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ORIGINAL ARTICLE - BRAIN TRAUMA

The distance of cervical vertebral dislocation could be a risk factor for blunt vertebral artery injury after traumatic cervical spine injury

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Abstract

Background Blunt vertebral artery injury (BVAI) is a well-known potentially fatal complication of cervical spine injury. The condition is reported to be associated with vertebral fractures and cervical hyperextension. However, appropriate patient screening methods remain to be elucidated. This study aimed to identify the risk factors associated with BVAI in patients with cervical spine injury.

Methods We conducted a retrospective, observational, single-centered study, including 137 patients with cervical spine injury transferred to our center from April 2007 to December 2016. Evaluation for BVAI was available in 62 patients based on magnetic resonance angiography or multi-detector computed tomography angiography. BVAI was classified using the Biffl grade.

Results Among the 62 patients evaluated, 13 (21%) were diagnosed with BVAI. All injuries were classified as Biffl grade 2 (50%) or 4 (50%). Univariate analysis of patients with and without BVAI showed that cervical dislocation ($p = 0.041$) and low average hemoglobin level ($p = 0.032$) were associated with BVAI. On multivariate logistic regression analysis, cervical dislocation (odds ratio 1.189; 95% confidence interval 1.011–1.399, $p = 0.036$) remained a significant predictor of BVAI. Based on receiver operating characteristic (ROC) analysis, a dislocation > 6.7 mm was selected as the optimal cutoff value for prediction of BVAI (sensitivity and specificity, 87.5% and 71.4%, respectively).

Conclusions BVAI frequently occurred in combination with cervical spine dislocation, and the distance of the cervical dislocation was identified as a useful predictor of BVAI.

Keywords Blunt cerebrovascular injury · Blunt vertebral artery injury · Cervical spine injury

Introduction

Blunt cerebrovascular injury is recognized as a potentially fatal complication of cervical spine injury. In 1999, screening criteria for blunt cerebrovascular injury were introduced for the first time [2]. Brommeland et al. also reported a screening and treatment protocol [4]. The reported risk factors for blunt cerebrovascular injury according to the Denver screening

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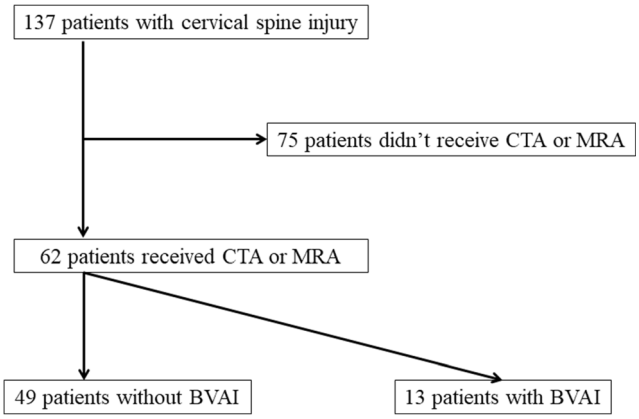

Fig. 1 137 patients with cervical spine injury

criteria include a GCS score ≤ 6, petrous bone fractures, diffuse axonal injury, motorcycle crash, cervical spine injury, thoracic or hepatic injury, cervical spine dislocation, and Le Fort II or III fractures [1, 2, 9, 12]. The presentation of blunt cerebrovascular injury is divided into two categories: embolization, which is related to an injured artery, and vascular stenosis or occlusion. These complications may lead to potentially fatal cerebrovascular infarction [8]. Blunt cerebrovascular injury is classified into blunt carotid artery injury and blunt vertebral artery injury (BVAI). BVAI is reported to be caused by vertebral fractures and cervical hyperextension. It occurs commonly at the C6 level but is known to be associated with the C1-6 levels. Moreover, in patients with grade IV BVAI, the C1/2 level is the most common predilection site [10, 13, 14]. Although BVAI can lead to potentially fatal ischemic brain injury, methods for appropriate patient screening remain to be elucidated, and many cases might have been missed or wrongly diagnosed. This retrospective study was conducted to identify the risk factors of this fairly rare condition associated with cervical trauma.

Methods

Study design and patient selection

We conducted a retrospective, observational, single-center study including 137 patients with cervical spine injury transferred to our institution from April 2007 to December 2016. Cervical spine injury was defined as cervical vertebral fracture, spinous process fracture, and/or transverse fracture. Evaluation for BVAI was available in 62 patients based on magnetic resonance angiography (MRA) or multi-detector computed tomography angiography (Fig. 1). We classified BVAI using the Biffl grade [9, 16]. At our center, we did not evaluate all patients for vascular lesions. Instead, we performed MRA or multi-detector computed tomography angiography for patients with a Glasgow coma scale (GCS) score < 14 or other severe traumatic injuries. The present study was approved by the Committee on Human Research at Saitama International Medical Center (18-033).

Data collection and diagnostic modalities

We collected patients' age, sex, total GCS score on admission, cause of injuries, Frankel grade, systolic blood pressure, blood examinations (CPK (U/l), AST (U/l), ALT (U/l), Hb (g/dl), D dimer (mg/dl)), result of whole body CT scan, MRA, BVAI Biffl grade (grade 1, irregularity of vessel wall or a dissection with < 25% luminal stenosis; grade 2, > 25% luminal narrowing or a raised intimal flap; grade 3, pseudoaneurysm; grade 4, complete occlusion; grade 5, transection of the artery with free extravasation of contrast or significant arteriovenous fistula) [9, 16], treatment for the cervical spine injury, and for BVAI. The result of CT included other organ injuries. In addition, we calculated the distance of cervical spine dislocation, which includes the dislocation of vertebral fracture, transverse fracture, and burst fracture, and we classified patients as having cervical spine dislocation if the dislocation was > 4 mm.

Treatment methods

Patients with cervical spine injuries were treated with anterior or posterior cervical fixation, laminoplasty, or halo vest application. We surgically repositioned interlocked facets. Patients diagnosed with BVAI were carefully observed with repeated CT and MRI; if they developed cerebral infarction due to BVAI, we prescribed clopidogrel 75 mg/day. Patients diagnosed with other organ injuries requiring treatment were managed accordingly.

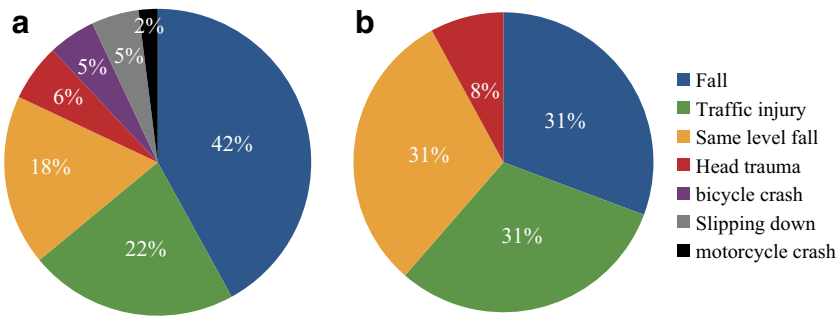

Fig. 2 The mechanism of injuries among all patients (**a**) and BVAI patients (**b**)

Table 1 Grade and location of blunt cerebrovascular injury lesions

Vessel	Grade 1	Grade 2	Grade 3	Grade 4	Grade 5	Total (%)
Rt VAI	0	3	0	3	0	6 (43)
Lt VAI	0	4	0	4	0	8 (57)
Total (%)	0	7 (50)	0	7 (50)	0	14 (100)

Statistical analysis

Quantitative variables are expressed as the mean ± standard deviation or median plus range, as appropriate. Univariate logistic regression and the chi-squared test or Fisher's exact test were performed to evaluate covariates for binary categorical dependent variables, as appropriate. Normality of the data was evaluated with the Shapiro-Wilk test. Non-normal variables were compared using the Mann-Whitney *U* test. Multivariable logistic regression analysis was performed to evaluate significant risk factors for BVAI. Only variables with $p < 0.10$ in the univariate analysis were included in the multivariable logistic regression model-building process; $p < 0.05$ were considered statistically significant. Odds ratios (ORs) are presented with 95% confidence intervals (CIs). The commercially available software SPSS (version 23; IBM Corp, Armonk, New York, USA) was used for all statistical analyses.

Results

Among the 62 patients evaluated with MRA and/or multidetector computed tomography angiography, the most common mechanism of injury was fall (42%). Other causes included traffic injury, same-level fall, head trauma, bicycle crash, sliding down, and motorcycle crash (Fig. 2a). Fourteen BVAI lesions were identified in 13 patients (21%), including 1 patient who developed BVAI in both his vertebral arteries. BVAI lesions were classified as Biffl grade 2 and 4 in 7 cases each (50% each) (Table 1). Only 3 patients diagnosed with BVAI exhibited abnormal CT findings: 2 of whom had

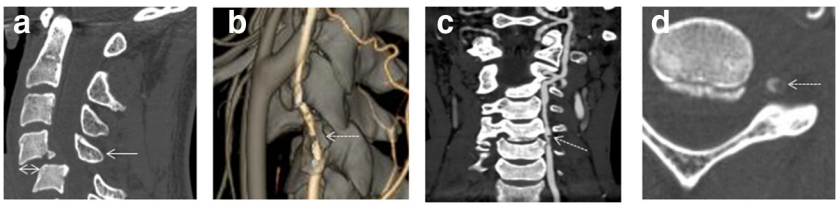

Fig. 3 A 31-year-old man with trauma due to a fall. **a** A C4 anterior dislocation fracture (white arrow). The distance of C4/5 was 8.3 mm (white two arrows). Sagittal (**b**), coronal (**c**), and axial (**d**) computed tomography showed that the left vertebral artery was partially occluded (Biffl grade 2; white-dotted arrow)

Table 2 Characteristics of 62 patients received CTA or MRA

Variable	Patients with BVAI, $n = 13$	Patients with non-BVAI, $n = 49$	*p* value
Age in years	63.1 ± 17.8	58.6 ± 18.3	0.441
Male sex	11 (84.6)	42 (85.7)	0.610
Total GCS < 15	4 (30.8)	15 (30.6)	0.619
High-energy trauma	2 (15.4)	9 (18.4)	0.583
Frankel grade C or D	8 (61.5)	30 (61.2)	0.622
Systolic BP	151 ± 50	143 ± 30.1	0.302
Blood examination			
CPK	626 ± 553	517 ± 620	0.375
AST	37.4 ± 14.5	48.8 ± 49.1	0.952
ALT	28.7 ± 11.7	31.8 ± 34.4	0.610
Hb	12.2 ± 2.3	13.7 ± 1.91	0.041
Cerebral infarction	2 (15.4)	1 (2)	0.109
Intracranial hemorrhage	3 (23.1)	12 (24.5)	0.615
Other organ injury	0 (0)	7 (14.3)	0.175
Cervical spine injury			
Dislocation	8 (61.5)	14 (28.6)	0.032
Transversarium	4 (30.8)	10 (20.4)	0.325
Burst	4 (30.8)	1 (2)	0.790

Table 3 Multivariate logistic regression model for risk factors of BVAI

Variable	OR	95% CI	*p* value
Hb	0.741	0.522–1.05	0.095
Dislocation	1.19	1.01–1.40	0.036

traumatic subarachnoid hemorrhage and 1 had acute epidural hematoma, traumatic intracerebral hemorrhage, and skull fracture. The remaining patients were suspected of having traumatic brain injury without abnormal radiographical findings. The most common mechanisms of injury in BVAI patients were falls, traffic injuries, and same-level falls, all of which occurred in equal proportions (Fig. 2b). A representative case is shown in Fig. 3. Only one patient (7.7%) was diagnosed with infarction due to BVAI; he was diagnosed with left BVAI (Biffl grade 4) and developed left occipital infarction.

Univariate analysis of patients with and without BVAI showed that cervical dislocation and low average Hb level were associated with BVAI (Table 2). In multivariate logistic regression analysis, cervical dislocation (OR 1.189; 95% CI 1.011–1.399, $p = 0.036$) remained a significant predictor for BVAI (Table 3). Based on receiver operating characteristic (ROC) analysis, a distance of dislocation greater than 6.7 mm was selected as the optimal cut-off values for predicting BVAI. The sensitivity and specificity were 87.5% and 71.4%, respectively (Fig. 4).

Discussion

Some studies on the risk factors for blunt cerebrovascular injury have been conducted, but none developed criteria focused on BVAI. Therefore, we focused on determining risk factors for BVAI other than those mentioned in the Denver screening criteria. Our data support the notion that cervical spine dislocation is a risk factor for BVAI, and ROC analysis revealed that a dislocation distance > 6.7 mm was identified as a significant risk factor for BVAI. Notably, a same-level fall accounted for 31% of our patients with BVAI, suggesting that high-energy trauma is not always a risk factor for BVAI.

BVAI correlates closely with cervical spine injury, because the vertebral arteries run through the transverse foramen of the cervical vertebrae. Regarding the type of cervical spine injury, transverse foramen injury, subluxation, and fractures involving the upper cervical spine were reportedly associated with BVAI [5, 6]. Moreover, other studies reported that the transverse process fracture pattern was associated with BVAI. Additionally, displacement into the foramen > 1 mm and the presence of gross fracture (> 2 mm displacement) were risk factors for BVAI [11]. In our study, cervical spine fractures occurred at C4/5 (38%) and C5/6 (38%), and the location of fractures was similar to that shown in previously published studies [11]. The type of fracture did not correlate with BVAI, but dislocation of cervical spine fractures did. Other characteristics were not associated with BVAI.

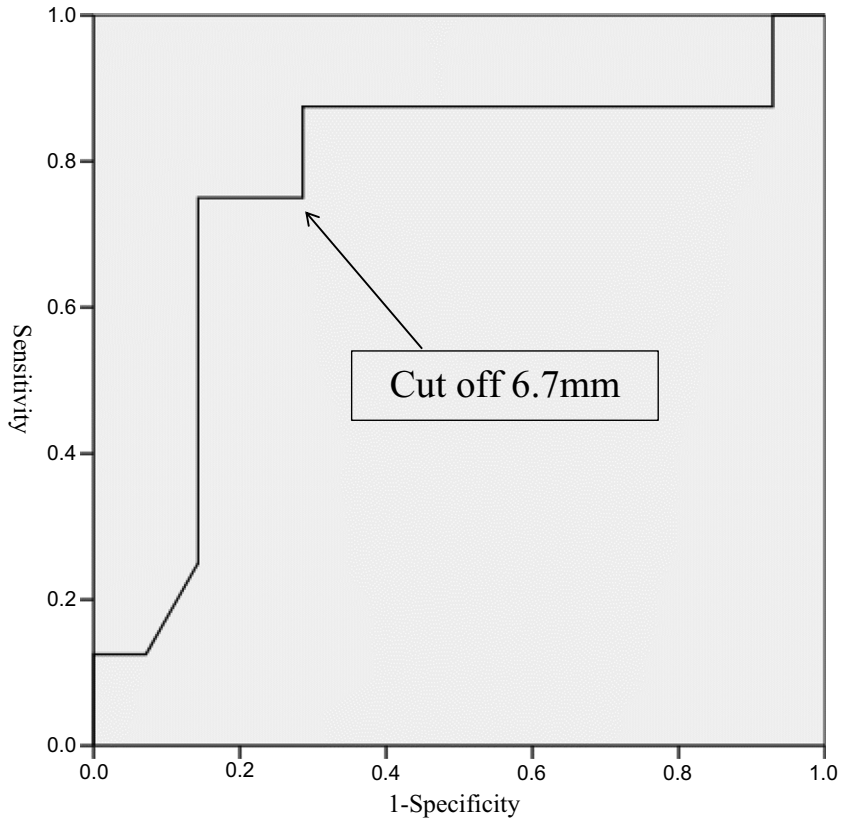

Fig. 4 ROC curve analysis

Other studies reported 20.2% of BVAI patients developed cerebral infarction—38% with grade 2 and 28% with grade 4, which were different from our results [3, 7, 15]. Additional information concerning patients with BVAI is needed to clarify the frequency of stroke rate associated with BVAI. Regarding management, several options including observation, antithrombotic therapy (anticoagulation and antiplatelet medication), endovascular therapy, and open surgery are suggested, but there is no consensus concerning treatment [7].

Some patients without cervical spine dislocation (> 4 mm) were diagnosed with BVAI in this study. Moreover, we performed vascular evaluation in only 62/137 patients with cervical spine injury, and thus may have missed some patients with BVAI. The cutoff point (> 6.7 mm) for dislocation of the cervical spine fracture could represent one of the clinical evaluation criteria, but clinicians must consider the possibility of vascular injury in all patients with cervical spine injury.

Conclusions

BVAI was frequently associated with cervical spine dislocation, and the distance of cervical dislocation was identified as a useful predictor of BVAI. We did not perform vascular evaluation of all patients who were transferred to our hospital for cervical spine injury, and thus some patients were likely missed. In addition to the Denver criteria, our findings suggest that MRA or computed tomography angiography should be performed in patients with cervical spine dislocation, especially when the dislocation is > 6.7 mm.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. For this type of study formal, consent is not required.

Informed consent Informed consent was waived due to the retrospective nature of the study.

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