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Blunt Cerebrovascular Injury in Trauma—Fixed or Modifiable Risk Factor for Stroke?

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ABSTRACT

Introduction: The epidemiology of blunt cerebrovascular injury (BCVI) lacks consistent findings. We sought to describe the epidemiology of BCVI and the outcomes associated with current treatment strategies within the Trauma Quality Improvement Program registry.

Methods: We analyzed data from patients ≥15 years of age with a blunt mechanism. BCVI was classified as low grade (1-2) and high grade (3-5).

Results: From 2017 to 2023, there were 5,798,774 patients that met inclusion. There were 53,940 had a documented BCVI, of which 36,183 were low grade and 19,747 were high grade. Among those without a BCVI, the incidence of stroke was 0.2% (n = 13,459, 95% confidence interval [CI] 0.2-0.2) compared to those with BCVI 3.3% (n = 1763, CI 3.1-3.4). Among those with a BCVI, those with stroke had a higher median composite injury severity score (29, 20-38 *versus* 20, 12-29, $P < 0.001$). Unadjusted stroke risk was as follows based on receipt *versus* nonreceipt: heparin (5% *versus* 3%, $P < 0.001$), low-molecular weight heparin (3% *versus* 3%, $P = 0.080$), aspirin (4% *versus* 3%, $P = 0.077$), and none (2% *versus* 4%, $P < 0.001$). Among those with low-grade BCVI, after adjusting for age, sex, injury severity score, and comorbidities, and mechanism of injury, the following associations with stroke: heparin (odds ratio 2.01, 95% CI 1.30-3.08), LWMH (1.12, 0.73-1.72), aspirin (1.67, 1.01-2.78), and no prophylaxis (0.63, 0.40-0.99). For high-grade: heparin (1.71, 1.13-2.59), LMHW (1.15, 0.76-1.73), aspirin (1.74, 1.06-2.86), and none (0.60, 0.39-0.92).

Conclusions: Unadjusted and adjusted stroke risk between those with and without anticoagulation or antiplatelet therapy demonstrated no benefit. Our findings call into question whether stroke is a modifiable event. High-quality trials are needed.

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Introduction

Background

Trauma is a common presentation to the emergency department and intensive care units in the United States, with the majority experiencing a blunt mechanism.[1] As a result of major blunt trauma to the head/neck, vascular disruptions can occur with previous reports demonstrating that blunt cerebrovascular injury (BCVI) occurs in 0.5-2% of all blunt trauma admissions.[2] The incidence is even higher among those in higher-risk groups, such as concomitant cervical spine fractures and basilar skull fractures and is highest among those with carotid or vertebral foramen fractures, with an incidence of up to 27-30%.[2] Furthermore, the risk of stroke is as high as 20% in those with BCVI.[3] Moreover, the diagnosis of BCVI has increased as imaging techniques continue to improve.[4] Computed tomography angiography remains the most commonly used imaging modality with high reliability.[5]

As the imaging quality continues to improve, particularly without the need for invasive methods to detect minor injuries, better data are needed to guide treatment strategies. This is particularly important as blunt trauma patients often have polytrauma, placing them at a risk for bleeding in other anatomic locations. Moreover, a previous systematic review found that anticoagulation (AC) is not without risk and increases the risk of bleeding events.[6] The best available data and expert consensus generally recommend treatment, but specific treatments and data on initiation timing and duration of therapy remain under contention.[7] There are also limited quality data guiding on when to screen for BCVI.[8] To that end, there also remain limited data on follow-up imaging and how to assess treatment response.[9] Larger datasets are needed to understand the epidemiology of the injuries, stroke risk, and potential treatment strategies.

Goal of this study

We sought to describe incidence, outcomes, and the outcomes associated with current treatment strategies of BCVI within the Trauma Quality Improvement Program (TQIP) databases from 2017 to 2023.

Methods

Ethics

We obtained data from the TQIP database, including facility keys, after approval from the American College of Surgeons. The US Army Medical Center of Excellence regulatory office reviewed protocol 24-00011n and determined the study met the criteria for research not involving human subjects, and therefore oversight was not required.

Trauma Quality Improvement Program description

The TQIP data are maintained by the American College of Surgeons since 2008. The database has mandatory data collection for level 1 trauma centers and also collects data from other centers that do not meet the level 1 criteria.[10] The goal of the program is to provide data to aid trauma centers for standardizing trauma care, providing local and national quality improvement, and to provide data needed for best practices guidelines. As of 2023, there are over 800 participating centers where trained registrars enter data for trauma visits that meet the entry criteria.[11]

Case selection and variables

We analyzed cases with a documented age of ≥15 y of age with a blunt mechanism using relevant abbreviated injury scale codes which have been previously described (supplemental table 1).[12] Using the Eastern Association for the Surgery of Trauma guidelines, BCVI injuries were further subcategorized into low grade (grade 1-2) and high grade (grade 3-5).[3] The diagnosis of stroke is based on the core quality metric and/or the I63 or I64 diagnostic code series. The AC (or antiplatelet) agent (if any) along with the time to initiation is captured as a core variable.[13] Subsequent AC methods are not captured nor are dosing data. Due to the relatively infrequent use, we did not include other options such as direct thrombin inhibitors or direct oral anticoagulants. TQIP captures aspirin and warfarin as AC options under the "other" category, and for practical purposes, we assumed the majority of these was aspirin. Prophylaxis initiation was based on the documented core quality metric. If the prophylaxis was documented as none, we used a prophylaxis start time as the hospital admission.

Data analysis

We performed all statistical analysis using Microsoft Excel (version 365, Redmond, WA) and JMP Statistical Discovery from SAS (version 17, Cary, NC). Continuous and ordinal variables are presented as median and interquartile ranges and compared using the Wilcoxon rank-sum test. Nominal variables are presented as numbers and percentages and compared using the Chi-square or Fisher exact test depending on the expected cell counts. The Cochran–Armitage trend test was used to assess changes over time. Multivariable logistic regression models were constructed to test for associations and adjust for effect modifiers. Nominal variables are presented as odds ratio with 95% confidence intervals (CIs). Continuous and ordinal variables are presented as unit odds ratio with 95% CI.

Results

From 2017 to 2023, there were 8,014,737 total encounters, of which, 5,798,774 met the inclusion for this analysis. There were 53,940 that met the criteria for BCVI yielding an incidence of 93 per 10,000, which increased over the study period (Table 1, Fig. 1, supplemental Fig. 1). Among those without a BCVI, the incidence of stroke was 0.2% (n = 13,459, CI 0.2-0.2). Among those with a BCVI, the incidence of stroke was 3.3% (n = 1,763, CI 3.1-3.4, Fig. 2, Table 2). In our multivariable logistic regression model adjusted for age, sex, mechanism of

Table 1 – Overall patient characteristics.

	No BCVI $n = 5{,}744{,}843$	BCVI $n = 53{,}940$	*P* value
Demographics			
Age	60 (38-75)	47 (31-65)	<0.001
Geriatric ≥70	35% (2,025,663)	19% (9984)	<0.001
Male	57% (3,258,153)	65% (34,866)	<0.001
Past medical history			
AC use	13% (752,511)	6% (3445)	<0.001
Diabetes	17% (956,807)	10% (5634)	<0.001
Hypertension	40% (2,308,137)	27% (14,470)	<0.001
Myocardial infarction	1% (454,453)	<1% (217)	<0.001
Stroke	3% (183,431)	2% (919)	<0.001
Tobacco use	19% (1,089,749)	22% (12,084)	<0.001
Mechanism of injury			
Collision	43% (2,498,013)	75% (40,622)	<0.001
Fall	57% (3,246,821)	25% (13,318)	
Composite injury severity score	9 (4-11)	21 (12-29)	<0.001
ISS >15	16% (929,954)	66% (35,447)	<0.001
Serious injury by body region			
Head/neck	18% (1,060,563)	81% (43,792)	<0.001
Face	<1% (20,396)	3% (1659)	<0.001
Thorax	15% (857,730)	36% (19,481)	<0.001
Abdomen	4% (252,628)	11% (5986)	<0.001
Extremities	20% (1,161,750)	16% (8701)	<0.001
Skin	<1% (10,939)	1% (287)	<0.001
Outcome			
Stroke	<1% (13,459)	3% (1763)	<0.001
Survival	97% (5,565,796)	86% (46,495)	<0.001

ISS = injury severity score.

injury, comorbidities, injury severity score, among those with a low-grade BCVI, no form of AC was associated with a reduced risk of stroke (Table 3). Similar findings were noted among those with a high-grade BCVI (Table 4). When adding the time to AC initiation variable, similar findings were also noted (supplemental table 2, supplemental table 3).

Discussion

In this large analysis from the TQIP of patients at risk for BCVI, we had several interesting findings. We found that the overall incidence was low among those that were at risk. This is particularly important given that most of the patients with BCVI were severely injured as evidenced by an injury severity score>15. Although this may reflect some element of under-detection due to less imaging performed on those with fewer injuries, reflecting potential missed diagnoses, we hypothesize that this still reflects a low incidence of injury within the low-risk population. Moreover, among those with BCVI, the stroke risk was relatively low and more common among those with more severe trauma as well. These findings suggest that better data on risk stratification methods are needed to assess which patients are at risk for stroke, which could help balance the risk benefit profile of treatment. Interestingly, we found no benefit with the AC selection for initial prophylaxis. Moreover, we noted potential signal of harm with some AC strategies and potential benefit with no documented AC during the hospital stay. Current Eastern Association for the Surgery of Trauma guidelines recommend routine computed tomography angiography for adult patients with high-risk cervical spine injuries.[3] For other blunt mechanisms, the use of a screening tool is recommended. The use of antithrombotic therapy is recommended as it has been shown to decrease the risk of stroke. To that end, our findings are disconcordant with these recommendations. Given the lack of a physiologically plausible reason for these findings, we would interpret these findings with caution and would only go so far as to interpret this as finding no benefit with the interventions. This is likely

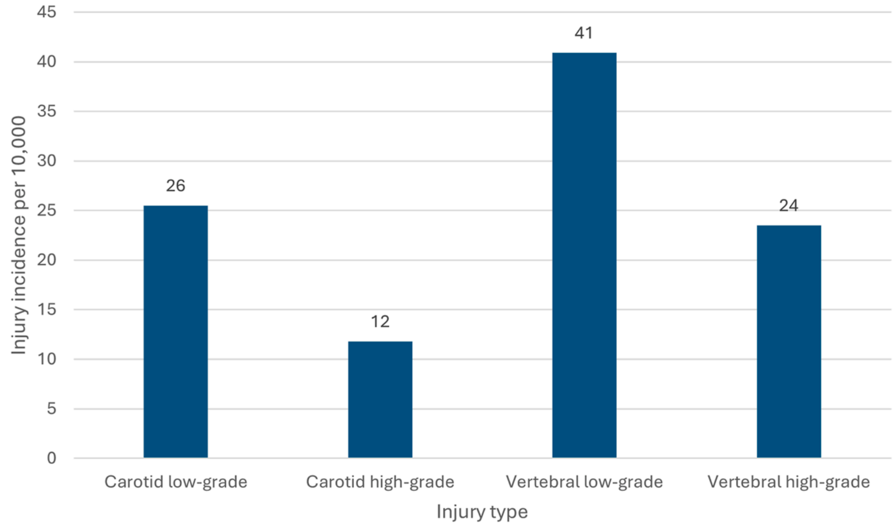

Fig. 1 – Incidence per 10,000 encounters by type and severity.

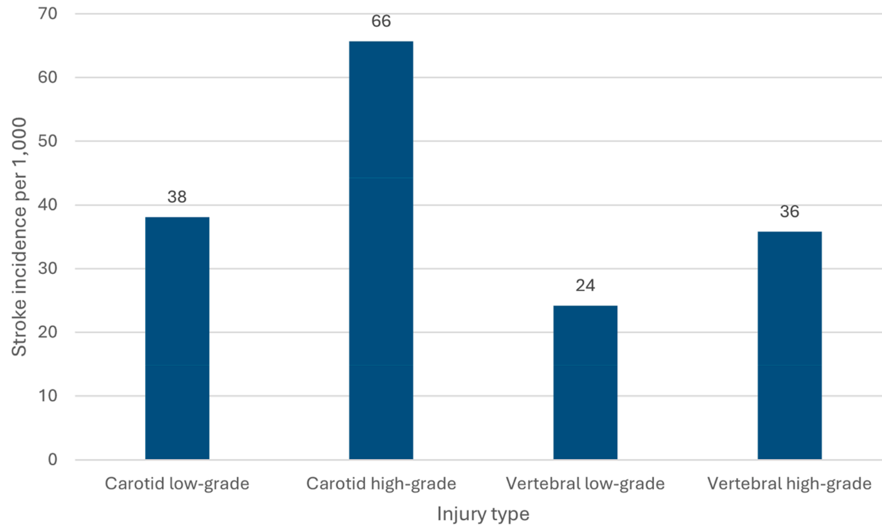

Fig. 2 – Incidence of stroke based on type and severity of BCVI.

Table 2 – BCVI patient characteristics.

	No stroke $n = 52,177$	Stroke $n = 1763$	P value
Demographics			
Age	47 (31-65)	47 (31-64)	0.764
Geriatric ≥70	19% (9700)	16% (284)	0.008
Male	65% (33,749)	63% (1117)	0.252
Past medical history			
AC use	6% (3344)	6% (101)	0.250
Diabetes	10% (5427)	12% (207)	0.070
Hypertension	27% (13,983)	28% (487)	0.442
Myocardial infarction	<1% (204)	1% (13)	0.033
Stroke	2% (864)	3% (55)	<0.001
Tobacco use	22% (11,732)	20% (352)	0.012
Mechanism of injury			
Collision	75% (39,183)	82% (1439)	<0.001
Fall	25% (12,994)	18% (324)	
Composite injury severity score	20 (12-29)	29 (20-38)	<0.001
ISS >15	65% (33,902)	88% (1545)	<0.001
Serious injury by body region			
Head/neck	81% (42,153)	93% (1639)	<0.001
Face	3% (1589)	4% (70)	0.026
Thorax	36% (18,585)	51% (896)	<0.001
Abdomen	11% (5618)	21% (368)	<0.001
Extremities	16% (8219)	27% (482)	<0.001
Skin	1% (269)	1% (18)	0.010
Initial AC			
UFH	19% (9747)	31% (542)	<0.001
LMWH	50% (26,262)	48% (850)	<0.001
Aspirin	4% (1998)	5% (82)	<0.001
None	24% (12,306)	14% (243)	<0.001
Time to initiation of AC	24.9 (2.1-57.5)	39.8 (11-77.9)	<0.001
Outcome			
Survival	87% (45,188)	74% (1307)	<0.001

ISS = injury severity score; LMWH = low-molecular weight heparin; UFH = unfractionated heparin.

Table 3 – Multivariable logistic regression model with stroke as the outcome variable among patients with low-grade BCVI.

Age	1.01 (1.00-1.01)
Sex	
Male	0.93 (0.81-1.06)
Female (reference)	
Mechanism of injury	
Collision	1.44 (1.20-1.73)
Fall (reference)	
History of anticoagulant use	0.99 (0.74-1.32)
History of diabetes	1.05 (0.83-1.32)
History of hypertension	1.01 (0.84-1.21)
History of myocardial infarction	1.70 (0.73-3.97)
History of stroke	2.34 (1.58-3.46)
History of tobacco use	0.98 (0.84-1.15)
Composite injury severity score	1.03 (1.03-1.04)
Initial unfractionated heparin	2.01 (1.30-3.08)
Initial low molecular weight heparin	1.12 (0.73-1.72)
Initial aspirin	1.67 (1.01-2.78)
No prophylaxis	0.63 (0.40-0.99)

due to an inherent selection bias for which available variables are unable to better delineate. Furthermore, the lack of benefit suggests that the stroke risk with BCVI may be fixed rather than potentially reducible with intervention. To that end, we were also unable to assess potential bleeding risks associated with AC.

Table 4 – Multivariable logistic regression model with stroke as the outcome variable among patients with high-grade BCVI.

Age	1.00 (0.99-1.00)
Sex	0.85 (0.74-0.98)
Male	
Female (reference)	
Mechanism of injury	1.31 (1.11-1.61)
Collision	
Fall (reference)	
History of anticoagulant use	0.76 (0.55-1.06)
History of diabetes	1.16 (0.93-1.46)
History of hypertension	1.24 (1.03-1.50)
History of myocardial infarction	1.80 (0.85-3.81)
History of stroke	2.12 (1.43-3.15)
History of tobacco use	0.81 (0.67-0.96)
Composite injury severity score	1.03 (1.02-1.03)
Initial unfractionated heparin	1.71 (1.13-2.59)
Initial low molecular weight heparin	1.15 (0.76-1.73)
Initial aspirin	1.74 (1.06-2.86)
No prophylaxis	0.60 (0.39-0.92)

We must highlight some of the similarities and differences between our study and previous published studies. When compared to the study published from another registry—the Alfred Hospital Trauma Registry—we noted a lower incidence, yet a strikingly identical mortality among those with BCVI.[14] Compared to a previous prospective study by Hundersmarck et al,[2] our incidence was lower than their reported incidence (0.59%), as was the subsequent stroke rate (28%). This suggests there may be some element of underdocumentation occurring with the TQIP registry. Multiple previous studies have found improved outcomes with aspirin over other forms of AC.[15,16] Interestingly, we found no benefit with any intervention and potential signal of harm. But again, that signal of harm should be interpreted with caution. However, our findings of no benefit are not unique. A previous report by Cothren et al[17] found an impressive 21% risk of stroke, yet no apparent benefit between antiplatelet and heparin therapy for BCVI. These varying epidemiological findings as well as treatment benefit findings highlight the need for prospective controlled trials.

Our study has several limitations which must be acknowledged. First, the use of the TQIP registry is subject to both entry errors and omissions. Participating centers use trained registrars to provide the data input, but this relies on clinical documentation which may contain errors. Second, both the core quality metric and diagnostic codes require that the clinical team evaluate the patient for a potential stroke. This requires clinical suspicion of the stroke, which in many patients may be subclinical or may not have a presenting syndrome in the more critically ill patients or patients that are unexaminable due to their other injuries. Future studies should incorporate standardized methods for evaluation of stroke. Third, the registry only captures the initial prophylaxis but does not capture subsequent methods nor does it capture dosing goals (e.g., prophylaxis *versus* therapeutic dosing). To that end, it also does not capture the clinical decision-making for selecting one modality over another. Fourth, we lack data on the timing of the stroke, so we are unable to assess for proximal cause, and the stroke could have potentially been present on arrival or early after injury. Fifth, TQIP only captures data from the index hospitalization. Therefore, we would not know about any strokes that occurred after discharge. Sixth, we must also highlight that we used abbreviated injury scale to assess severity of the BCVI, which may not completely encompass all of the radiological findings that were relevant to clinical decision-making, such as precise size and location. Seventh, we assumed that all "other" prophylaxis was aspirin based on clinical practices, but this assumption may not be valid across all centers. Lastly, although our analysis adjusted for measured potential effect modifiers, such methods will never provide the balance that a prospective controlled trial will for both measured and unmeasured effect modifiers.

Conclusions

Unadjusted and adjusted stroke risk between those with and without AC or antithrombotic therapy demonstrated no benefit for patients with BCVI. Our findings call into question whether stroke in the setting of BCVI is a modifiable event.

High-quality trials are needed before any strong recommendations for treatment strategies can be made.

Supplementary Materials

Supplementary data related to this article can be found at https://doi.org/10.1016/j.jss.2025.11.029.

Declaration of Generative AI and AI-Assisted Technologies in the Writing Process

None.

Disclosure

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Disclaimer

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Ethical Approval

The US Army Medical Center of Excellence regulatory office reviewed protocol 24-00011n and determined the study met the criteria for research not involving human subjects, and therefore oversight was not required.

CRediT authorship contribution statement

Steven G. Schauer: Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Michael D. April:** Writing – review & editing, Methodology. **Andrew D. Fisher:** Writing – review & editing, Methodology. **Julie A. Rizzo:** Writing – review & editing, Methodology, Conceptualization.

REFERENCES

1. Schauer SG, April MD, Fisher AD, et al. A survey of low titer O whole blood use within the trauma quality improvement program registry. *Transfusion*. 2024;64(Suppl 2):S85–s92.
2. Hundersmarck D, Slooff WBM, Homans JF, et al. Blunt cerebrovascular injury: incidence and long-term follow-up. *Eur J Trauma Emerg Surg*. 2021;47:161–170.
3. 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;88:875–887.
4. Miller PR, Fabian TC, Bee TK, et al. Blunt cerebrovascular injuries: diagnosis and treatment. *J Trauma*. 2001;51:279–285. ; discussion 285–6.
5. Malhotra A, Wu X, Kalra VB, Schindler J, Matouk CC, Forman HP. Evaluation for blunt cerebrovascular injury: review of the literature and a cost-effectiveness analysis. *AJNR Am J Neuroradiol*. 2016;37:330–335.
6. Eck RJ, Elling T, Sutton AJ, et al. Anticoagulants for thrombosis prophylaxis in acutely ill patients admitted to hospital: systematic review and network meta-analysis. *BMJ*. 2022;378:e070022.
7. Brommeland T, Helseth E, Aarhus M, et al. Best practice guidelines for blunt cerebrovascular injury (BCVI). *Scand J Trauma Resusc Emerg Med*. 2018;26:90.
8. Leichtle SW, Banerjee D, Schrader R, et al. Blunt cerebrovascular injury: the case for universal screening. *J Trauma Acute Care Surg*. 2020;89:880–886.
9. Biffl WL, Ray Jr CE, Moore EE, et al. Treatment-related outcomes from blunt cerebrovascular injuries: importance of routine follow-up arteriography. *Ann Surg*. 2002;235:699–706. ; discussion 706–7.
10. Blackmore AR, Leonard J, Madayag R, Bourg PW. Using the Trauma Quality Improvement Program metrics data to enhance clinical practice. *J Trauma Nurs JTN*. 2019;26:121–127.
11. Newgard CD, Fildes JJ, Wu L, et al. Methodology and analytic rationale for the American College of Surgeons Trauma Quality Improvement Program. *J Am Coll Surg*. 2013;216:147–157.
12. Dawson-Gore CC, Myers EK, Cooper EH, Evans LL, Schauer SG, Acker S. The smallest suffer stroke: understanding stroke and treatment patterns in children with blunt cerebrovascular injury within the Trauma Quality Improvement Program database. *Surgery*. 2025;183:109353.
13. Schauer SG, April MD, Fisher AD, et al. Venous thromboembolic events associated with blood product administration in an era of whole blood use. *Am J Surg*. 2024;238:115887.
14. Stanislaus V, Mitra B, Zhang WW, et al. The incidence and characteristics of clinically relevant blunt cerebrovascular injury at an adult level 1 trauma centre: a retrospective cohort study. *Trauma*. 2024;26:289–296.
15. Bonow RH, Witt CE, Mossa-Basha M, et al. Aspirin versus anticoagulation for stroke prophylaxis in blunt cerebrovascular injury: a propensity-matched retrospective cohort study. *J Neurosurg*. 2021;135:1413–1420.
16. Momic J, Yassin N, Kim MY, et al. Antiplatelets versus anticoagulants in the treatment of blunt cerebrovascular injury (BCVI) - a systematic review and meta-analysis. *Injury*. 2024;55:111485.
17. Cothren CC, Biffl WL, Moore EE, Kashuk JL, Johnson JL. Treatment for blunt cerebrovascular injuries: equivalence of anticoagulation and antiplatelet agents. *Arch Surg*. 2009;144:685–690.