DANISH MEDICAL JOURNAL

Original Article

Blunt cerebrovascular injuries and association with cervical spine injury

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Dan Med J 2025;72(1):A01240067. doi: 10.61409/A01240067

ABSTRACT

INTRODUCTION. Blunt cerebrovascular injuries (BCVI) associated with cervical spine injuries (CSI) carry a high risk of morbidity and mortality. This nationwide Danish study, covering the years 2017-2023, aimed to identify key BCVI predictors in patients with CSI to support improved early detection and management strategies.

METHODS. The study analysed data from four level-1 trauma centres using the Abbreviated Injury Scale to classify BCVI cases. Factors assessed included age, sex, type of cervical injury and the Injury Severity Score (ISS).

RESULTS. Age and sex were not significant predictors of BCVI ($p = 0.12$, $p = 0.65$). However, any form of CSI was a strong predictor ($p < 0.001$; odds ratios (OR) = 26.3; confidence intervals (95% CI): 16.84-41.12), as were cervical spine ligamentous injuries ($p = 0.0007$; OR = 5.4; 95% CI: 2.3-12.89). An increase in ISS score significantly correlated with BCVI risk ($p = 0.001$; OR = 1.03 per unit increase; 95% CI: 1.01-1.05). Specific cervical fractures were not independent predictors of BCVI.

CONCLUSIONS. From a Danish cohort of patients admitted to a level 1 trauma centre, we found a BCVI incidence of three per thousand. In case of verified injury to the cervical region, the incidence rose to 6.25%. Our findings underscore the need for increased vigilance and a standardised nationwide algorithm to prevent disability, loss of health-related quality of life, and mortality in CSI patients at risk of BCVI.

FUNDING. The study was funded by Offerfonden, Dagmar Marshall Fonden, and Torben & Alice Frimodt Fonden.

TRIAL REGISTRATION. The data collection was approved by the local ethical committee and the Central Denmark Region Office for Research: 1-45-70-19-23.

Trauma to the neck and head is commonly presented to the emergency department [1]. A rare, but potentially severe complication is blunt cerebrovascular injuries (BCVI), involving damage to the vertebral or carotid arteries supplying the cerebral circulation, typically resulting from blunt trauma to the neck, head or chest. Undetected BCVI carries mortality and morbidity rates as high as 40% and 80%, respectively [2]. There is a strong correlation between cervical spine trauma and BCVI, with reported incidences ranging from 30.4% to 78%, depending on the injury mechanism [3-5]. The proximity of the cerebrovascular system to the cervical spine increases the likelihood of injury to the vertebral and carotid arteries in case of fracture. From the C6 to the C1, the vertebral artery runs within the osseous entity foramen transversarium, making it particularly vulnerable in case of fracture or forced trauma.

Forced trauma to the neck, with or without cervical spine fractures, can result in arterial trauma and tearing of the intima layer of the vessel, promoting platelet aggregation, thereby potentially causing thrombus formation and eventually leading to vessel occlusion or embolism. Most BCVIs remain clinically silent [4, 6] and were previously perceived as being infrequent due to the need for invasive and advanced screening techniques, such

as digital subtraction angiography (DSA), which were rarely performed [7]. Less invasive techniques, such as computed tomographic angiography (CTA) and magnetic resonance angiography (MRA), have since been developed and have become a popular BCVI screening tool. Following the adoption of CTA, Eastman et al. [8] demonstrated a substantial reduction in the time from trauma centre admission to diagnosis, with an almost 30-hour decrease along with a decline in the stroke rate among BCVI patients from 15.2% to 3.8%. These findings underscore the compelling rationale for maintaining CTA as the primary screening modality.

Early detection and appropriate management of high-risk patients with BCVIs is crucial to prevent devastating neurological deficits such as posterior circulation stroke, cortical blindness and death, which are potentially catastrophic consequences following BCVI in cervical spine-injured patients [5, 6]. Therefore, we need to identify the risk factors that correlate with BCVI when the patient arrives at the emergency department.

However, no routine screening protocol for the target population is currently in place in Denmark. Thus, the purpose of this study was to quantify the risk of BCVI in patients with cervical spine injuries (CSI) admitted to level-1 trauma centres in Denmark.

Methods

Data from all trauma patients admitted to the four level-1 trauma centres in Denmark (Aarhus University Hospital (AUH), Rigshospitalet (RH), Aalborg University Hospital (AAUH) and Odense University Hospital (OUH)) from 2017 to 2022 were retrieved by the Danish Clinical Quality Program (RKKP). Thus, a retrospective population-based national cohort could be established.

Data sources

Data were extracted from the cohort by diagnosis using the Abbreviated Injury Score (AIS) [9] to identify patients with blunt trauma to the upper cervical region.

The study obtained institutional review board approval and received authorisation from the RKKP.

Inclusion and exclusion criteria

All patients with non-penetrating injuries to the neck were included, and patients with penetrating injuries (e.g. stab wounds, gunshots, etc.) were excluded.

The complete list of included AIS codes for cervical spine injuries is shown in Supplementary Table 1.

Outcome measures

The primary outcome was BCVI, defined through AIS codes for injury to the blood vessels of the neck and head. All patients with verified vascular injury of the carotids or arteria (a.) vertebralis were registered as outcome cases. The complete list of included AIS codes for BCVI outcome is shown in Supplementary Table 2.

Other variables

Other variables registered were age, sex, injury severity score (ISS) [10], Glasgow Coma Scale (GCS) [11] and place of arrival (AUH, AAUH, OUH or RH).

Statistical analyses

The cases identified were tested using inferential statistics to evaluate the independent association between potential risk factors and the development of BCVI. In the analysis of BCVI versus non-BCVI, Welch's t-test was used to assess continuous variables, and the χ^2 test and Fisher's exact test were used to evaluate categorical variables. For univariate analyses exploring any association between individual risk factors and BCVI when

having a fracture, the Fisher's exact test and the χ^2 test were used. Logistic regression was performed to calculate crude odds ratios (OR) with 95% confidence intervals (95% CI) to evaluate the magnitude and precision of associations.

A multivariable logistic regression model was created to evaluate the adjusted associations of each potential exploratory variable for predicting BCVI likelihood. Variables with a univariate significance level of 0.25 or less and variables deemed clinically relevant were eligible for inclusion in the analysis. A p-value < 0.05 was considered statistically significant.

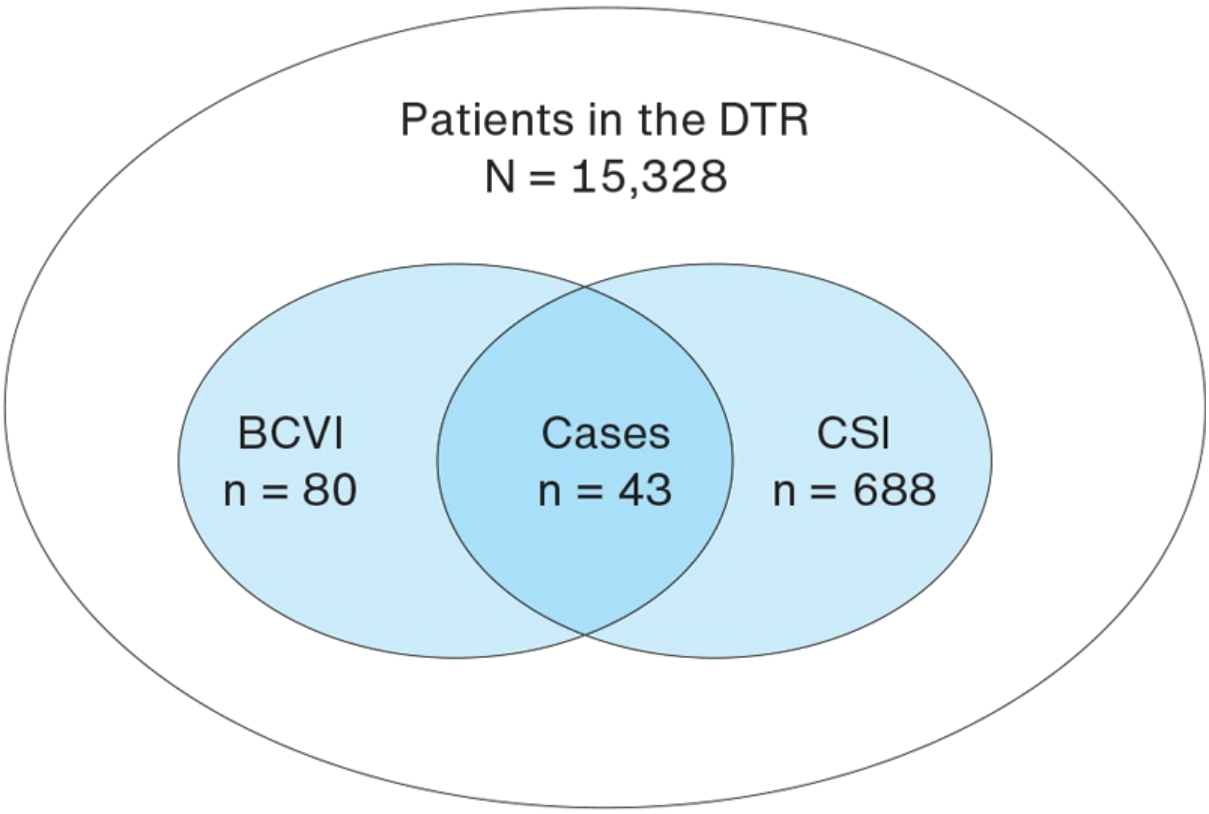
Statistical analysis was performed using Stata (StataCorp. 2023. Stata Statistical Software: Release *17.* College Station, TX, USA: StataCorp LLC.) The statistics were conducted with the Department of Clinical Epidemiology, Institute of Clinical Medicine, Health, Aarhus University, Denmark (DCE) [12].

Trial registration: The Local Ethical Committee and the Office for Research in the Central Denmark Region approved the data collection: 1-45-70-19-23.

Results

A total of 15,328 patients were admitted to the four Level 1 trauma centres in Denmark during the six-year study period. A total of 688 patients with CSI from DTR were identified and included for analysis. In the total cohort, 80 patients (0.52%) were diagnosed with BCVI among whom 37 had BCVI in the carotid artery (CA) and 43 in the vertebral artery (VA), whereas 43 patients (6.25%) had both confirmed CSI and BCVI (see **Figure 1** and Supplementary Material). Demographic data and baseline characteristics are listed in Supplementary Table 1. The incidence of BCVI in the total cohort was thus three per thousand, rising to 6.25 in the case of verified CSI.

FIGURE 1 Patient identification through Danish Trauma Register.



BCVI = blunt cerebrovascular injuries; CSI = cervical spine injuries; DTR = Danish Trauma Register.

The mean age was 54.8 years in the BCVI group and 53.6 years in patients with CSI but without BCVI. This difference was not statistically significant (t-test: p = 0.7).

A total of 29 (67%) of the BCVI patients were male, and 14 were female. There was no statistically significant difference between sexes in the BCVI versus non-BCVI group (p = 0.4).

A significant difference between the BCVI versus non-BCVI group was seen in patients with a higher injury severity score (ISS). The median ISS in the BCVI group was 23 in contrast to 20.7 in the non-BCVI group (Mann-Whitney U: $p \leq 0.003$).

The median GCS was slightly higher in the BCVI group (12.2) than in the non-BCVI group (12.1), but this difference was not statistically significant (Mann-Whitney U: p = 0.09).

Baseline characteristics of the study population are shown in Supplementary Table 1.

Predictors of blunt cerebrovascular injuries in patients with cervical spine injury

The results of the uni- and multivariate logistic regression model for BCVI are shown in Supplementary Table 2 and Supplementary Table 3.

Age (p = 0.12) and sex (p = 0.65; OR = 0.86; 95% CI: 0.44-1.66) were not predictive of BCVI. The presence of any

CSI was predictive of BCVI (p = < 0.001; OR = 26.3; 95% CI: 16.84-41.12) alongside c-spine ligamentous injuries (p = 0.0007; OR = 5.4; 95% CI: 2.3-12.89), which occurred in 34 cases.

Each one-unit increase in ISS was statistically significant for BCVI (p = 0.001; OR = 1.03; 95% CI: 1.01-1.05).

The presence of fractures involving atlanto-axial (odontoid) (p = 0.83) facet subluxations/dislocations (p = 0.2) and the transverse foramen were not independent predictors of BCVI.

Controlling for confounding variables by a multivariate regression model (Supplementary Table 3), any CSI, ISS and C-spine ligamentous injuries independently predicted BCVI. C-spine facet fractures, age and GCS met the criteria for inclusion into the multivariate model (p < 0.25) but were not independent risk factors for BCVI (p < 0.05).

Discussion

Our study revealed multiple significant findings with noteworthy clinical implications. Two key findings arose. Firstly, any CSI was strongly predictive of BCVI, underscoring the need for attentive screening in the case of CSI. Secondly, cervical spine ligamentous injuries were independently significant in association with BCVI, highlighting the importance of their potential as an indicator for early detection and management.

Motor vehicle accidents (MVA) are the leading cause of BCVI, accounting for 70% of cases in China, according to Hwang et al. [13] and other studies [1, 2]. The primary cause of BCVI may vary with geographical location, and MVAs may not apply universally across all countries and regions. Most studies [1, 2] highlighted MVAs as the leading cause of BCVI, but other notable risk factors include sports injuries, pedestrian accidents, assault, near-hanging, strangulation, falls and crush injuries [13]. Thus, the leading cause of BCVI may vary across different populations and countries.

In our study, we recorded a BCVI incidence of 6.25% within cervical spine injuries, notably below the wider reported 30.4% to 78% range [3-5]. This disparity may be rooted in various factors, such as the infrequency of the injury, potentially resulting in underreporting and subsequent under-detection. Additionally, diverse mechanisms of injury across cases may potentially contribute to this observed difference. Understanding these nuances is crucial for accurate diagnosis and management strategies in clinical settings.

The diagnosis of stroke after BCVI can be difficult due to symptom latency. Thus, most strokes occur after an asymptomatic period of hours to days and even months [14]. The present guidelines on BCVI screening may not catch patients presenting with atypical radiographic or injury findings [14, 15]. Identifying the condition at an early stage provides a narrow treatment window, potentially averting the onset of thromboembolic complications and adverse effects [14, 15]. This study showed some of the risk factors that need to be taken into consideration when assessing a trauma patient. Miller et al. [6] performed a prospective analysis comparing CTA and MRA versus DSA, reporting CTA sensitivity and specificity of 53% and 99%, respectively, for the finding of vertebral artery injuries (VAI), and 47% and 99% for the finding of carotid artery injuries (CAI), making CTA unfavourable compared to DSA. Similar results were seen for MRA compared to DSA. Nevertheless, CTA continues to be the predominant screening method, primarily because of its widespread availability, speed and effectiveness [8].

Our study suggested a potential link between lower GCS [11] and increased odds of BCVI in the presence of fractures (univariate analysis, p = 0.164). Even though this result did not reach a statistical significance, it may very well have clinical significance, indicating the importance of screening patients with a low GCS and cervical fractures for BCVI. However, it must be remembered that in our material, 525 patients with a CSI had a GCS ≥ 14. Among the CSI patients with a confirmed BCVI, 29 of 42 (69%) had a GCS ≥ 14 (Supplementary Table 4).

Previously, a GCS ≤ 6 was considered a risk factor for BCVI [16], but our results showed that - in the Danish cohort - more than two-thirds of BCVI cases had only a mild head injury. Although it is critical to be suspicious of BCVI in patients with a GCS ≤ 8, we emphasise the need for awareness of BCVI, also in individuals with a higher GCS. Given the lingering risk of BCVI and its potential societal costs and individual morbidity, thorough screening remains imperative to avoid missed diagnoses.

The data were retrieved from Danish nationwide registries and clinical databases and are characterised by high completeness and validity [17]. Reporting trauma data to the DTR is mandatory, which ensures a high level of data completeness. Even so, underreporting or selective reporting may potentially occur, impacting the overall data quality. Certain cases or details may be missed or inaccurately recorded, affecting the comprehensiveness of the data. Furthermore, the data may have inherent inaccuracies or inconsistencies due to variations in data collection methods or interpretations of injury severity, which may potentially introduce bias or errors in the analysis. The Head Committee of the DTR has introduced standardised severity registration using AIS/ISS in the past year. This is an internationally recognised severity assessment method for individual injuries and the cumulative impact of multiple injuries on each patient. All staff responsible for injury registration have attended authorised training. Thereby, the Committee has reduced the risk of variation in data reporting [18]. AIS/ISS registration was not consistently implemented across all four hospitals during the entire study period, which may be a limitation. However, since 2020/2021, AIS coding has become standard practice and mandatory at all four trauma centres, ensuring its inclusion in the database. Although we accounted for multiple factors in our analysis, there may still be unknown confounding variables impacting the observed links between cervical spine injuries and BCVI. Data were only retrieved from registries and not by review of the individual patient's medicine records, which might have added further details and important information to the study, including fracture type according to the AO classification [19], use of medication, known arteriosclerosis, etc. We acknowledge that some diagnosed vascular injuries might be asymptomatic and without clinical significance. However, these data are unfortunately not included in the national trauma database, which limits our ability to address this aspect.

Ethics

Approval was obtained from RKKP (DTR-2023-03-01), and patient consent was not required for inclusion in this study.

All studies were approved by the Regional Ethics Committee (1-16-02-44-23) and conducted in accordance with Section 10, subsections 1 and 1 of the Danish Data Protection Act. Additionally, the study agreed with the Helsinki Declaration II and followed the Vancouver rules.

Conclusions

From a Danish cohort of patients admitted to a level 1 trauma centre, we found a BCVI incidence of three per thousand. In the case of verified injury to the cervical region, the incidence increased to 6.25%. Two-thirds of the patients with CSI and, subsequently, BCVI showed only mild symptoms in the initial phase, which underlines the need for awareness and for a nationwide algorithm to prevent further disability, loss of health-related quality of life and death in this patient cohort.

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Accepted 5 November 2024

Conflicts of interest Potential conflicts of interest have been declared. Disclosure forms provided by the authors are available with the article at ugeskriftet.dk/dmj

Acknowledgements The authors take this opportunity to express their gratitude to the Department of Clinical Epidemiology, Institute of Clinical Medicine, Health, Aarhus University, for their contribution to the statistical analyses. Furthermore, we are indebted to the manager and staff of the Regional Clinical Quality Program (RKKP) for assistance with the data collection for this study.

References can be found with the article at ugeskriftet.dk/dmj

Cite this as Dan Med J 2025;72(1):A01240067

doi 10.61409/A01240067

Supplementary material https://content.ugeskriftet.dk/sites/default/files/2024-11/a01240067-supplementary.pdf

REFERENCES

1. Sethi RK, Kozin ED, Fagenholz PJ et al. Epidemiological survey of head and neck injuries and trauma in the United States. Otolaryngol Haed Neck Surg. 2014;151(5):776-84. https://doi.org/10.1177/0194599814546112
2. Davis JW, Holbrook TL, Hoyt DB et al. Blunt carotid artery dissection: incidence, associated injuries, screening, and treatment. J Trauma. 1990;30(12):1514-7.
3. Franz RW, Willette PA, Wood MJ et al. A systematic review and meta-analysis of diagnostic screening criteria for blunt cerebrovascular injuries. J Am Coll Surg. 2012;214(3):313-27. https://doi.org/10.1016/j.jamcollsurg.2011.11.012
4. Lebl DR, Bono CM, Velmahos G et al. Vertebral artery injury associated with blunt cervical spine trauma: a multivariate regression analysis. Spine (Phila Pa 1976). 2013;38(16):1352-61. https://doi.org/10.1097/BRS.0b013e318294bacb
5. Biffl WL, Moore EE, Elliott JP et al. The devastating potential of blunt vertebral arterial injuries. Ann Surg. 2000;231(5):672-81. https://doi.org/10.1097/00000658-200005000-00007
6. Miller PR, Fabian TC, Croce MA et al. Prospective screening for blunt cerebrovascular injuries: analysis of diagnostic modalities and outcomes. Ann Surg. 2002;236(3):386-93;discussion 93-5. https://doi.org/10.1097/01.SLA.0000027174.01008.A0
7. Du PZ, Barton D, Bridge N, Ganapathy V. Cervical fracture patterns associated with blunt cerebrovascular injures when utilizing computed tomographic angiography: a systematic review and meta-analysis. Spine J. 2022;22(10):1716-25. https://doi.org/10.1016/j.spinee.2022.05.009
8. Eastman AL, Muraliraj V, Sperry JL, Minei JP. CTA-based screening reduces time to diagnosis and stroke rate in blunt cervical vascular injury. J Trauma Acute Care Surg. 2009;67(3):551-6. https://doi.org/10.1097/TA.0b013e3181b84408
9. Association for the Advancement of Automotive Medicine. Abbreviated Injury Scale 2005. Update 2008. Association for the Advancement of Automotive Medicine, 2008
10. Baker SP, O'Neill B, Haddon W Jr., Long WB. The injury severity score: a method for describing patients with multiple injuries and evaluating emergency care. J Trauma. 1974;14(3):187-96.
11. Teasdale G, Jennett B. Assessment of coma and impaired consciousness. A practical scale. Lancet. 1974;2(7872):81-4. https://doi.org/10.1016/s0140-6736(74)91639-0
12. Department of Clinical Epidemiology. Consulting. https://kea.au.dk/consulting (2 Jan 2024)
13. Hwang PYK, Lewis PM, Balasubramani YV et al. The epidemiology of BCVI at a single state trauma centre. Injury. 2010;41(9):929-34. https://doi.org/10.1016/j.injury.2010.03.006
14. Burlew CC, Sumislawski JJ, Behnfield CD et al. Time to stroke: a Western Trauma Association multicenter study of blunt cerebrovascular injuries. J Trauma Acute Care Surg. 2018;85(5):858-66. https://doi.org/10.1097/TA.0000000000001989
15. Burlew CC, Biffl WL, Moore EE et al. Blunt cerebrovascular injuries: redefining screening criteria in the era of noninvasive diagnosis. J Trauma Acute Care Surg. 2012;72(2):330-5;discussion 336-7;quiz 539. https://doi.org/10.1097/TA.0b013e31823de8a0
16. Biffl WL, Moore EE, Offner PJ et al. Blunt carotid arterial injuries: implications of a new grading scale. J Trauma. 1999;47(5):845-53. https://doi.org/10.1097/00005373-199911000-00004

17. Thygesen LC, Daasnes C, Thaulow I, Brønnum-Hansen H. Introduction to Danish (nationwide) registers on health and social issues: structure, access, legislation, and archiving. Scand J Pub Health. 2011;39(7 suppl):12-6. https://doi.org/10.1177/1403494811399956
18. Regionernes Kliniske Kvalitetsudviklingsprogram. Dansk Traumeregister (DTR). www.rkkp.dk/kvalitetsdatabaser/databaser/dansk-traumeregister/ (2 Jan 2024)
19. AO Foundation. Trauma, spine. https://surgeryreference.aofoundation.org/spine/trauma (2 Jan 2024)

