American Journal of Emergency Medicine 71 (2023) 117–122

Contents lists available at ScienceDirect

American Journal of Emergency Medicine

journal homepage: www.elsevier.com/locate/ajem

Trauma mechanisms and patterns of blunt cervical vascular injury: A descriptive study using a nationwide trauma registry

Junichiro Shibata [a,b], Yohei Okada [b,c,d,*], Itsuki Osawa [e], Atsushi Shiraishi [f], Tadahiro Goto [b]

[a] Faculty of Medicine, The University of Tokyo, Tokyo, Japan
[b] TXP Medical Co. Ltd., Tokyo, Japan
[c] Preventive Services, School of Public Health, Graduate School of Medicine, Kyoto University, Kyoto, Japan
[d] Health Services and Systems Research, Duke-NUS Medical School, National University of Singapore, Singapore
[e] Department of Emergency and Critical Care Medicine, The University of Tokyo Hospital, Tokyo, Japan
[f] Emergency and Trauma Center, Kameda Medical Center, Chiba, Japan

ARTICLE INFO

Article history:
Received 28 February 2023
Received in revised form 5 June 2023
Accepted 15 June 2023

Keywords:
Blunt cervical vascular injury
Carotid artery
Vertebral artery
Co-occurring injury
Network analysis

ABSTRACT

Objective: Blunt cervical vascular injury (BCVI) is a non-penetrating trauma to the carotid and/or vertebral vessels following a direct injury to the neck or by the shearing of the cervical vessels. Despite its potentially life-threatening nature, important clinical features of BCVI such as typical patterns of co-occurring injuries for each trauma mechanism are not well known. To address this knowledge gap, we described the characteristics of patients with BCVI to identify the pattern of co-occurring injuries by common trauma mechanisms.
Methods: This is a descriptive study using a Japanese nationwide trauma registry from 2004 through 2019. We included patients aged ≥13 years presenting to the emergency department (ED) with BCVI, defined as a blunt trauma to any of the following vessels: common/internal carotid artery, external carotid artery, vertebral artery, external jugular vein, and internal jugular vein. We delineated characteristics of each BCVI classified according to three damaged vessels (common/internal carotid artery, vertebral artery, and others). In addition, we applied network analysis to unravel patterns of co-occurring injuries among patients with BCVI by four common trauma mechanisms (car accident, motorcycle/bicycle accident, simple fall, and fall from a height).
Results: Among 311,692 patients who visited the ED for blunt trauma, 454 (0.1%) patients had BCVI. Patients with common/internal carotid artery injuries presented to the ED with severe symptoms (e.g., the median Glasgow Coma Scale was 7) and had high in-hospital mortality (45%), while patients with vertebral artery injuries presented with relatively stable vital signs. Network analysis showed that head-vertebral-cervical spine injuries were common across four trauma mechanisms (car accident, motorcycle/bicycle accident, simple fall, and fall from a height), with co-occurring injuries of the cervical spine and vertebral artery being the most common injuries due to falls. In addition, common/internal carotid artery injuries were associated with thoracic and abdominal injuries in patients with car accidents.
Conclusions: Based on analyses of a nationwide trauma registry, we found that patients with BCVI had distinct patterns of co-occurring injuries by four trauma mechanisms. Our observations provide an important basis for the initial assessment of blunt trauma and could support the management of BCVI.

1. Introduction

Blunt cervical vascular injury (BCVI) is a non-penetrating trauma to the carotid and/or vertebral vessels, caused by direct injury to the neck or shearing of the cervical vessels. [1-3] Since cervical vessels are adjacent to many vital organ systems, even innocuous-appearing injuries can lead to immediate or delayed life-threatening complications that require intervention in most patients. [4-6]

Despite its clinical importance, the low incidence of BCVI (approximately 1% of blunt trauma) hinders the understanding of its clinical characteristics, such as typical injury mechanisms and patterns of co-occurring injuries. [7-13] For example, a previous study that developed and validated a model for predicting BCVI identified predictive factors including CT scan findings, but did not reveal any predictive value of patterns of co-occurring injury by injury mechanisms. [14] Although this is an important finding, often times, emergency physicians and

Abbreviations: BCVI, blunt cervical vascular injury; ED, emergency department; JTDB, the Japan Trauma Data Ban; AIS, Abbreviated Injury Scale; ISS, injury severity score.

* Corresponding author at: Department of Preventive Services, Graduate School of Medicine, Kyoto University, Kyoto, Japan.
E-mail address: yokada-kyf@umin.ac.jp (Y. Okada).

https://doi.org/10.1016/j.ajem.2023.06.033
0735-6757/

acute care surgeons would benefit from knowledge on predictive factors of BCVI at the initial evaluation. Specifically, it would be valuable to know when and what type of injury requires further investigation of the cervical vessels. Understanding the frequent injury mechanisms and patterns of co-occurring injuries to suspect BCVI at initial triage may support appropriate decision-making to perform contrast-enhanced CT or angiography of cervical vessels.

To address this knowledge gap, based on a Japanese nationwide trauma registry, we aimed to describe the characteristics of patients with BCVI by using network analysis [15,16] to identify the pattern of co-occurring injuries by common trauma mechanisms.

2. Methods

2.1. Study design and setting

This is a descriptive study using data from the Japan Trauma Data Bank (JTDB), [17] collected from January 2004 through May 2019. The study protocol was approved by the ethics committee of the National Defense Medical College Research Institute in Japan (ID No. 2548), the institution responsible for the JTDB, and the requirement for informed consent was waived due to the retrospective nature of the study.

2.2. Japan Trauma Data Bank

The Japan Trauma Data Bank (JTDB) is a nationwide, multicenter registry of trauma patients in Japan established in 2003. [17] 192 emergency medical centers participated in the JTDB during the study period. Each case of trauma is recorded with an Abbreviated Injury Scale (AIS) code (version 1998), [18] which is recorded by medical staff after the patient has been treated or hospitalized. [19] Facilities participating in JTDB are required to record in the registry all cases of severe trauma with an AIS score ≥ 3. Data included in the JTDB are the following: patient demographics (e.g., age, sex), prehospital information (e.g., vital signs on contact, prehospital treatments, modes of transport to the hospital), vital signs upon emergency department (ED) arrival, examinations (e.g., CT scan, angiography), treatments (e.g., blood transfusion, intubation, surgical operation), trauma mechanism (e.g., car accident, fall), diagnosed diseases (and AIS code in the case of trauma), and outcomes. The JTDB was approved by the ethics committee of the Japanese Association for the Surgery of Trauma, and the approval document is available on the JTDB website. [17]

2.3. Study population

Among all the patients in the JTDB, we included patients aged ≥13 years presenting to the ED with BCVI. Blunt cervical vascular injury was defined as a blunt trauma to any of the following five vessels based on the AIS code (version 1998): [18] common/internal carotid artery, external carotid artery, vertebral artery, external jugular vein, and internal jugular vein.

2.4. Data collection

For each enrolled patient, we collected patient demographics (age and sex), triage vital signs (systolic blood pressure [SBP], heart rate [HR], respiratory rate [RR], and Glasgow Coma Scale [GCS]), injured cervical vessels and co-occurring injuries based on the AIS code, trauma mechanisms of BCVI (e.g., car accident, fall from a height), severity score of patients using the injury severity score (ISS), [20] information on initial treatment at the ED (e.g., intubation, blood transfusion), angiography of the cervical vessel and surgical operations of the neck performed during their hospital stay, and dispositions (in-hospital mortality and length of hospital stay). We categorized the trauma mechanisms as follows: car accident (i.e., car driver or passenger), motorcycle/bicycle accident, simple fall such as fall from stairs, fall from a height, and others.

2.5. Statistical analysis

First, we categorized all patients with BCVI into three groups based on the injured vessel as follows: common/internal carotid artery injury, vertebral artery injury, and other cervical vascular (external carotid artery, external jugular vein, or internal jugular vein) injuries. Patients with two or more injured vessel including common/internal carotid artery (i.e., multiple BCVIs) were grouped into common/internal carotid artery injuries, because carotid injury is more critical and the number of patients with multiple BCVIs were small (e.g., carotid and vertebral, $n = 7$). We then used summary statistics to delineate the patient characteristics in each group.

Next, we conducted network analysis to investigate the patterns of co-occurring injuries in patients with BCVI by trauma mechanism. Network analysis is a statistical method for structurally representing groups of objects or people and the relationships among them. [15,16] A network structure consists of nodes and edges, where the nodes represent the objects to be analyzed and the edges represent the relationships among the objects. In this study, we applied network analysis to patients stratified by four trauma mechanisms (car accident, motorcycle/bicycle accident, simple fall, and fall from a height), with the injured body regions as nodes and the frequencies of each injury co-occurrence as edges, [21] The number of patients with co-occurring injuries were counted, and percentages of the patients with co-occurrences out of the full sample were visualized as thickness of the edges.

All analyses were conducted using Python version 3.8.8. Continuous variables were expressed as medians and interquartile ranges (IQR). Categorical variables were summarized as counts (n) and percentages (%).

3. Results

3.1. Patient characteristics, overall

Of the 338,744 patients in JTDB from 2004 to 2019, 311,692 patients (98%) visited the ED for blunt trauma. Of these, we identified 454 (0.1%) patients presenting to the ED with BCVI (Fig. 1). The demographic and clinical characteristics of the patients are shown in Table 1 and information on the missing values is shown in Supplemental Table 1. The median (IQR) age was 61 (37–72) years, and 341 (75%) were male. Patients tended to initially have mild altered mental status, though the severity in vital signs differed across injured vessels groups. A total of 110 (24%) patients were injured by car accidents, 100 (22%) by motorcycle/bicycle accidents, 82 (18%) by simple falls, and 66 (14%) by falls from a height (Supplemental Table 2). Of the 454 patients who presented to the ED with BCVI, 105 (23%) patients had common/internal carotid artery injuries, 262 (58%) patients had vertebral artery injuries, and 87 (19%) patients had other BCVIs. Of the 105 patients with common/internal carotid artery injuries, 7 (7%) had co-occurring vertebral artery injuries. After hospitalization, 111 (24%) patients died in hospital.

3.2. Patient characteristics, by injured vascular cite

As shown in Table 1, among 105 patients with common/internal carotid artery injuries, the median (IQR) age was 51 (35–69), 74 (70%) were male, and tended to have critical vital signs on triage (e.g., a median GCS level of 7). Approximately half of the injuries were due to motor vehicle accidents (e.g., car/motorcycle accidents). After hospitalization, 13 (12%) of patients had cervical angiography, and 47 (45%) died. As shown in Table 2, the frequently co-occurring injuries were as follows: head injuries (e.g., skull fracture), 58 (55%); thoracic injuries (e.g., rib fracture), 54 (51%); and spinal injuries, 43 (41%). Detailed information on initial treatment, angiography, and surgical operation is shown in Supplemental Table 3. By contrast, among 262 patients with a vertebral artery injury, the median (IQR) age was 64 (44–73), 203

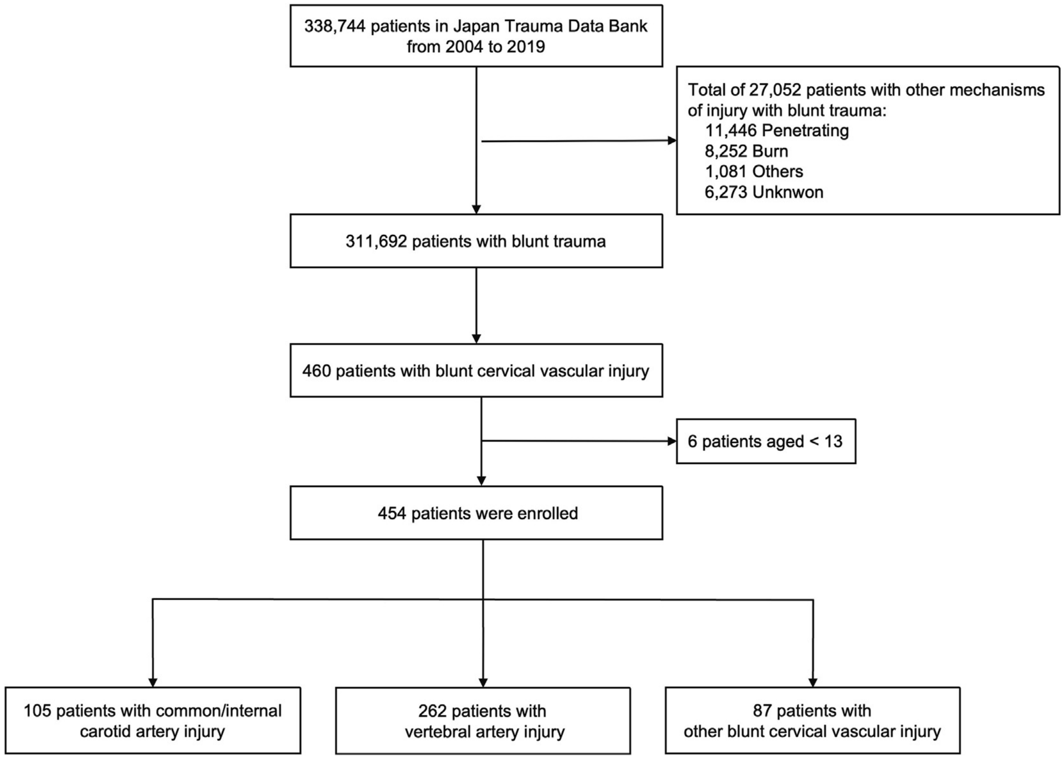

Fig. 1. Flow chart of patient selection.
Legend: Others ($n = 87$) includes patients with blunt injuries in the carotid external artery, jugular external vein, or jugular internal vein. 7 patients with both common/internal carotid artery and vertebral artery injuries were classified into the common/internal carotid artery injury group.

Table 1
Characteristics of patients with blunt cervical vascular injury.

Variables	Overall ($n = 454$)	Common/internal carotid artery ($n = 105$)	Vertebral artery ($n = 262$)	Others (n = 87)
Patient characteristic at ED visit				
Age, median (IQR), year	61 (37–72)	51 (35–69)	64 (44–73)	59 (30–72)
Male, n (%)	341 (75%)	74 (70%)	203 (77%)	64 (74%)
Triage vital signs, median (IQR)				
Systolic blood pressure, mmHg	118 (85–143)	107 (64–132)	121 (97–145)	119 (79–143)
Heart rate, /min	80 (67–101)	87 (66–111)	76 (64–93)	92 (73–110)
Respiratory rate, /min	20 (15–24)	20 (12–28)	20 (16–23)	20 (16–26)
Glasgow coma scale	13 (4–15)	7 (3–14)	14 (9–15)	14 (3–15)
Trauma mechanism, n (%)				
Car accident	110 (24%)	32 (30%)	54 (21%)	24 (28%)
Motorcycle/Bicycle accident	100 (22%)	24 (23%)	52 (20%)	24 (28%)
Simple fall	82 (18%)	3 (3%)	71 (27%)	8 (9%)
Fall from a height	66 (14%)	10 (10%)	45 (17%)	11 (13%)
Others	96 (21%)	36 (35%)	40 (15%)	20 (23%)
Injury severity score, median (IQR)	22 (16–33)	26 (17–35)	20 (16–28)	20 (14–34)
In-hospital management				
Initial treatment in the ED, n (%)				
Intubation	157 (35%)	44 (42%)	76 (29%)	37 (43%)
Cardiopulmonary resuscitation	40 (9%)	13 (12%)	16 (6%)	11 (13%)
Chest drainage	43 (9%)	15 (14%)	13 (5%)	15 (17%)
Blood transfusion	86 (19%)	27 (26%)	32 (12%)	27 (31%)
Neck CT, n (%)	375 (83%)	85 (81%)	226 (86%)	64 (74%)
Neck angiography, n (%)	83 (18%)	13 (12%)	60 (23%)	10 (11%)
Neck surgical operation, n (%)				
Vascular surgery or embolization	37 (8%)	9 (9%)	11 (4%)	17 (19%)
Cervical spine fixation	70 (15%)	2 (2%)	67 (26%)	1 (1%)
Outcomes				
In-hospital mortality, n (%)	111 (24%)	47 (45%)	41 (16%)	23 (26%)
Length of hospital stay, median (IQR), day	22 (6–46)	14 (1–48)	25 (13–47)	12 (2–34)

Legend: Others (n = 87) includes patients with blunt injuries in the carotid external artery, jugular external vein, or jugular internal vein.
Abbreviations: ED, emergency department; IQR, interquartile range.

Table 2
Co-occurring injuries among patients with blunt cervical vascular injury.

Variables, n (%)	Overall (n = 454)	Common/internal carotid artery (n = 105)	Vertebral artery (n = 262)	Others (n = 87)
Injured body regions				
Head	216 (48%)	58 (55%)	117 (45%)	41 (47%)
Face	101 (22%)	25 (24%)	48 (18%)	28 (32%)
Neck (other than BCVI)	42 (9%)	15 (14%)	5 (2%)	22 (25%)
Thorax	184 (41%)	54 (51%)	77 (29%)	53 (61%)
Abdomen	55 (12%)	19 (18%)	19 (7%)	17 (20%)
Spine	305 (67%)	43 (41%)	241 (92%)	21 (24%)
Upper extremity	109 (24%)	23 (22%)	53 (20%)	33 (38%)
Lower extremity	134 (30%)	41 (39%)	61 (23%)	32 (37%)
Unspecified	22 (5%)	6 (6%)	12 (5%)	4 (5%)
Skull fracture	63 (13%)	26 (25%)	21 (8%)	16 (18%)
Facial bone fracture	60 (13%)	16 (15%)	25 (10%)	19 (22%)
Thoracic vascular injury	18 (4%)	8 (8%)	6 (2%)	4 (5%)
Thoracic aorta	14 (3%)	4 (4%)	2 (1%)	1 (1%)
Rib fracture	110 (23%)	36 (34%)	43 (16%)	31 (36%)
Spine injury - cervical	282 (59%)	30 (29%)	240 (92%)	12 (14%)
Fracture without spinal cord injury	175 (37%)	22 (21%)	144 (55%)	9 (10%)
Spinal cord injury	150 (32%)	11 (10%)	137 (52%)	2 (2%)
Spine injury - thorax	38 (8%)	8 (8%)	24 (9%)	6 (7%)
Fracture without spinal cord injury	37 (8%)	8 (8%)	24 (9%)	5 (6%)
Spinal cord injury	11 (2%)	1 (1%)	8 (3%)	2 (2%)
Spine injury - lumbar, n (%)	36 (8%)	14 (13%)	16 (6%)	6 (7%)
Fracture without spinal cord injury	36 (8%)	14 (13%)	16 (6%)	6 (7%)
Spinal cord injury	4 (1%)	1 (1%)	3 (1%)	0 (0%)

Legend: Each injury is based on the Abbreviated Injury Scale (1998 version).
Abbreviations: BCVI, blunt cervical vascular injury.

(77%) were male, and triage vital signs were relatively stable. Of these, 116 (44%) of injuries were fall-related, 60 (23%) had in-hospital cervical angiography, and 41 (16%) died in hospital. Regarding co-occurring injuries, cervical spine injury was prominent (240 [92%]), 144 (55%) had vertebral fractures without spinal cord injury, and 137 (52%) had spinal cord injury (with or without vertebral fractures).

3.3. Patterns of co-occurring injuries in patients with BCVI through network analysis

Fig. 2 shows the pattern of injuries by trauma mechanism among patients with BCVI through network analysis. Although co-occurring head-vertebral-cervical injuries were common across all trauma

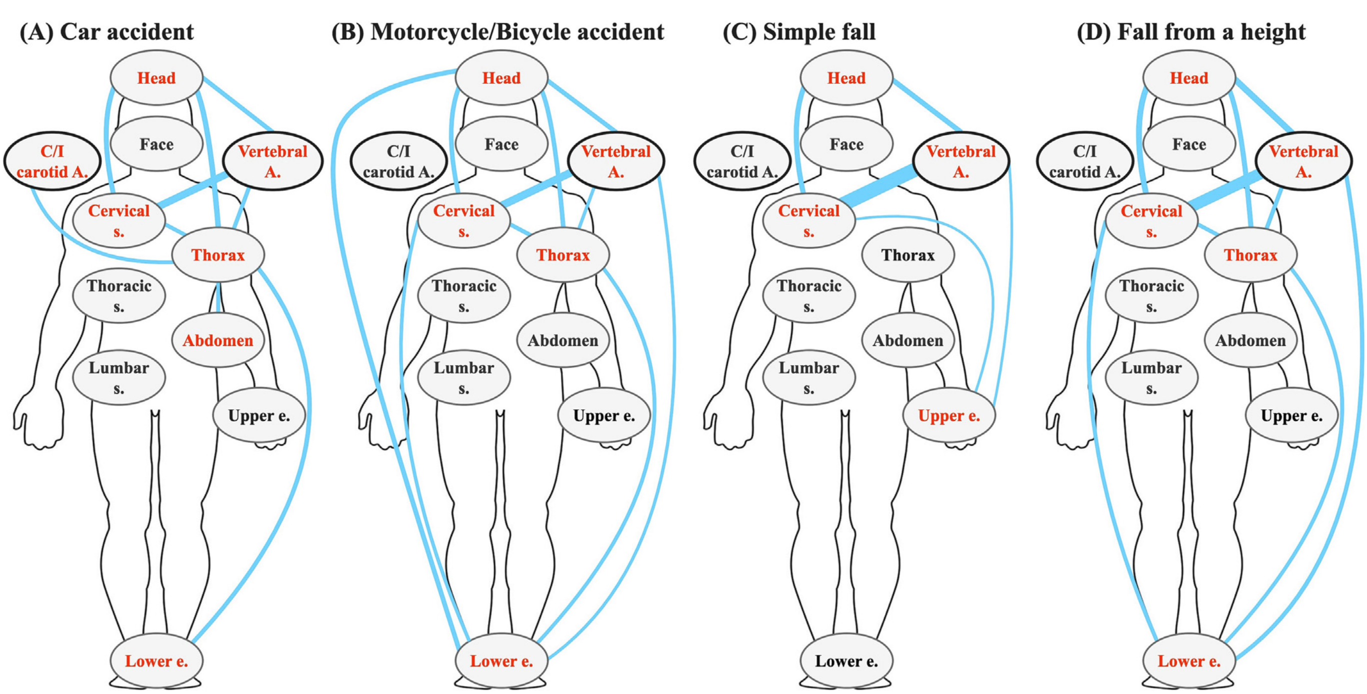

Fig. 2. Patterns of injuries in patients with blunt cervical vascular injuries by trauma mechanism.
Legend: Shown are patterns of injuries in patients with blunt cervical vascular injury, where the node represents the injury to each body region (e.g., head, face) and the edge represents the co-occurrence of injuries. The thickness of the edges reflects the percentage of the co-occurrence. Each figure represents the patterns of injuries by (A) car accidents, (B) Motorcycle/bicycle accidents, simple falls, and (D) falls from a height. A, B, and D show the top 10 most frequent patterns, while C shows the top 5 most frequent patterns. Body parts shown in red are injury sites that are distinct of each trauma mechanism based on the Supplemental Table4.
Abbreviations: C/I carotid A., common/internal carotid artery; vertebral A., vertebral artery; Cervical s., cervical spine; Thoracic s., thoracic spine; Lumbar s., lumbar spine; Upper e., upper extremities; Lower e., lower extremities.

mechanisms, the following unique patterns were found: (A) car accident: patients were more likely to have co-occurring thoracic and abdominal injuries rather than extremity injuries; (B) motorcycle/bicycle accident: patients were likely to have upper/lower extremity injuries; (C) simple fall: patients were likely to have vertebral artery injuries with cervical spine injuries and/or upper extremity injuries; (D) fall from a height: patients had various injuries including extremities, whose pattern was similar to the pattern of injury by motorcycle/bicycle accidents. The number of injured body parts for each trauma mechanism is shown in Supplemental Table 4 and the frequencies of combinations of injuries in Supplemental Table 5.

4. Discussion

In this retrospective study using a nationwide trauma registry, we identified 454 patients (0.1%) with BCVI among 311,692 patients who visited the ED with blunt trauma. We found that patients with common/internal carotid artery injuries presented to the ED with severe symptoms, while patients with vertebral artery injuries had relatively stable vital signs. In the network analysis, we delineated and visualized patterns of co-occurring injuries by four trauma mechanisms. Co-occurring head-vertebral-cervical injuries was common across all trauma mechanisms, with co-occurring injuries of the cervical spine and vertebral artery being the most common injuries due to falls. Each trauma mechanism has distinct injury patterns (e.g., thoracic or abdominal co-occurring in car accidents). These characterizations could support management for patients with blunt trauma.

Previous studies have reported that BCVI is found in approximately 1% of patients with blunt traumas, [7-13] but in our study, the BCVI rate was at about 0.1%, despite that our study was conducted using a nationwide registry. Such differences in the incident rate might be likely attributable to the differences in the study population and regional characteristics. While the incidence of BCVI in patients with blunt trauma was relatively small, we should not overlook the fact that BCVI can lead to fatal complications such as secondary stroke or arterial dissection. [22-29] Furthermore, patients with common/internal carotid artery injuries presented to the ED in severe states, and thus may have higher rates of neurological sequelae and mortality. [8,22,30-32]

In addition to these findings, we also elucidated the patterns of BCVI-related injury by common blunt trauma mechanisms. In our study, approximately 30% of common/internal carotid artery injuries were due to car accidents, and these patients were likely to have a co-occurring thoracoabdominal injury. The underlying mechanisms could be the following, according to earlier studies: [33-36] 1) direct external force from impact with the steering wheel or seat (e.g., steering wheel injury), 2) deceleration due to an external force, and 3) being caught between the steering wheel and the thoracic spine. While a trunk or large vessel injury might attract the physician's attention, BCVI may also concurrently occur due to the above injury mechanisms (i.e., neck overstretching). By contrast, almost half of vertebral vessel injuries were fall-related, including simple falls in our study. Falling forward from a standing height may have caused cervical spine injuries due to the energy applied to the head and neck in a short time. [37-40] In addition, cervical spine injuries were associated with vertebral artery injuries in all trauma mechanisms, even in simple falls, suggesting that patients with head injuries and upper extremity injuries may also have a risk of BCVI because these injuries could lead to neck overstretching. As simple falls are a major problem for the aging population, these injury patterns may be beneficial for future research for appropriate decision-making at the initial evaluation.

Although the Denver criteria, [41] one of the current major screening indexes for BCVI, includes several items for comorbid injuries (e.g., complex skull fracture, thoracic vascular injuries), it is not designed to evaluate patients from the perspective of injury mechanisms as presented in our study. [42] We found that considering injury mechanisms can provide important information for clinicians upon initial triage. Taken together, the patterns of injury mechanisms and comorbid injuries elucidated in our study could serve as an important basis for future studies aiming to improve the diagnosis rate of BCVI by assessing the association of patterns of injuries co-occurring with BCVI.

5. Limitations

Our study has several limitations. First, since facilities participating in JTDB mainly register high-severity injuries (AIS score ≥ 3), [17] our study might not fully include BCVI with less severe injuries. Second, the JTDB does not include patients who actually had BCVI but were not diagnosed, which is a potential source of selection bias. Third, some facilities do not input information on imaging tests (e.g., neck CT, angiography), which are generally considered essential for the diagnosis of BCVI, into JTDB, which could lead to underestimation of the actual rate of BCVI. Forth, while the JTDB can ascertain the broad classification of the trauma mechanisms (e.g., car accident, fall from a height), there was detailed information on the mechanisms of the injury was not available (e.g., for a car accident, how fast and how the collision occurred). In addition, data on fatal complications, such as secondary strokes, and follow-up information after patients were discharged from the hospital could not be obtained. Such information could have given more depth to the findings of this study. Lastly, the results of our study regarding the frequencies of injury mechanisms and patterns for patients with BCVI may differ in countries and regions other than Japan. For example, in Japan, blunt trauma accounts for most of the trauma (>90% of all traumatic injuries in JTDB [19]), and the legal speed limit is lower than in other countries (80 km/h on local roads and 100 km/h on highways). Yet, since the structure of the human body and the mechanisms of trauma themselves are similar, our findings is interpretable in the context of other countries. Yet, since the structure of the human body and the mechanisms of trauma itself are similar, our findings could be interpreted in the context of other countries.

6. Conclusions

Among patients with BCVI registered in a nationwide trauma database, there were distinct patterns of co-occurring injuries by four trauma mechanisms. Further research to assess the association between trauma mechanism and patterns of injury co-occurring with BCVI is encouraged.

Ethics approval and Patient consent for participate

The study protocol was approved by the ethics committee of the National Defense Medical College Research Institute in Japan (ID No. 2548), the representative institution in the JTDB, and the requirement for informed consent was waived due to the retrospective nature of the study.

Consent for publication

Not applicable.

Funding/Support

Not applicable.

Author's Contributors

All authors conceived and designed the study. JS performed the statistical analyses and drafted the initial manuscript. YO, IO, TG, and AS supervised the study. All authors interpreted the data, critically revised the manuscript for important intellectual content, and approved the final manuscript.

CRediT authorship contribution statement

Junichiro Shibata: Writing – original draft, Formal analysis, Conceptualization. **Yohei Okada:** Writing – review & editing, Supervision, Conceptualization. **Itsuki Osawa:** Writing – review & editing, Supervision, Methodology. **Atsushi Shiraishi:** Writing – review & editing, Data curation. **Tadahiro Goto:** Writing – review & editing, Supervision, Conceptualization.

Declaration of Competing Interest

Mr. Shibata is a researcher at TXP Medical Co., Ltd. Dr. Okada has received a research grant from the ZOLL foundation and the JSPS-KAKENHI (23K16253), and an overseas scholarship from JSPS Overseas Research Fellowship, the FUKUDA foundation for medical technology and the International medical research foundation. These organizations have no role in conducting this research. Dr. Goto is the Chief Scientific Officer of TXP Medical Co., Ltd.

Acknowledgements

We are grateful to the Japanese Association for the Surgery of Trauma (Trauma Registry Committee) and the Japanese Association for Acute Medicine (Committee for Clinical Care Evaluations) for providing the data set. We also thank Naoki Kanda, Daisuke Kasugai, Hiroshi Kamijo, Mikio Nakajima, and Kohei Yamada for comments that greatly improved the manuscript.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ajem.2023.06.033.

References

[1] Alao TWM. Neck trauma. StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2022 Published July 4. Accessed February 9, 2023. https://www.ncbi.nlm.nih.gov/books/NBK470422/. Published July 4. Accessed February 9, 2023.
[2] Plitt AR, Kafka B, Rickert K. Blunt cervical vascular injury. In: Madden CJ, Jallo J, editors. Neurotrauma; 2019. https://doi.org/10.1093/med/9780190936259.003.0014. Published November 1.
[3] Al-Harthy A, Al-Hinai A, Al-Wahaibi K, Al-Qadhi H. Blunt cerebrovascular injuries: a review of the literature. Sultan Qaboos Univ Med J. 2011;11(4):448–54. http://www.ncbi.nlm.nih.gov/pubmed/22087392.
[4] Al-Thani H, El-Menyar A, Mathew S, et al. Patterns and outcomes of traumatic neck injuries: a population-based observational study. J Emerg Trauma Shock. 8(3): 154–158. https://doi.org/10.4103/0974-2700.160723
[5] Foreman PM, Harrigan MR. Blunt traumatic extracranial cerebrovascular injury and ischemic stroke. Cerebrovasc Dis Extra. 2017;7(1):72–83. https://doi.org/10.1159/000455391.
[6] Brommeland T, Helseth E, Aarhus M, et al. Best practice guidelines for blunt cerebrovascular injury (BCVI). Scand J Trauma Resusc Emerg Med. 2018;26(1):90. https://doi.org/10.1186/s13049-018-0559-1.
[7] Hwang PYK, Lewis PM, Balasubramani YV, Madan A, Rosenfeld JV. 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.
[8] Miller PR, Fabian TC, Bee TK, et al. Blunt cerebrovascular injuries: diagnosis and treatment. J Trauma. 2001;51(2):279–85. discussion 285–6. https://doi.org/10.1097/00005373-200108000-00009.. discussion 285–6.
[9] Lee TS, Ducic Y, Gordin E, Stroman D. Management of carotid artery trauma. Craniomaxillofac Trauma Reconstr. 2014;7(3):175–89. https://doi.org/10.1055/s-0034-1372521.
[10] 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 393–5. https://doi.org/10.1097/01.SLA.0000027174.01008.A0.. discussion 393–5.
[11] Stein DM, Boswell S, Sliker CW, Lui FY, Scalea TM. Blunt cerebrovascular injuries: does treatment always matter? J Trauma. 2009;66(1):132–43. discussion 143–4. https://doi.org/10.1097/TA.0b013e318142d146. discussion 143–4.
[12] Weber CD, Lefering R, Kobbe P, et al. Blunt cerebrovascular artery injury and stroke in severely injured patients: an international multicenter analysis. World J Surg. 2018;42(7):2043–53. https://doi.org/10.1007/s00268-017-4408-6.
[13] Schneidereit NP, Simons R, Nicolaou S, et al. Utility of screening for blunt vascular neck injuries with computed tomographic angiography. J Trauma. 2006;60(1): 209–15. discussion 215–6. https://doi.org/10.1097/01.ta.0000195651.60080.2c.. discussion 215–6.
[14] Shibahashi K, Hoda H, Ishida T, Motoshima T, Sugiyama K, Hamabe Y. Derivation and validation of a quantitative screening model for blunt cerebrovascular injury. J Neurosurg. 2021:1–10. https://doi.org/10.3171/2020.8.JNS202589.
[15] Hevey D. Network analysis: a brief overview and tutorial. Heal Psychol Behav Med. 2018;6(1):301–28. https://doi.org/10.1080/21642850.2018.1521283.
[16] Luke DA, Harris JK. Network analysis in public health: history, methods, and applications. Annu Rev Public Health. 2007;28:69–93. https://doi.org/10.1146/annurev.publhealth.28.021406.144132.
[17] Japan Trauma Data Bank Official Website. Accessed February 9, 2023. https://www.jtcr-jatec.org/traumabank/dataroom/ethics2.htm.
[18] Association for the Advancement of Automotive Medicine. The Abbreviated Injury Scale 1990 Revision—Update 98; 1998.
[19] Japan Trauma Care and Research. Japan Trauma Data Bank Annual Report 2021. Published. Accessed February 9, 2023. http://www.jast-hp.org/trauma/pdf/jtdb2021.pdf; 2021.
[20] Baker SP, O'Neill B. The injury severity score: an update. J Trauma. 1976;16(11): 882–5. https://doi.org/10.1097/00005373-197611000-00006.
[21] Lamontagne ME. Exploration of the integration of care for persons with a traumatic brain injury using social network analysis methodology. Int J Integr Care. 2013;13: e038. https://doi.org/10.5334/ijic.1055.
[22] Fabian TC, Patton JH, Croce MA, Minard G, Kudsk KA, Pritchard FE. Blunt carotid injury. Importance of early diagnosis and anticoagulant therapy. Ann Surg. 1996; 223(5):513–22. discussion 522–5. https://doi.org/10.1097/00000658-199605000-00007.. discussion 522–5.
[23] Biffl WL, Moore EE, Ryu RK, et al. The unrecognized epidemic of blunt carotid arterial injuries: early diagnosis improves neurologic outcome. Ann Surg. 1998;228(4): 462–70. https://doi.org/10.1097/00000658-199810000-00003.
[24] Schicho A, Luerken L, Meier R, et al. Incidence of traumatic carotid and vertebral artery dissections: results of cervical vessel computed tomography angiogram as a mandatory scan component in severely injured patients. Ther Clin Risk Manag. 2018;14:173–8. https://doi.org/10.2147/TCRM.S148176.
[25] Simon LV, Nassar Ak MM. Vertebral artery injury. StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2022 Published July 18. Accessed February 9, 2023. https://www.ncbi.nlm.nih.gov/books/NBK470363/. Published July 18. Accessed February 9, 2023.
[26] Davis JW, Holbrook TL, Hoyt DB, Mackersie RC, Field TO, Shackford SR. Blunt carotid artery dissection: incidence, associated injuries, screening, and treatment. J Trauma. 1990;30(12):1514–7. http://www.ncbi.nlm.nih.gov/pubmed/2258964.
[27] van Wessem KJP, Meijer JMR, Leenen LPH, van der Worp HB, Moll FL, de Borst GJ. Blunt traumatic carotid artery dissection still a pitfall? The rationale for aggressive screening. Eur J Trauma Emerg Surg. 2011;37(2):147–54. https://doi.org/10.1007/s00068-010-0032-y.
[28] Nedeltchev K, Baumgartner R. Traumatic cervical artery dissection. Front Neurol Neurosci. 2005;20:54–63. https://doi.org/10.1159/000088149.
[29] Cadena R. Blunt cerebrovascular injuries: early recognition and stroke prevention in the emergency department. Emerg Med Pract. 2020;22(Suppl. 12):1–43. http://www.ncbi.nlm.nih.gov/pubmed/33320488.
[30] Carrillo EH, Osborne DL, Spain DA, Miller FB, Senler SO, Richardson JD. Blunt carotid artery injuries: difficulties with the diagnosis prior to neurologic event. J Trauma. 1999;46(6):1120–5. https://doi.org/10.1097/00005373-199906000-00030.
[31] Biffl WL, Ray CE, Moore EE, Mestek M, Johnson JL, Burch JM. Noninvasive diagnosis of blunt cerebrovascular injuries: a preliminary report. J Trauma. 2002;53(5): 850–6. https://doi.org/10.1097/00005373-200211000-00008.
[32] Cothren CC, Moore EE, Ray CE, et al. Screening for blunt cerebrovascular injuries is cost-effective. Am J Surg. 2005;190(6):845–9. https://doi.org/10.1016/j.amjsurg.2005.08.007.
[33] Fadl SA, Sandstrom CK. Pattern recognition: a mechanism-based approach to injury detection after motor vehicle collisions. Radiographics. 39(3):857–876. https://doi.org/10.1148/rg.2019180063
[34] Toney-Butler TJVM. Motor vehicle collisions. StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2021 Published September 5. Accessed February 9, 2023. https://www.ncbi.nlm.nih.gov/books/NBK441955/. Published September 5. Accessed February 9, 2023.
[35] Yoganandan N, Pintar FA, Gennarelli TA, Maltese MR. Patterns of abdominal injuries in frontal and side impacts. Annu Proce Assoc Adv Automot Med. 2000;44:17–36. http://www.ncbi.nlm.nih.gov/pubmed/11558081.
[36] Ndiaye A, Chambost M, Chiron M. The fatal injuries of car drivers. Forensic Sci Int. 2009;184(1–3):21–7. https://doi.org/10.1016/j.forsciint.2008.11.007.
[37] Unguryanu TN, Grjibovski AM, Trovik TA, Ytterstad B, Kudryavtsev AV. Mechanisms of accidental fall injuries and involved injury factors: a registry-based study. Inj Epidemiol. 2020;7(1):8. https://doi.org/10.1186/s40621-020-0234-7.
[38] Freeman MD, Eriksson A, Leith W. Head and neck injury patterns in fatal falls: epidemiologic and biomechanical considerations. J Forensic Leg Med. 2014;21:64–70. https://doi.org/10.1016/j.jflm.2013.08.005.
[39] Torretti JA, Sengupta DK. Cervical spine trauma. Indian J Orthop. 2007;41(4): 255–67. https://doi.org/10.4103/0019-5413.36985.
[40] Donnally III CJ, DiPompeo CMVM. Vertebral compression fractures. StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2022 Published February 12. Accessed February 9, 2023. https://www.ncbi.nlm.nih.gov/books/NBK448171/. Published February 12. Accessed February 9, 2023.
[41] Deng F, Hacking C. Denver criteria for blunt cerebrovascular injury. Radiopaedia.org. Radiopaedia,org; 2015. https://doi.org/10.53347/rID-41637.
[42] Ritter JT, Kraus CK. Blunt traumatic cervical vascular injury without any modified Denver criteria. Clin Pract Cases Emerg Med. 2018;2(3):200–2. https://doi.org/10.5811/cpcem.2018.4.37719.