criteria. And MVCs were a slightly higher rate of BCVI than falls. MVCs in our group were about 9 percent, so a pretty high proportion. Almost one in ten of our MVCs have a BCVI.

But, at the same time, falls were 7.6 percent. So our data for falls – even though less common than MVCs, and MVCs do seem to be a predictor of BCVI – our rate for falls is still more than double anything previously published. So in light of thatwe do think that our data is generalizable across both a wide range of patients and a variety of trauma centers.

And then your last question was about whole body CT scanning and risks to the patient and IV contrast. Prior to our implementation of our universal screening for BCVI our "trauma scans" were CT scans of the head, neck, or head, C-spine, chest, abdomen, and pelvis.

When we added a CTA of the neck, essentially the CTA of the neck replaces the CT of the C-spine. And then we pulled the bony images from the CTA of the neck.

Prior to adding a CTA of the neck our contrast load was governed by the CT of the abdomen. For patients less than 200 pounds, we give 120 milliliters of IV contrast; for patients over 200 pounds we give 150.

After implementation or after adding the CTA of the neck routinely we still give the same contrast loads. So it is still based on the CTA scan of the abdomen which is governed by patient weight. So that's why we say that we didn't change the contrast loads.

For radiation dosing, published data indicates that a whole body CT is somewhere in the neighborhood of about 24 millisieverts.

Adding a CTA of the neck and subtracting a CT of the C-spine is an addition of about an additional 1.5 millisieverts which is about 6 percent. So it's about a 6 percent increase in the total body radiation to the patient. I hope I answered those questions sufficiently.

NICOLE A. STASSEN, M.D. (Rochester, New York): After finding the BCVI what treatment, antiplatelet agents, anticoagulation, was used for the injures? What percentage of patients were unable to be treated secondary to other injuries?

JONATHAN A. BLACK M.D. (Birmingham, Alabama): Sure. Yes. So our typical treatment algorithm is aspirin, for the most part. For every injury we consult our neuro-endovascular colleagues and they review the images to confirm that they believe them to be real injuries.

Most of the time we treat with 81 milligrams of aspirin. For injuries that they believe are more severe then we sometimes load with 325. But that's our typical treatment algorithm.

There are times where we cannot treat, so significant head bleeds or hemorrhagic shock or other indications like that would be reasons why we would not treat.

SAMIR FAKHRY, M.D. (Nashville, Tennessee): The practice we implemented at the Level 1 centers I have practiced at was to use neck CTA for all our full activations in blunt patients and only selected partial activation patients. This simplified screening. Can you provide the BCVI detection rates in your study for full activations as compared to partial activations?

JONATHAN A. BLACK M.D. (Birmingham, Alabama): Off the top of my head I don't. I'm sorry. I probably could have dove back into our data and pulled it out but I don't know it off the top of my head.

D'ANDREA K. JOSEPH, M.D. (Roslyn, New York): With your protocol for universal screening you did not add additional contrast. How comfortable are you that you did not miss even more patients?

BRANDON BRUNS, M.D. (Annapolis, Maryland): Do you have a guideline for follow-up of imaging of injury identified on your initial scan? Do you treat based on the screening exam alone?

We have noted that many of the BCVIs noted on initial screen either resolve by the 24–28 hour dedicated neck CTA or change grades, leading to possible changes in management.

JONATHAN A. BLACK M.D. (Birmingham, Alabama): Yes, it's a good question and it's a valid point. Like I said, we don't routinely screen again or we don't routinely image again.

Our practice is typically just to treat with aspirin, even for injuries that we think are, you know, "questionable Grade 1." We do run or we consult our neuro-endovascular colleagues and have them evaluate every scan so it's not just a neuro-radiologist, there is a treating practitioner who is also involved in the discussion of whether or not to treat.

But when in doubt we tend to give aspirin, especially if there aren't other contraindications. I guess, you know, big picture, we think that the risk of aspirin is low when compared to the risk of a potential stroke.

DAVID H. LIVINGSTON, M.D. (Newark, New Jersey): Are we finally simply using presence of a neck as an entry criteria? Is there any other down such as MVC or pedestrian struck?

DEBORAH M. STEIN, M.D., M.P.H. (San Francisco, California): Are these injuries clinically relevant? With the advances in CT technology are we just detecting a bunch of injuries that are not likely to cause clinically relevant complication.

We are certainly seeing this with other vascular injuries in the rest of the body. What was the rate of stroke detection followed by the detection of a BCVI prior to implementation of this imaging protocol?