*Original Research Article*

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# Incidence of Traumatically Induced Vertebral Artery Occlusion Associated with Cervical Spine Injuries: Prospective Study Using Magnetic Resonance Angiography

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**Abstract**

*Background:* Although the vertebral artery injuries (VAI) associated with cervical spine trauma are usually clinicallyoccult, they may cause fatal ischemic damage to the brain stem and cerebellum. *Methods:* We performed a prospective study using magnetic resonance angiography (MRA) to determine the frequency of VAI associated with cervical spine injuries and investigate the clinical and radiological characteristics. Between August 2011 TO January 2017, 108 consecutive patients with cervical spine fractures and/or dislocations were prospectively evaluated for patency of the VA, using the MRA, at the time of injury. *Results:* Complete disruption of blood flow through the VA was demonstrated in twenty two patients with unilateral occlusion in 20 patients (18.3%). There were 20 men and 4 women with a mean age of 45 (range, 24 -50 years). Unilateral occlusion of the right and left vertebral artery occurred in 10 patients and of bilateralin 4. Regarding the cervical injury type, Distraction/extension, distraction/flexion, and lateral flexion injuries were the major mechanisms of injury. Dissection and occlusion were the frequent vascular injury patterns. Facet joint dislocations and the fractures extending into the transverse foramen were the spine injury patterns closely associated with VAI. All patients presented with good patency of the contralateral VA. None of the patients developed secondary neurological deterioration due to vertebrobasilar ischemia during the follow-up period with a mean duration of 60 months. *Conclusions:* VAI should be suspected in patients with cervical trauma that have cervical spine fractures and/or dislocations or transverse foramen fractures.

**Keywords:** Cervical Spine; Computed Tomographic Angiography; Injury; Vertebral Artery.

## Introduction

Vertebral artery injury (VAI) is considered as a rare entity. Blunt trauma screening has yielded an incidence of 0.24% to 2%. Up to 20% are found to have associated with VAI, when a targeted group of people who have had head injury or blunt trauma of cervical spine are being screened for VAI.

Vertebral Artery Injury is usually followed by posterior cerebral circulation stroke and death.[1]Most common cause of posterior cerebral circulation stroke in patients below the age of 45 years is traumatic dissection. Though TVAI is mostly asymptomatic it has profound consequences of basilar territory infarction and death. Blunt or penetrating trauma may lead to TVAI. Blunt TVAI tends to occur where vessels are exposed to shearing forces, principally at junctions between fixed and mobile segments [2]. Most of the VAI patients are asymptomatic if the VA is damaged unilaterally, thus VA injuries are mostly underdiagnosed or misdiagnosed [3]. At this time, there is no level 1 or 2 evidence available to guide the management of various grades of VAI [1]. To screen and diagnose VAI Magnetic Resonance Angiography imaging modality is being used. MRA and MRI can be done at the same time, which is frequently indicated for evaluation of patients with suspected SCI, with little additional time. Additionally, early-phase vertebra-basilar ischemia can be detected with a perfusion and diffusion MRI. Contrast injection is not required and allows imaging of other cervical and cerebral vasculature [3].

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A prospective study was also performed using MRA to investigate the incidence, path mechanism of vertebral artery injuries following blunt cervical spine trauma and the detailed clinical features, including long-term neurologic outcomes, restoration of blood flow in the occluded arteries, and collateral circulation to the vertebra-basilar territory in the brain.

*Aim of the Study*

To study the Incidence and Radiographic features of vertebral artery injury/occlusion associated with Non-penetrating cervical spine trauma.

## Materials and Methods

Magnetic Resonance Angiogram Vertebral artery [7], Sample Size – 108 Cases, Study Type-Prospective Study, Imaging Tool- Radiant DiCOM Viewer.

1. For statistical analysis, the Pearson Correlation method is used.
2. The results were considered statistically significant if the $p$ value was $\leq 0.05$ (alpha value). All analyses were conducted using following Python v3.6 libraries. I. Statistics-scipy v0.18.1ii. Data wrangling-pandas v0.19.6, pandasql v0.7.3ii. Charting-matplotlib v2.0.

### *Inclusion and Exclusion Criteria*

*Inclusion Criteria*

1. Admission or transfer to our institute within 48 hours of injury;
2. Injury to the cervical spine with radiographically evident fractures and/or dislocations;
3. Spinal injury occurring between the levels of C2 vertebra and C6/7 spinal segment, which is consistent with the second segment of the vertebral arteries
4. All MRAs were performed on a 1.5-Tesla superconducting magnetic resonance imager (MAGNETOM, Siemens, and Erlangen, Germany) at admission.
5. The MRA technique consisted of a 2-dimensional time-of flight pulse sequence (repetition time 27 milliseconds, echo time 9 milliseconds, flip angle 20°, field-of-view 23 cm).
6. All patients in whom vertebral artery occlusion had been detected at initial MRA underwent follow-up MRA study 1–17 months after injury to investigate restoration of blood flow in the occluded vertebral artery.
7. Regarding neurologic examination, not only specific findings for spinal cord injury but those for vertebra basilar ischemia (*e.g.*, dizziness, vertigo, dysarthria, aphasia/dysphagia, visual field defect, blurry vision, drowsiness, and altered consciousness) were carefully evaluated and prospectively recorded in all patients.
8. Sub axial cervical Spine Injury types were classified according to Allen et al.
9. Neurologic status evaluated by the American Spinal Injury Association (ASIA) impairment scale (AIS).

*Patients with Concomitant Penetrating Trauma were Excluded*

Denver Grading Scale for BCVI [10]

- Grade I: Vessel wall irregularity or a dissection/ intramural hematoma with less than 25% luminal stenosis
- Grade II: Intraluminal thrombus or raised intimal flap is visualized, or dissection/intramural hematoma with 25% or more luminal narrowing.
- Grade III: Pseudoaneurysm
- Grade IV: Vessel occlusion
- Grade V: Vessel transaction

*Denver Screening Criteria [13]* General guidelines to determine which blunt cerebrovascular injury (BCVI) patients should be evaluated for arterial injury." Signs/symptoms of BCVI: Arterial hemorrhage, cervical bruit in patient less than 50 years of age, expanding cervical hematoma, focal neurologic deficit, neurologic exam incongruous with head CT scan findings, stroke on secondary CT scan. "Risk factors for BCVI: High-energy transfer mechanism with LeFort II or III fracture, cervical spine fracture pattern (subluxation, fracture extending into the transverse foramen, fractures of C1-C3), basilar skull fracture with carotid canal involvement, diffuse axonal injury with a Glasgow Coma Scale score less than 6, near hanging with anoxic brain injury.

*Outcome of Treatment [16]* Outcome of Treatment Measured by Modified Rankin Scale *(mRS)* the scale runs from 0-6, running from perfect health without symptoms to death. 0 - No symptoms. 1 - No significant disability. Able to carry out all usual activities, despite some symptoms." "2 - Slight disability. Able to look after own affairs without assistance, but unable to carry out all previous activities. 3 - Moderate disability. Requires some help, but able to walk unassisted. 4 - Moderately severe disability. Unable to attend to own bodily needs without assistance, and unable to walk unassisted. 5 - Severe disability. Requires constant nursing care and attention, bedridden, incontinent. 6 - Dead.

## Result

*Vertebral Artery Injury and Sex*

Vertebral Artery Injuries Usually Occurs in Male patients. Fisher Exact test analysis of the data shows it is not statistically significant p.>0.05. (Table 2 and Graph 2a,b).

*Leftc 6: C7 Facet dislocation*


**Fig. 1:** Sagittal

*Fracture C7 Tranverse proce*

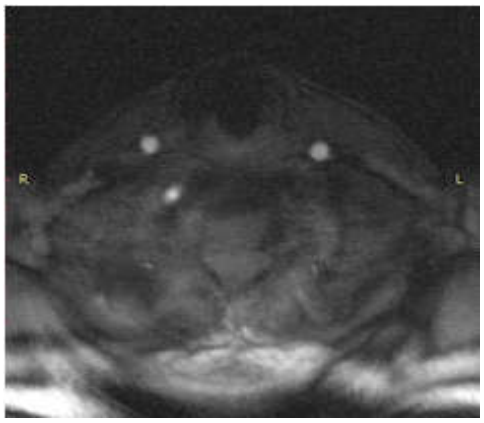



**Fig. 2:** Axial

*Left Vertebral Artery Total Occlusion*

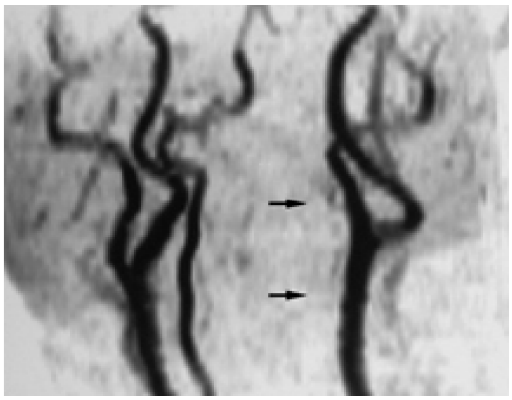


**Fig. 3:** MRA Left Vertebral Artery Total Occlusion

*MRI Cervical Spine*

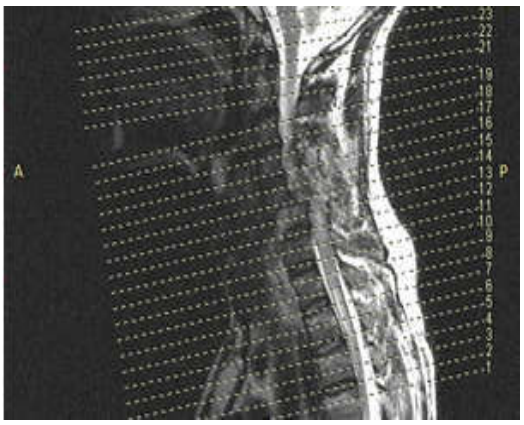



**Fig. 4:** Sagittal

*C6- C7 B/L Facet Dislocation*

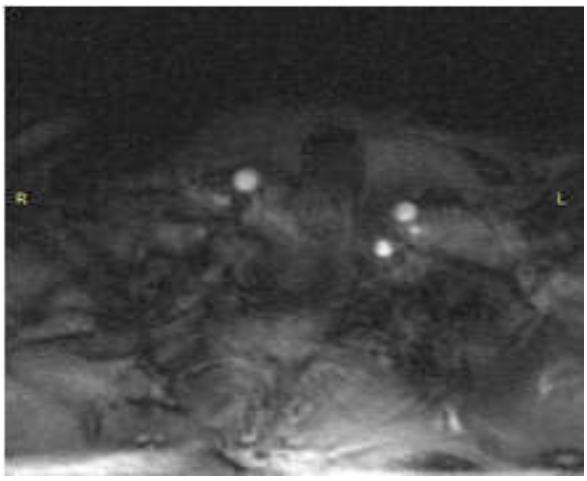



**Fig. 5:** Axial

*Right Vertebral Artery Total Occlusion*

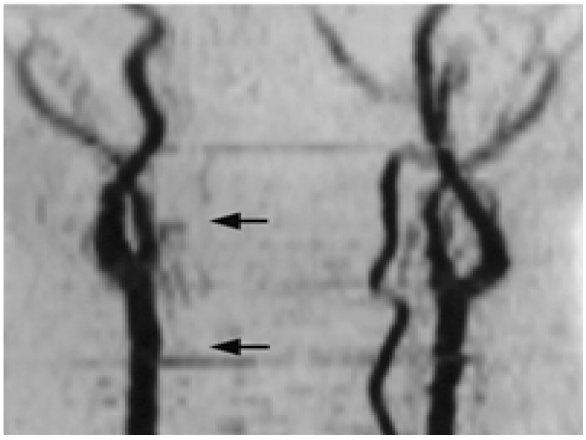
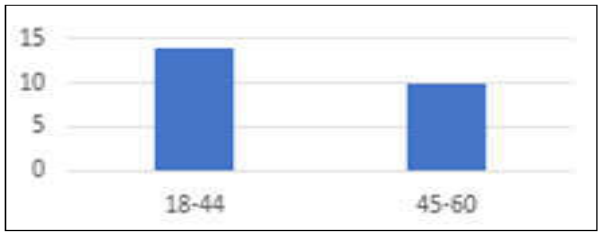


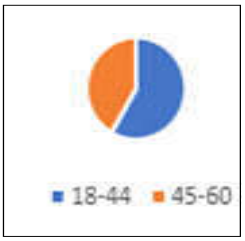
**Fig. 6:** MRA right vertebral artery total occlusion

**Table 1:**

| Age Rang | No of Patients |
|---|---|
| Age Rang | 14 |
| 45-60 | 10 |




**Graph 1a:**




**Graph 1b:**

*Vertebral Artery Injury and Cause of Injury*

All the Vertebral Artery Injuries Are Caused by Motor Vehicle Accident (Table 3).

*Admission Gcs and Vertebral Artery Injury*

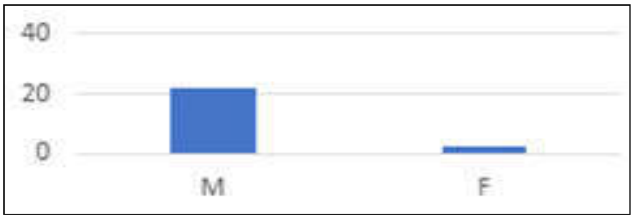
Mild Traumatic Brain Injury is the most common presentation of blunt cervical spine injury. Data analysis by Fisher Exact Test shows it is not statistically significant p >.0.05 (Table 4 and Graph 4a,b).

*Vertebral Artery Injury*

24 patients had vertebral artery injury, who were screened after sustaining blunt cervical trauma (22.22%). Out of 24 patients, 10 had unilateral vertebral artery injury on the right and left

**Table 2:**

| Sex | No of Patients |
|---|---|
| M | 22 |
| F | 2 |

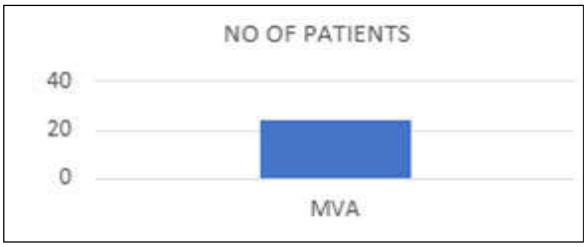



**Graph 2a:**


**Graph 2b:**

**Table 3:**

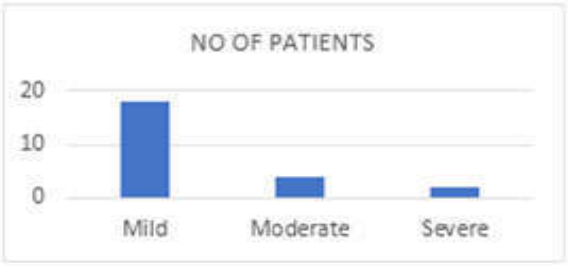
| Cause of Injury | No of Patients |
|---|---|
| MVA | 24 |




**Graph 3a:**

**Table 4:**

| Admission GCS | No of Patients |
|---|---|
| Mild | 18 |
| Moderate | 4 |
| Severe | 2 |




**Graph 4a:**


**Graph 4b:**

respectively and 4 of them had bilateral vertebral artery injury (Table 5). And it was found to be statistically significant (Figure 5a) p >.05.

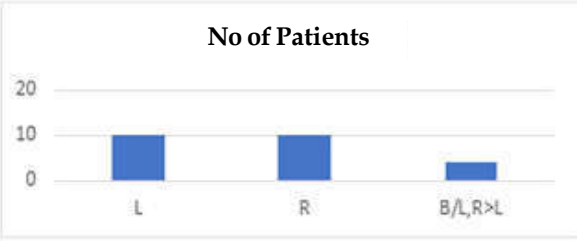
Type 2 and 4 (10 each) of Denver grading of vertebral artery injuries is more common than type 1(4) in the blunt cervical spine injury patients.

A sizable proportion of patients with fracture of foramen transverium, had vertebral artery injury. In each case treatment was individualized to the patient. All patients were treated with Aspirin, because systemic anticoagulation is relatively contraindicated in the setting of multiple injuries.

P=0.0030157481411465705 (Statistically Significant)

**Table 5:**

| Side of VA | No of Patients |
|---|---|
| L | 10 |
| R | 10 |
| B/L;R>L | 4 |

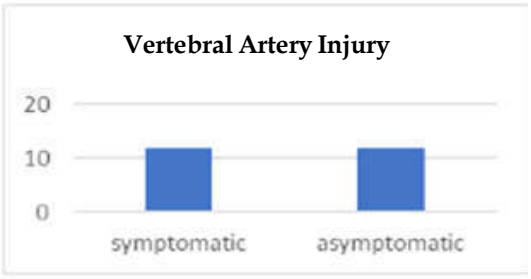



**Graph 5a:**


**Graph 5b:**

*VA Injury and Neurologic Symptoms*

Twelve patients were asymptomatic to vertebral artery injuries; twelve patients were symptomatic, and they were treated with Aspirin. None of the patients developed irreversible neurological deficit. Based on the logistic regression analyses, no significant association was found between a particular symptom and the presence of a VA injury ($p$ = 0.05 in each case). Furthermore, there was no significant association between the presence of any neurologic symptoms and VA injury ($p$ = 0.05), there was no significant association between VA abnormalities in asymptomatic patients with a highly suspicious mechanism of injury and the presence of fractures ($p$=0.82). Likewise, there was no significant association between the presence of VA abnormalities and cervical spine fractures in symptomatic patients ($p$= 0.498).



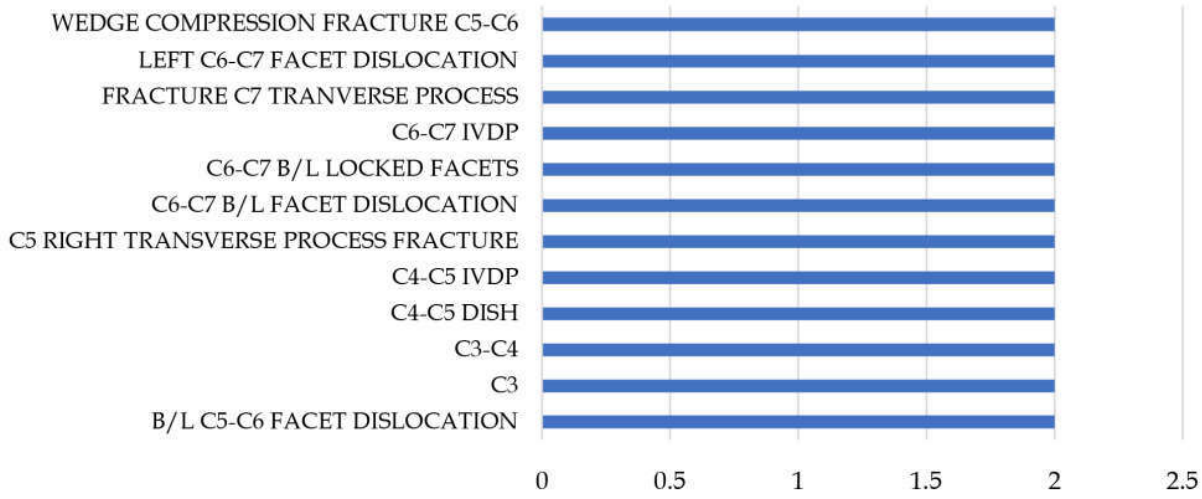

**Graph 6:**

*VA Injury and Spine Fractures*

There was no significant association between the presence of cervical spine fractures and a VA abnormality ($p$=0.856). Transverse process fractures were the most common fracture associated with a VA abnormality (7.6%, $n$ = 5), but there was no significant association between transverse process fractures and VA abnormalities ($p$=1.479), or between VA abnormalities and any other particular fracture pattern ($p$ =0.05 in each case). Independent samples $t$-test showed that the presence of an affected vessel either by stenosis, dissection, or occlusion did not affect clinical outcomes as measured by mRS ($p$ =1.0). Logistic regression analyses, however, showed no significant association between VA injury and the presence of each symptom as an independent variable ($p$ = 0.879 in each case). Furthermore, the single regression model using any symptom as a predictor of VA injury also showed no significant association ($p$=0.05).

*Vertebral Artery Injury and Mechanism of Injury*

Out of 24 patients with vertebral artery injuries 10 patients had compression flexion injury stage 1 (41.7%) and their association with vertebral artery injury was found to be statistically significant by Fisher t test and the both distraction flexion injury and compression flexion of ALLEN et al grading are more common in causing vertebral artery injuries (Table 8) and they were found to be statistically significant (Figure 8a). However, the flexion injuries are more common in causing vertebral artery injury rather than extension injury.




**Graph 7:**

However, the flexion injuries are more common in causing vertebral artery injury rather than extension injury P = 0.00039766408242027627 (Statistically Significant).

*Vertebral Artery Injury and Asia Scale*

Fisher exact test showed the ASIA grading of spinal cord injury is statistically significant (Figure 9a) in which A (complete) is more commonly associated with vertebral artery injuries (Table 7).

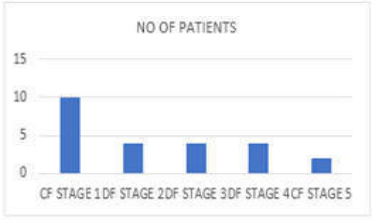
P=0.0094795195474415908 (Statistically Significant).

*Vertebral Artery Injury and Treatment*

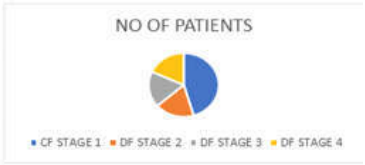
Antiplatelet therapy for VAI was aspirin. All symptomatic patients for vertebral artery insufficiency are given aspirin. No level 1 or 2 evidence exists regarding the management of various grades of TVAI.

**Table 6:**

| Injury Stage Aillen et al | No of Patients |
|---|---|
| CF STAGE 1 | 10 |
| DF STAGE 2 | 4 |
| DF STAGE 3 | 4 |
| DF STAGE 4 | 4 |
| CF STAGE 5 | 2 |




**Graph 8a:**




**Graph 8b:**

**Graph 9a:**

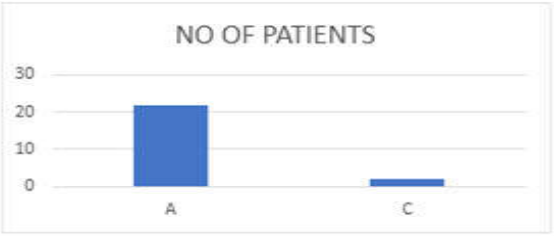



**Table 7:**

| Asia Grade | No of Patients |
|---|---|
| A | 22 |
| C | 2 |

**Graph 9b:**

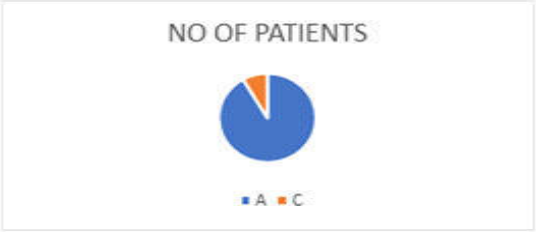
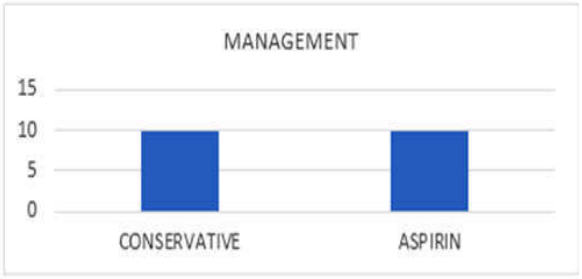


**Table 8:**

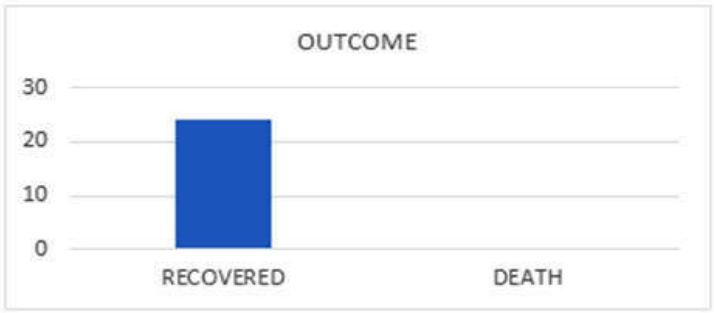
| Conservative | Aspirin |
|---|---|
| 10 | 10 |




**Graph 10:**

**Table 9:**

| Recovered | Death |
|---|---|
| 24 | 0 |




**Graph 11:**

*VA Injury and Clinical Outcome*

Independent samples *t*-test showed that the presence of an affected vessel either by stenosis, dissection, or occlusion did not affect clinical outcomes as measured by mRS ($p = 1.0$). In addition, because of our highly selected population, patients in this study likely had an increased incidence of neurologic deficits, fractures, and significant mechanisms of injury compared with the general population with blunt cervical spine trauma. In general, our institution favors screening these high-risk patients, which may not reflect the current practice at other centers. Completed their vascular imaging at outside hospitals before transfer to our institution, because we were not able to review their imaging studies.

## Discussion

Traumatic vertebral artery injury (TVAI) presents a clinical challenge since it is hard to detect, has a diverse presentation and there are no widely accepted guidelines on diagnosis and management. Most evidence available on TVAI is class 3, based on case series from individual institutions. The natural history of asymptomatic TVAI is relatively well understood since so many are treated conservatively. Typically, adequate collateral circulation ensures that there are no adverse clinical events, although patients who do experience vertebral artery territory ischemia often suffer major neurological insults. These may be prevented if TVAI is confirmed by screening and the patient managed in a timely fashion. Recent data indicate that 90% of stenotic lesions resolve and 67% of occluded vessels recanalise [2].

The overall mortality of TVAI has been estimated at 4–8% [17]. Late presentation of TVAI may be due to delayed ischaemic deficit associated with vasospasm. There is no discussion of the recurrence rate in a series of pure TVAI (excluding carotid injuries) and neither is there data to suggest the time window during which patients with TVAI are at highest risk of ischaemic events.

Unilateral TVAI is estimated to be symptomatic in only up to 20% of cases due to extensive collateral supply within the posterior circulation [17]. Symptomatic TVAI may present with ischemic symptoms directly after the injury or may present with posterior circulation insufficiency in a delayed manner, up to 3-6 months in some cases [18].

In the symptomatic subgroup of TVAI, neurological symptoms occurred in only 70%

within the first 24 h post-injury according to a small series [19]. Delayed presentation and recurrent events may lead to sudden later deterioration, resulting in misdiagnosis and medico-legal concern surrounding the original trauma. Prior knowledge of TVAI, even if treated conservatively, is vital should the patient re-present at a later date with posterior circulation ischaemic symptoms [2].

TVAI may even be asymptomatic in the presence of serious radiological features of TVAI such as arteriovenous fistulae [20].

The key presenting complaints of symptomatic TVAI are due to ischemia of the cerebellum, brainstem and the primary visual cortex. Symptoms include headache, neck pain, sensory and gait disturbance, dizziness, nausea and Vomiting, altered consciousness, and speech and visual abnormalities.

On physical examination, findings suggestive of TVAI can be classified into those directly due to posterior circulation ischemia and those relating to traumatic injuries commonly associated with TVAI.

Examination findings of posterior circulation ischemia include dysarthria, impaired balance and coordination, ataxic gait, visual field defects, diplopia, nystagmus, Horner's syndrome, hiccups, lateral or medial medullary syndrome, lower cranial nerve palsies, papillary abnormalities and impaired consciousness.

Physical examination findings suggestive of associated trauma based upon the mechanisms suggested by the Denver criteria are neck tenderness, maxillofacial injuries, skull base fracture, and head trauma, signs of hanging, high impact, flexion/ extension or deceleration injury.

In view of the high proportion of TVAI that is initially asymptomatic, a high index of suspicion should be maintained for it based upon the mechanism of trauma and the nature of associated injuries. Associated injuries are seen in most (93%) patients [2].

Spinal cord injury coexists in 50–59% of patients with TVAI and complete cord injury is more commonly associated with TVAI (50%) than incomplete cord injury (12%), presumably due to greater forces exerted on the neck at the time of injury.

The majority of events of blunt cerebrovascular injuries seem to develop within 10–72 h after the injury.

The advantages of actively screening for TVAI include treatment planning, with a view to anticoagulation, and preventing delayed presentation with ischaemic posterior circulation events. In addition, once TVAI lesions are detected, close follow-up can be instituted to ensure resolution of the lesion and to pick up the late complications of pseudo aneurysm formation, residual stenosis or arteriovenous fistula. It is important to avoid attributing depressed consciousness solely to concomitant TBI and hypoxia or hypovolemia from associated trauma. The problems of searching for TVAI include the invasive nature and availability of the gold standard investigation, i.e. digital subtraction angiography (DSA), which cannot routinely be justified in head and neck injury patients. Other methods of screening for TVAI include CT and MR angiography (CTA and MRA). DSA is the gold standard, but itself carries 0.5% risk of stroke. The sensitivity of CTA in detecting VAI has improved over time, with one series showing 99% sensitivity of multislice CTA for angiographically proven VAI [2].

MRA has been shown to be a valid technique for imaging vertebral artery pathology and some centers have started using it for detecting TVAI. MRA is quite accurate in the detection of near or total occlusion of the extra cranial neck vessels [2]. However, because occlusion is the most common vertebral artery injury, the majority can be successfully detected by noninvasive MRA [3].

Duplex ultrasonography (USS), although the least invasive and most readily accessible modality, suffers from poor sensitivity.

Radiologically proven TVAI may be graded according to clinical presentation and radiological severity. Taking these factors into account, treatment may either be medical with antiplatelet agents or heparin or can be endovascular. We recommend high-grade and symptomatic injuries to be treated by endovascular approaches. Asymptomatic injuries with a low-radiological grade can be managed medically if there are no contraindications. Follow-up MR Angiography may be performed a few weeks post-presentation to assess for resolution or progression of the injury. Several retrospective studies have reported that neurological outcome with antiplatelet therapy is equivalent or superior to heparin anticoagulation. Our study primarily intended to address the issue of whether VA injury is associated with clinical outcome after blunt cervical trauma, and secondarily attempted to determine any association between VA injury and clinical or radiographic patterns in these patients.

## Review of Literature

Friedman et al. reported that 9 of 37 patients (24%) with cervical spinal trauma had evidence of vertebral artery injury [22]. Our study with 24 out of 108 patients (22.22%) is consistent with the Friedman et al. This rate is lower than that reported by Willis et al. (46%) [21] and may reflect either a difference in demographic characteristics of the patient population or the lower sensitivity of MRA compared with conventional angiograph.

The low rate of symptomatic unilateral vertebral artery injury may suggest that screening for the VA injury in asymptomatic patients may not be cost-effective. One must consider, however, that although it is initially asymptomatic, a unilateral VA injury is a serious condition that warrants close follow-up. Husni and Storer [23] showed that in 23 patients with vertebrobasilar insufficiency induced by rotational occlusion of one vertebral artery, the contralateral vertebral artery was hypoplastic in 11 and stenosed in 1. This suggests that even partial occlusion of the contralateral patent VA, such as from simple head rotation, may be sufficient to induce symptoms. Potsch and Bohl suggested that although unilateral VA obliteration may not in itself produce neurologic symptoms, it compromises the posterior circulation sufficiently to become an occult risk for acute brainstem insult [24].

Unilateral vertebral occlusion in the presence of sufficient contralateral collateral vertebral artery flow presents with less morbidity than either intimal dissection or pseudo aneurysm formation, vertebral artery flow presents with less morbidity than either intimal dissection or pseudo aneurysm formation, because the latter tend to be associated with a higher propensity for distal embolization. Complete occlusion, as discussed above, may increase the susceptibility to ischemia and decrease the margin of safety in the event of further compromise of the contralateral vertebral artery. The reported incidence of vertebral artery occlusion in distractive flexion injury was 75% by Louw [26], 28% by Giacobetti [25] et al., and 50% by the current authors. Taken together, these studies suggest that asymptomatic patients discharged with a diagnosis of unilateral vertebral artery injury should be cautioned against engaging in activities that may increase the probability of compromise of the remaining vertebral artery and should be counseled about the symptoms of vertebrobasilar insufficiency.

## Conclusion

Our study shows that even in a highly selected population, the clinical outcome of patients who suffer blunt cervical trauma with and without spine fractures is associated with the presence of VA abnormalities. Furthermore, a highly suspicious mechanism of injury in asymptomatic patients was associated with the finding of a VA abnormality. Given the rare but potentially devastating consequences of a VA injury, however, screening may still be worthwhile. A randomized prospective study would better determine the value of VA imaging in the setting of blunt cervical trauma and to clarify its potential cost-effectiveness.

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