Vertebral artery injury in major trauma patients in Saudi Arabia: A retrospective cohort study

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Blunt vertebral artery injury (VAI) is associated with severe cervicocephalic trauma and may have devastating consequences. This study aimed to determine the incidence and nature of VAI in polytrauma patients. The secondary objective was to assess the association of VAI with previously suggested risk factors. It was a retrospective observational study of all polytrauma patients admitted to the trauma unit between April 2018 and July 2019, who had CT neck angiography to diagnose blunt VAI according to modified Denver criteria. Out of 1084 admitted polytrauma patients, 1025 (94.6%) sustained blunt trauma. Of these, 120 (11.7%) underwent screening CT neck angiography. VAI was detected in 10 (8.3%; 95% CI 4.1–14.8) patients. There were three patients with Grade I injury, two with Grade II, and five with Grade IV injury. Among all trauma admissions, the incidence of diagnosed VAI was 0.9% (95% CI 0.5–1.8). Among patients suspected of VAI, there was no univariable association of VAI with C-Spine fracture: OR 4.2 (95% CI 0.51–34.4; p = 0.18). There were two (20%) deaths related to VAI. Traumatic VAI was uncommonly detected in this major trauma service in Saudi Arabia. High suspicion and liberal screening by CT angiography in cases where VAI is possible should be considered to avoid missed injuries.

Abbreviations
BCVI  Blunt cerebrovascular injury
VAI  Vertebral artery injury
KSMC  King Saud Medical City
ED  Emergency Department
CT  Computed tomography
CTA  Computed tomography angiography
CI  Confidence interval
OR  Odds ratio
AUROC  Area under the receiver operating characteristic

Blunt cerebrovascular injury (BCVI) includes any form of non-penetrating damage to the internal carotid and vertebral arteries1. The understanding of BCVI has significantly improved over the past decade of trauma care due to advanced imaging modalities. BCVI includes two clinical entities: vertebral artery injury (VAI) and carotid artery injury. Blunt VAI is an uncommon entity, but important to diagnose with a view to preventing medium to longer-term stroke2. VAI presents a clinical challenge since it is difficult to detect, has a diverse presentation, and there are no widely accepted guidelines on diagnosis and management. VAI, although frequently asymptomatic, can have disastrous consequences related to basilar territory infarction and death.

A high index of suspicion for VAI, based on the mechanism of trauma and the nature of associated injuries, should be considered. Cervical spine fractures have been previously reported as being the only independent

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predictor of VAI. Other potential risk factors include high-energy mechanisms, facial fractures, the base of skull fractures, and diffuse axonal injury with GCS < 6. The reported incidence is highly variable in the literature (0.5–2% of all trauma patients). For those reasons, there have been several screening criteria set up for the detection of VAI, including the Denver, Memphis, and Boston criteria based on injury mechanism, injury pattern, and symptoms. The modified Denver criteria are the most widely used in practice. However, a balance between excess imaging and missed VAI has not been adequately validated in terms of diagnostic accuracy (sensitivity, specificity, positive predictive value, and negative predictive value) and cost-effectiveness. It has been suggested that early diagnosis and management (conservative versus interventional) may improve outcomes.

This study aimed to determine the incidence and nature of VAI in blunt polytrauma patients in a major trauma centre in Saudi Arabia. The secondary aim was to determine variables independently associated with VAI.

Methods

Setting. King Saud Medical City (KSMC) is a tertiary care centre in Riyadh with 1400 inpatient beds. In 2018, a total of 36,052 trauma patients presented to the emergency department (ED) of KSMC, of which 3552 patients were admitted. A dedicated trauma unit admits all polytrauma patients.

Design. This was an observational study based on the retrospective data of all polytrauma patients admitted under the trauma unit between 01 April 2018 and 31 July 2019, who had CT neck angiography to diagnose VAI according to the modified Denver criteria. All blunt polytrauma patients who present to our ED are investigated with whole-body CT as part of the trauma imaging protocol, which includes CT brain, face, cervical spine, chest, abdomen, and pelvis. If the whole-body CT report suggests BCVI according to modified Denver criteria, we investigate further with a neck CT angiogram. We searched the "Carestream Vue Motion" radiology image database used in our institution to identify all patients who underwent CT angiography neck after trauma during the study period. After the selection of these patients, an explicit chart review of medical records was conducted to extract the data.

Data. Extracted data included demographic details (gender, age), mechanism of injury, injuries of the head, face, & neck, and the CT angiography of neck findings. Furthermore, we extracted data on the modified Denver criteria, such as traumatic brain injury (TBI) with neurologic exam incongruous with head CT scan findings, the base of skull fractures involving the carotid canal, Le Fort fracture type 2 or 3, mandibular fracture, cervical spine fracture, and its pattern, and occipital condyle fracture. If the CT angiography of the neck detected VAI, the grading of injury, the segment of the vertebral artery involved, site of injury, associated vascular injuries, management, and complications, including disability and death, were also extracted.

Grades of VAI. Radiologically, the VAI is classified into five categories. The Grade I is a mild intimal injury or irregular intima with <25% luminal narrowing, Grade II is dissection with raised intimal flap/intramural hematoma with luminal narrowing >25%/intraluminal thrombosis, Grade III is pseudoaneurysm, Grade IV is vessel occlusion/thrombosis, and Grade V is complete transection of the vessel.

Segments of Vertebral arteries. The vertebral artery is typically divided into four segments: V1 (pre-foraminal) is from the origin to the transverse foramen of C6, V2 (foraminal) is from the transverse foramen of C6 to the transverse foramen of C2, V3 (atlantic, extradural or extraspinal) is from C2 to the dura, and V4 (intradural or intracranial) is from the dura to their confluence to form the basilar artery.

Treatment and follow up of VAI. The treatment and follow up protocol is described in Fig. 1.

Analysis. Categorical variables were presented using frequency tables and differences assessed using Fisher’s exact test or the chi-square test. Numerical variables were summarised using mean and standard deviation for continuous variables, and for ordinal variables or variables with skewed distribution, median & interquartile range were used. Differences between means were reported using Student’s t-test, and the difference between medians reported using the Wilcoxon Rank Sum test. Variables exhibiting some association on univariable analysis (p < 0.10) were further assessed using multivariable logistic regression analysis. The performance of the model was assessed using the area under the receiver operator curve. Hosmer–Lemeshow goodness of fit as reported and variance inflation factors were used to assess for multi-collinearity. The independent association of variables with VAI was reported using adjusted OR and 95% confidence intervals. A p value of <0.05 was considered statistically significant. All the analyses were conducted using Stata v 15.1 (College Station, Texas, USA).

The study was approved by the Institutional Review Board (IRB) of the KSMC with a reference number of H1R1-08-Apr19-04.

Results

A total of 1084 polytrauma patients were admitted during the study period, of which 59 (5.4%) patients were penetrating trauma. Out of 1025 (94.6%) blunt trauma patients, 120 (11.7%) underwent screening CT neck angiography (Fig. 2).

Demographics were mainly young males with a mean age of 33.8 (SD 13.0) years. The age distribution is presented in Fig. 3.

There were 84 (70%) patients with C-Spine fractures. Among the other indications for CTA neck, according to modified Denver criteria, were traumatic brain injury (TBI) with neurologic exam incongruous with head CT
scan findings (n = 46), the base of skull fractures (n = 8), facial fractures (n = 49). Of these, 18, 2, and 19 patients did not have C-Spine fractures, respectively. A comparison of variables, sub-grouped by the diagnosis of C-Spine fractures is presented in Table 1.

There were 10 (8.3%; 95% CI 4.1–14.8) patients with VAI. Among all trauma presentations, the incidence of VAI was 0.9% (95% CI 0.5–1.8). There was no univariable association of VAI with C-Spine fracture: OR 4.2 (95% CI 0.51–34.4; p = 0.18). When adjusted for potential confounders, VAI was not independently associated with any of the potential predictive variables (Table 2), and in particular, when adjusted for other variables, the presence of a C-Spine fracture was not significantly associated with VAI (OR 3.32 (95% CI 0.30–6.2).

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**Figure 1.** Treatment and follow up of VAI.

**Figure 2.** Selection of patients.
Figure 3. Demographics age distribution.

| Variable                  | C-Spine fracture (n=84) | No C-Spine fracture (n=36) | p value |
|---------------------------|-------------------------|----------------------------|---------|
| Age (mean years, SD)      | 31.7 (12.2)             | 34.8 (13.3)                | 0.24    |
| Male sex (%)              | 74 (88.1%)              | 31 (86.1%)                 | 0.76    |
| Mechanism                 |                         |                            | 0.27    |
| Motor Vehicle Collision (%)| 73 (86.9%)              | 28 (77.8%)                 |         |
| Falls (%)                 | 10 (11.9%)              | 7 (19.4%)                  |         |
| Assault (%)               | 1 (1.2%)                | 1 (2.8%)                   |         |
| Respiratory rate (mean breath/min, SD) | 19.7 (2.6)          | 20.3 (19.4)                | 0.23    |
| Pulse rate (mean beat/min, SD) | 88.2 (19.3)           | 99.4 (21.9)                | 0.006   |
| Systolic Blood Pressure (mean mm Hg, SD) | 122.8 (20.0)          | 121.8 (22.6)               | 0.80    |
| Glasgow Coma Scale        |                         |                            | 0.27    |
| 3–8 (%)                   | 1 (1.2%)                | 1 (2.8%)                   |         |
| 9–12 (%)                  | 10 (11.9%)              | 7 (19.4%)                  |         |
| 13–15 (%)                 | 73 (86.9%)              | 28 (77.8%)                 |         |
| International Normalized Ratio (mean, SD) | 1.1 (0.15)           | 1.1 (0.16)                 | 0.88    |
| Injury Severity Score     |                         |                            | 0.88    |
| 0–15 (%)                  | 32 (38.1%)              | 12 (33.3%)                 |         |
| 16–25 (%)                 | 32 (38.1%)              | 15 (41.7%)                 |         |
| >25 (%)                   | 20 (23.8%)              | 9 (25%)                    |         |
| Intubated (%)             | 39 (46.4%)              | 27 (75%)                   | 0.004   |
| Blood transfusion (%)     | 20 (23.8%)              | 16 (44.4%)                 | 0.024   |
| Traumatic Brain Injury (%)| 28 (33.3%)              | 18 (50%)                   | 0.08    |
| Base of Skull fracture (%)| 6 (7.1%)                | 2 (5.6%)                   | 0.009   |
| Facial fracture (%)       | 30 (35.7%)              | 19 (52.8%)                 | <0.001  |

Table 1. Comparison of patients with suspected VAI with or without C-Spine fractures.

| Variable     | Adjusted OR (95% CI) | p value |
|--------------|----------------------|---------|
| C-Spine fracture | 3.32 (0.30–6.2)     | 0.32    |
| Pulse rate    | 0.99 (0.96–1.03)     | 0.91    |
| Intubation    | 1.05 (0.26–4.15)     | 0.94    |
| Blood transfusion | 2.22 (0.55–9.0)  | 0.26    |
| Facial fracture | 0.48 (0.08–3.0)    | 0.43    |

Table 2. Results of the multivariable logistic regression model.
The area under the receiver operating characteristic (AUROC) for the model was 0.65 (95% CI 0.50–0.81) (Fig. 4). The p value for Hosmer–Lemeshow Goodness of fit was 0.76. Variance inflation factors for all variables were less than 1.6, with a mean VIF of 1.27.

There were three patients with Grade I injury, two with Grade II, and five patients with Grade IV injury. The nature (Table 3), outcome, and follow up at three months (Table 4) of the VAI are described below.

There were only two (20%) deaths related to VAI.

The first patient was a 27-year-old female unrestrained front seat passenger involved in high-speed motor vehicle collision sustained severe head, face, neck, and chest trauma. On presentation, she was hemodynamically stable, GCS 3 (intubated, and ventilated), and her ISS was 22. CT angiography neck and brain showed bilateral internal carotid arteries were tapered and blocked entirely in the proximal extracranial portion about 1.8 cm after the origin. Bilateral vertebral arteries were also not showing any distal flow above the C1 level. There was diffuse brain edema with the multiple hypodense areas in the brain with the obliteration of the sulci. She was admitted to ICU and died after five days.

The second patient was a 39-year-old male restrained driver involved in high-speed motor vehicle collision sustained head, neck, and severe chest injuries. On presentation, the patient was hypotensive, GCS 3 (intubated, and ventilated), and his ISS was 29. He responded to fluid resuscitation, and bilateral intercostal drains were inserted for hemo-pneumothoraces. His CT neck and chest angiography demonstrated bilateral subclavian and vertebral arteries injury. There was also right posterior superior mediastinal hematoma with no visible underlying active contrast extravasation. CT brain confirmed bilateral cerebellar and pontomedullary areas of low attenuation, most likely acute ischemic insult. Considering his poor prognosis, the patient was palliated and died after 13 days of ICU stay.

**Table 3. Nature of the VAI.**

| Sl. No | Grade of injury | Segment involved | Side of VAI injury | Nature of C-spine fractures | Associated vascular injuries |
|-------|----------------|------------------|-------------------|-----------------------------|-----------------------------|
| 1     | IV             | V3               | Left              | C1 left lateral mass fracture | No                          |
| 2     | IV             | V3               | Bilateral         | C2 right transverse process fracture | Bilateral internal carotid arteries |
| 3     | I              | V3               | Right             | C1 right lateral mass fracture | No                          |
| 4     | I              | V3               | Left              | C0 left occipital condyle fracture | No                          |
| 5     | II             | V2               | Right             | C2 right pedicle and transverse process fracture | No                          |
| 6     | IV             | V1, V2           | Right             | C5 right transverse foramen with facet dislocation | No                          |
| 7     | II             | V2               | Left              | C2, C3, C4 left transverse process fractures | No                          |
| 8     | I              | V1               | Right             | C6-C7 fracture-dislocation | No                          |
| 9     | IV             | V1, V2, V3       | Bilateral         | C6, C7 left transverse process fractures | Bilateral Subclavian arteries |
| 10    | IV             | V1, V2, V3       | Right             | C6 right foramen transverse-sarrium fracture | No                          |

**Figure 4.** Area under the receiver operating characteristic (AUROC) curve.
shown that satisfactorily results in many studies with the advantage of avoiding contrast. Still, the major disad-
outcomes would be invaluable to assess such uncommon but clinically significant injuries. The investigations
should be the focus of future studies. A national trauma registry with systematic data collection of data on patient
reported on the hospital outcome of death, functional status, and longer-term functional outcomes of survivors
OR 3.32), but our confidence in this point estimate was limited due to the small number of cases. While we
and may suffer from Type II error. There was a signal that c-spine fractures were associated with V AI (odds ratio,
country. With only 10 cases of V AI, our attempts to develop a model to predict V AI was grossly underpowered
fixed. However, it includes consecutive patients during the time period from the most active trauma centre in the
vantage is a lack of timely availability at many institutions and the incompatibility of ventilatory and orthopaedic
expensive, thus computerized tomographic angiography (CTA) has become the most common screening method
posterior circulation events.
contra-indicated due to concomitant injuries, the advantages of screening for BCVI at the time of presentation
in 9 of the 10 cases of V AI suggests a clinically significant finding and a high degree of suspicion to image the
vertebral artery in such patients. The only patient who did not have a cervical vertebra fracture had a C0 left
occipital condyle fracture. While this is strictly not part of the cervical vertebrae, it is clinically prudent to con-
terior the two occipital condyles and the first cervical vertebra as one functional unit. As such, although statistical
significance could not be demonstrated due to the small numbers, there were signals of association of V AI with
sub-types of cervical vertebral fractures.
Blunt trauma to the cervical spine can cause injury to the vertebral artery, although no specific cervical
vertebral fracture pattern has been associated with V AI15. However, the initial presentation of unilateral V AI
is usually asymptomatic; only 12–20% of the patients present with ischemic signs and symptoms14. Fractures
involving the transverse foramen and subluxation are highly associated with V AI by 46–75% of cervical trauma15.
Bilateral injury to the cerebrovascular arteries occurs in 18–25% of patients with V AI. Only 9 case reports were
published regarding blunt trauma to three or four cerebrovascular arteries16. The mortality due to blunt carotid
injury is 13–38%, whereas the death due to V AI is about 8–18%17.
Stroke is the most feared complication of V AI and reported in 10–13% of patients. Therefore, early screen-
ing in patients with V AI may decrease the incidence of stroke18. Even in cases where antplatelet agents may be
contra-indicated due to concomitant injuries, the advantages of screening for BCVI at the time of presentation
aids planning for the treatment, close follow-up, and possible preventing delayed presentation with ischaemic
posterior circulation events.
Catheter angiography is the gold standard modality to diagnose V AI, but since it is time-consuming and
expensive, thus computerized tomographic angiography (CTA) has become the most common screening method
for V AI in acute trauma setting19. As described in the literature, the sensitivity of CTA neck to diagnose V AI
reaches up to 99%20, and it is considered as a modality of choice for diagnosis. Magnetic resonance imaging has
shown that satisfactorily results in many studies with the advantage of avoiding contrast. Still, the major disadv-
antage is a lack of timely availability at many institutions and the incompatibility of ventilatory and orthopaedic
fixation equipment with the magnet.
This study is limited in being a retrospective cohort, and only a small sample of patients with V AI were identi-
fied. However, it includes consecutive patients during the time period from the most active trauma centre in the
country. With only 10 cases of V AI, our attempts to develop a model to predict V AI was grossly underpowered
and may suffer from Type II error. There was a signal that c-spine fractures were associated with V AI (odds ratio,
OR 3.32), but our confidence in this point estimate was limited due to the small number of cases. While we
reported on the hospital outcome of death, functional status, and longer-term functional outcomes of survivors
should be the focus of future studies. A national trauma registry with systematic data collection of data on patient
outcomes would be invaluable to assess such uncommon but clinically significant injuries. The investigations
and association of variables to V AI will require ongoing surveillance using this registry.

| Sl. No | Grade of injury | Outcome | Follow up CTA neck |
|--------|-----------------|---------|-------------------|
| 1      | IV              | Discharged | No interval change |
| 2      | IV              | Death    | N/A               |
| 3      | I               | Discharged | Normal            |
| 4      | I               | Discharged | Normal            |
| 5      | II              | Discharged | No interval change |
| 6      | IV              | Discharged | No interval change |
| 7      | II              | Discharged | Interval improvement |
| 8      | I               | Discharged | Normal            |
| 9      | IV              | Death    | N/A               |
| 10     | IV              | Discharged | No interval change |

Table 4. Outcome, and follow up (at three months) of the VAI.
Conclusion
Traumatic VAI was found to be an uncommon entity in the largest major trauma service in Saudi Arabia. Deaths in the setting of diagnosed VAI were uncommon. The association with traditional risk-factors could not be proven. We, therefore, continue to recommend the utilization of local protocols for assessment of VAI and ongoing surveillance for missed injuries.

Use of experimental animals and human participants
The experiment protocol for involving human data was following the guidelines of national/international/institutional or Declaration of Helsinki in the manuscript. The study was approved by the Institutional Review Board (IRB) of the KSMC with a reference number of H1R1-08-Apr19-04. The IRB committee approved a waiver of the requirement to seek informed consent from the participants for a retrospective review of their data.

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Author contributions
S.C. conceived and designed the study. S.H.A. and K.H.B. participated in the data collection and conduct of the research. B.M. analyzed the data. M.F. independently reviewed the positive cases of VAI in the “Carestream Vue Motion”–the radiology platform and confirmed. S.C., S.H.A., K.H.B. prepared the manuscript. B.M. and M.F. did a critical review and necessary editing of the manuscript. All authors read and approved the final manuscript.

Competing interests
The authors declare no competing interests.

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