Blunt vertebral artery injury in occipital condyle fractures

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OBJECTIVE A shifting emphasis on efficient utilization of hospital resources has been seen in recent years. However, reduced screening for blunt vertebral artery injury (BVAI) may result in missed diagnoses if risk factors are not fully understood. The authors examined the records of blunt trauma patients with fractures near the craniocervical junction who underwent CTA at a single institution to better understand the risk of BVAI imposed by occipital condyle fractures (OCFs).

METHODS The authors began with a query of their prospectively collected trauma registry to identify patients who had been screened for BVAI using ICD-9-CM diagnostic codes. Grade and segment were recorded in instances of BVAI. Locations of fractures were classified into 3 groups: 1) OCFs, 2) C1 (atlas) fractures, and 3) fractures of the C2–6 vertebrae. Univariate and multivariate analyses were performed to identify any fracture types associated with BVAI.

RESULTS During a 6-year period, 719 patients underwent head and neck CTA following blunt trauma. Of these patients, 147 (20%) had OCF. BVAI occurred in 2 of 43 patients with type I OCF, 1 of 42 with type II OCF, and in 9 of 62 with type III OCF ($p = 0.12$). Type III OCF was an independent risk factor for BVAI in multivariate modeling (OR 2.29 [95% CI 1.04–5.04]), as were fractures of C1–6 (OR 5.51 [95% CI 2.57–11.83]). Injury to the V₄ segment was associated with type III OCF ($p < 0.01$).

CONCLUSIONS In this study, the authors found an association between type III OCF and BVAI. While further study may be necessary to elucidate the mechanism of injury in these cases, this association suggests that thorough cerebrovascular evaluation is warranted in patients with type III OCF.

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KEYWORDS blunt trauma; vertebral artery; cerebrovascular; injury; occipital condyle; cervical spine

BLUNT vertebral artery injuries (BVAIs) are rare in trauma patients but are potentially devastating when untreated. Documented injury rates suggest that BVAI occurs in less than 1% of all blunt trauma admissions.^{24,29} However, undiagnosed BVAI carries a poor prognosis;⁵ even with treatment, patients face high mortality rates⁵ and often have profound deficits.^{16,25} Our institution has routinely performed CTA of the head and neck in all patients with cervical spine and basilar skull fractures, respectively, as outlined by the modified Denver Screening Criteria for blunt cerebrovascular injury (BCVI).¹⁸

However, given the relatively low incidence of these injuries, modifications to screening criteria have been suggested to eliminate unnecessary imaging.^{4,6,9,18,27} To reduce unnecessary imaging, emphasis is placed on understand-

ing the risk factors associated with BVAI.^{26,31} There is currently a paucity of literature describing the relationship of occipital condyle fracture (OCF) and BVAI. At our institution, experience has led us to suspect such an association.

Considering the relationship between OCFs and BVAI may serve to optimize emergency management decisions. To this end, we examined the records of blunt trauma patients with fractures near the craniocervical junction who underwent CTA at our institution.

Methods

We identified all patients who underwent CTA for suspected BCVI at a single, Level I trauma center during a 6-year period (July 2009 to July 2015). Approval for this study was obtained from the institutional review board.

ABBREVIATIONS BCVI = blunt cerebrovascular injury; BVAI = blunt vertebral artery injury; OCF = occipital condyle fracture.

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Collected Data

We began with a query of the prospectively collected data in the trauma registry at our hospital to identify patients who had been screened for BVAI using ICD-9-CM diagnostic codes (801.00–801.99, 805.00–805.08, 805.10–805.18, 806.00–806.09, 806.10–806.19). We reviewed all relevant medical records. Prospectively collected data included sex, age, mechanism of injury, fracture grading, and hospital course. To be included, patients had to have a history and injury consistent with blunt trauma. Patients were excluded if their injury resulted from penetrating trauma such as a knife or missile wound.

All patients meeting the modified Denver Screening Criteria¹⁸ underwent screening with CTA. All diagnoses were made by an attending neuroradiologist, with the primary outcome being BVAI. All BVAIs were graded according to the scale proposed by Biffl et al.,⁷ wherein a grade I injury is characterized by intimal irregularity or dissection/hematoma with < 25% luminal stenosis, grade II injury is vessel dissection or thrombus with ≥ 25% luminal stenosis, grade III injury indicates the presence of a pseudoaneurysm, grade IV is vessel occlusion, and grade V is complete vessel transection. An instance of BVAI was included in our final analysis only if it occurred above the level of V₂. Any vertebral artery injury below V₂ was felt unlikely to be directly related to OCF and thus was not included in OCF comparisons.

OCFs were recorded as type I, II, or III according to the Anderson and Montesano classification.³ An illustration of the OCF variants based on this classification scheme is shown in Fig. 1. Fractures of the cervical spine were recorded for the purpose of statistical regression, given the known association between fractures of cervical vertebrae and BVAI.¹³ Any cervical spine fractures, excluding spinous process fractures, were also noted. Fractures of the C7 vertebra were not included, as the vertebral artery does not pass through C7 in 95% of patients.¹⁷

Statistical Analysis

Categorical variables are reported as frequencies and percentages, and continuous variables are reported as means with standard deviation. Univariate analysis was performed to identify associations between BVAI and clinical and radiographic risk factors. Comparisons were made using the chi-square test (alternatively, the Fisher exact test when more than 80% of the values were less than 5) for categorical variables and the unpaired t-test for continuous variables.

Multivariate analysis was performed with logistic regression and initially included all variables that had p values of < 0.20 on univariate analysis. A variable was excluded from the model if its removal resulted in no significant difference in interpretation of other variables. Calibration was checked using the Hosmer-Lemeshow goodness-of-fit test. The final multivariate analysis results are presented as odds ratios with 95% confidence intervals.

A p value ≤ 0.05 was considered statistically significant. Data analysis was conducted using IBM SPSS (version 22, IBM Corp.).

FIG. 1. Illustration of the 3 types of OCFs based on the Anderson and Montesano classification scheme. **A:** A type I comminuted fracture of the occipital condyle. **B:** A type II skull base fracture extending into the condyle. **C:** A type III avulsion fracture of the occipital condyle in the region of the alar ligament. Copyright Jonathan P. Young. Published with permission. Figure is available in color online only.

Results

Patient Population

During the 6-year period, 719 patients (mean age 41.8 years) underwent head and neck CTA after blunt trauma. Of these patients, 147 (20%) had OCF. The most common causes of fracture were motor vehicle collisions (55%)

and motorcycle collisions (16%). Most patients were male (69%). Sixty-one (8%) patients had BVAI diagnosed by CTA, with grades II and IV being the most common types of injury (39% and 41%, respectively). Fractures of C1–6 vertebrae were present in 465 (65%) patients. The mean length of hospital stay for patients who suffered BVAI was 20 ± 31 days, and the mean length of stay for patients without BVAI was 14 ± 16 days ($p = 0.01$). Complete patient demographics are given in Table 1.

Variables Associated With BVAI

BVAI occurring with OCF is given by vertebral artery segment and fracture type in Table 2. BVAI occurred in 2 of 43 (5%) patients with type I OCF, 1 of 42 (2%) with type II OCF, and in 9 of 62 (14%) patients with type III OCF. Nine of 12 (75%) injuries occurred with type III OCF, and 3 of 12 (25%) injuries occurred with types I and II. Five of 9 (56%) injuries occurred in the V_4 segment ($p < 0.01$). Figure 2 illustrates the 4 segments of the vertebral artery as it traverses the cervical spine. A case example of a type III OCF fracture with V_4 segment injury is shown in Fig. 3.

Univariate analysis of factors associated with BVAI is shown in Table 3. BVAI occurred in 9 of 62 (14%) patients with OCF fractures ($p = 0.08$). BVAI occurred in 52 of 465 (11%) fractures of C1–6 vertebrae ($p < 0.01$). Patients with BVAI had a mean age of 44.8 ± 19.5 ($p = 0.20$). The mechanism of injury did not appear related to the occurrence of BVAI ($p = 0.96$).

The final variables included in the multivariate model were type III OCFs and fractures of C1–6 vertebrae. Type III OCF was an independent risk factor for BVAI (OR 2.29 [95% CI 1.04–5.04], $p = 0.04$). Fractures of C1–6 were also an independent risk factor for BVAI (OR 5.51 [95% CI 2.57–11.83], $p < 0.01$). This is shown in Table 4.

Discussion

Screening for BVAI remains a challenge in the emergency management of trauma patients. Due to the poor prognosis of untreated BVAI, early diagnosis is critical. The cost and contrast burden that CTA places on patients requires careful consideration of fracture patterns that put patients at risk for BVAI. We reviewed the records of 719 patients from a prospectively collected trauma database, which allowed for reliable identification of all patients who underwent CTA of the neck after blunt traumatic injury to identify clinical and radiographic risk factors for cerebrovascular injury. Specifically, we examined the relationship between BVAI and fractures of the occipital condyle. Our multivariate model demonstrates an increased risk for BVAI in patients with type III OCFs, while accounting for the increased risk imposed by other fractures of the cervical spine. Type III OCF may serve to inform the nature of the trauma and the concurrent risk of BVAI, and in some cases, may also suggest a direct mechanism of injury.

Occipital Condyle Fracture

Our analysis suggests that the majority of BVAs associated with OCF tend to occur with high-grade injury, which in our cohort occurred most commonly in high-velocity injuries.

TABLE 1. Patient characteristics

Characteristic	Value
No. of pts	719
Male	497 (69)
Female	222 (31)
Age, yrs	
Mean	41.8 ± 18.7
Range	3–91
Fracture type	
OCF	147 (20)
C1–6	465 (65)
Mechanism of injury	
MVC	395 (55)
MVCP/assault	64 (9)
MCC/ATV	118 (16)
Other	30 (4)
Fall	112 (16)
No. of pts w/ BVAI	61 (8)
Biffl grade of BVAI	
I	8 (13)
II	24 (39)
III	4 (7)
IV	25 (41)
V	0 (0)
Mean no. of hospital days*	
w/ BVAI	20 ± 31
w/o BVAI	14 ± 16

ATV = all-terrain vehicle; MCC = motorcycle collision; MVC = motor vehicle collision; MVCP = motor vehicle collision with pedestrian; pts = patients. Values are presented as the number of patients (%) unless stated otherwise. Mean values are presented as the mean $\pm$ SD.

* $p = 0.01$.

locity injuries. Past studies of OCF have cited incidences of 4.4% to 16.4% in cases of blunt trauma.^{8,21} One previous study by Reddy and colleagues linked craniocervical junction trauma with reduced flow velocities at V_3 and highlighted subtle changes in flow dynamics within this region of the vertebral artery.²⁸ Given the anatomical position of the occipital condyle anterior to the course of the vertebral artery as it enters the skull,¹ it follows that increased translational force to the condyle increases the risk of vertebral artery injury as indicated by our data. However, it seems unlikely that an OCF in isolation is likely to cause direct trauma to the vertebral artery without significant fracture or dislocation.

TABLE 2. Vertebral artery segment injured by fracture type

OCF Type	Vertebral Segment*			p Value†
	V_2	V_3	V_4	
I	1	1	0	
II	0	1	0	
III	3	1	5	<0.01

* Values represent the number of vertebral segments.

† Fisher exact test.

FIG. 2. Illustration of the segments of the vertebral artery. The V₁ segment extends from its origin to the C6 transverse foramen. V₂ extends from the transverse foramen of C6 to the transverse foramen of C2. V₃ extends from C2 to the dura. V₄ extends from the dura to the confluence of the vertebral and basilar arteries. Copyright Jonathan P. Young. Published with permission. Figure is available in color online only.

Screening Considerations

While these data suggest that high-grade OCFs may warrant further evaluation for BVAI, available imaging modalities have inherent limitations. CTA has gained wide acceptance in trauma settings given its speed and excellent diagnostic accuracy. Conventional angiography remains the gold standard for diagnosis.¹¹ However, patient selection for conventional angiography is dependent on the clinical scenario and is usually reserved for patients likely to require intravascular intervention. CTA has been

TABLE 3. Univariate analysis of factors associated with BVAI

Characteristic	No. of Pts w/ BVAI	p Value
Sex		0.41
Male	45/497 (9)	
Female	16/222 (7)	
Mean age, yrs	44.8 ± 19.5	0.20
Type III OCF	9/62 (14)	0.08
Fractures of C1–6 vertebrae	52/465 (11)	<0.01
Mechanism of injury		0.96
MVC	35/395 (9)	
MVCP/assault	4/64 (6)	
MCC/ATV	10/118 (8)	
Other	2/30 (7)	
Fall	10/112 (9)	

Values are presented as the number of patients (%) unless stated otherwise. Mean values are presented as the mean ± SD.

validated with high specificity and sensitivity in patients meeting the Denver Screening Criteria.⁷ MRA has been described in screening for vertebral artery injuries, but it appears to be less sensitive than conventional angiography (sensitivity = 0.2)²⁰ and is limited by resolution.⁷ Other authors have proposed the addition of flow-based imaging, relying on Doppler mechanics to increase the sensitivity of screening.⁷

The most definitive screening guidelines to date¹⁸ were adapted from the Denver Screening Criteria.⁷ Among the recommended criteria for CTA following blunt trauma are cervical or basilar skull fractures, infarct or cervical hematoma, and focal neurological deficits not explained by head CT imaging.⁷ Others have additionally noted a strong association between combined C1–2 fractures and BVAI;⁷ however, we did not find an association between fractures of the atlas independently with BVAI. Previously, authors showed that hyperextension and subluxation injuries increase the risk of BVAI.⁷

Typical treatment paradigms rely on the degree of injury and take into account the cervical injury and patient characteristics. For example, in most cases the presence of

FIG. 3. Sagittal (A) and axial (B and C) CT angiograms obtained in a representative case of a type III OCF (*) with a grade IV BVAI. The vertebral artery occlusion extends from C3 to the occiput, encompassing the V₂ and V₃ segments of the artery. This was the case of a 40-year-old woman in a motor vehicle collision.

TABLE 4. Multivariate model of risk for BVAI in patients with fracture

Fracture Type	OR (95% CI)	p Value
Type III OCF	2.29 (1.04–5.04)	0.04
C1–6	5.51 (2.57–11.83)	<0.01

Homer-Lemeshow goodness-of-fit test $p = 0.02$.

vertebral artery injury with juxtaposed cervical fracture is reevaluated with imaging after reduction of the fracture before additional treatment measures are considered. Adjunct treatment usually involves anticoagulation therapy,^{12,15,23,30} and sometimes stenting with or without coiling, especially in cases of pseudoaneurysm.^{2,10} At our institution, we administer anticoagulant or antiplatelet medication in the early postoperative period (12–24 hours). While no standard of care has been established, the CADISS (Cervical Artery Dissection in Stroke Study) trial showed the benefit of medical therapy for cervical artery dissection within 7 days.²² Given the importance of stroke prevention,¹⁴ emphasis of any treatment plan relies on early detection of arterial injury, especially before operating, to protect the contralateral artery during surgery and to inform cautious manipulation of fractured bony structures ipsilateral to the lesion.

Limitations

Some authors have argued that reliance on clinical and radiological risk factors without angiographic studies is not adequately sensitive screening.^{14,19} Indeed, any attempts to reduce CTA utilization could increase the risk of BVAI going undetected until a complete understanding of the associated risks is achieved, and estimating the true cost reduction of alterations to current screening guidelines could prove difficult to achieve. Some authors have estimated the costs associated with CTA studies in BCVI,³² but costs associated with CTA at our own institution are beyond the scope of the present study. However, we would posit that type III OCF warrants a high clinical index of suspicion, even in the setting of continued efforts to reduce unnecessary resource utilization.

Although patients were uniformly screened with CTA based on criteria that encompassed all spine and occipital condyle fractures, this was not a randomized controlled trial. Given its retrospective nature and reliance on a trauma database, follow-up data were not available and outcomes are not presented. Additionally, the number of patients with isolated OCFs is relatively small due to the uncommon nature of the injury. Powering a larger study would likely require a longer study duration involving multiple institutions, which could fail to accurately capture incidence rates given variability in treatment and frequently changing screening techniques. The size of this study limits the strength of its conclusion but warrants further exploration of the relationship between OCF and BVAI.

Conclusions

Our data suggest that type III OCFs are correlated with BVAI. Specifically, the V₄ segment is often involved when

type III OCF is present. As screening for BVAI is continually refined, this relationship may justify further examination. High-grade OCF could warrant consideration of BVAI, as OCF informs a history of significant translational force required to place strain on the vertebral arteries.

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Disclosures

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author Contributions

Conception and design: Burks, Conner, Bohnstedt. Acquisition of data: Briggs, Bonney, Smitherman, Ghafil, Pryor, O'Connor. Analysis and interpretation of data: Burks, Conner, Glenn. Drafting the article: Burks, Smitherman, O'Connor. Critically revising the article: Briggs, Baker, Glenn. Reviewed submitted version of manuscript: Baker. Approved the final version of the manuscript on behalf of all authors: Briggs. Statistical analysis: Burks, Glenn, Pryor, Bohnstedt. Study supervision: Bohnstedt.

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