Risk factors for vertebral artery injuries in cervical spine trauma

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Abstract

Blunt cerebrovascular injuries (*i.e.* involvement of carotid and vertebral arteries) are increasingly being recognized in setting of cervical spine trauma/fractures and are associated with high incidence of stroke/morbidity and mortality. The incidence of vertebral artery injuries (VAI) is more common than previously thought and regular screening is seldom performed. However there exists no screening criteria and conflicting reports exists between spine and trauma literature. Many clinicians do not routinely screen/evaluate patients presenting with cervical spine trauma for potential VAI. This article provides a brief summary of existing evidence regarding the incidence of VAI in the background of cervical trauma/fractures. The type and fracture pattern that is associated with a high risk of VAI warranting mandatory screening/further work-up is discussed. A brief overview of diagnostic modalities and their respective sensitivity/specificity along with available treatment options is also summarized.

Introduction

Vertebral artery injuries (VAI) are increasingly being detected in traumatic settings owing to improvement and advances in imaging modalities. They are uncommon injuries following trauma and its incidence is 0.5%.[1] Though majority of them are asymptomatic, symptomatic VAI could be devastating resulting in stroke, irreversible neurological sequelae and mortality. The mortality rate following VAI reported in English literature is 8-18%.[2] VAI could be broadly classified into: i) spontaneous and ii) traumatic.[3] Up to 70% of traumatic VAI have an associated cervical spine fracture.[4] In an instructional course survey of Cervical Spine Research Society (Am) in 2006, majority of audience and panel participants did not routinely screen for VAI in patients with cervical spine trauma and fractures unless there was neurological findings of a potential or probable vascular cause.[1] The evaluation and management of VAI is controversial owing to conflicting reports in trauma *vs*. spine literature. The authors hereby summarize the existing evidence in English literature for screening, detection, diagnosis and management of VAI in a setting of cervical spine trauma. They also summarize the patterns of cervical spine fractures that are associated with high incidence of VAI calling for mandatory evaluation and prompt treatment to minimize mortality and complications.

Anatomy

The Vertebral artery arises from subclavian artery and ascends cranially on either side of the spinal column to the base of skull where they unite at the lower border of pons to form the midline basilar artery. Left Vertebral artery is dominant in 70% of individuals and up to 10% may have unilateral hypoplasia.[5] The course of vertebral artery could be divided into four parts (V1-4)[6] as depicted in Figure 1a. i) *Extra-osseous segment* (V1): starts at the base of neck at its origin from subclavian artery running between longus coli and scalenus anterior muscles up to its entry into the foramen transversarium of C6 (most commonly though variations of its entry into C5 and C7 exists); ii) *foraminal segment* (V2): its course in formaen transversarium ascending cranially from C6 to C1; iii) *extraspinal segment* (V3): starts as the vertebral artery exits the foramen transversarium of C1 abruptly turning ventral and cephalad towards foramen magnum where it pierces the duramater; iv) *intradural segment* (V4): at the base of skull where it pierces the duramater up to the lower border of pons where it unites with its contralateral counterpart to form the basilar artery.

The second and third parts of vertebral artery are most at risk following cervical spine trauma owing to its close proximity to osseous structures and Carpenter was the first to describe an association between cervical spine fractures and VAI.[7] The severity of VAI can vary from simple intimal tears to complete occlusion and transection. Transactions of Vertebral artery is usually fatal. Cothren *et al.* originally described cerebrovascular injury scaling for traumatic carotid artery injuries (known as the Denver criteria)[8] and the same has extended applications for vertebral artery injuries too.

Questions

The question we want to address are: i) which part/segment of vertebral artery is most at risk following cervical spine trauma? ii) What patterns of cervical spine fractures are associated with higher risk for traumatic VAI? iii) What is the investigation of choice to diagnose and screen for traumatic VAI? iv) What are the treatment options in managing traumatic VAI?

Discussion

There are very few published reports of traumatic VAI in children and its true/exact incidence is unknown and probably under reported. The most common part of vertebral artery at risk in adults is foraminal segment (V2) and in children/adolescents is third part (extraspinal segment).[9,10] This may be due to higher laxity of ligaments at cranio-vertebral junction with large head in children.

The key fracture patterns accounting for >93% of traumatic VAI are:[11,12] i) cervical spine/facet subluxation; ii) cervical facet dislocation: unilateral or bilateral (esp. C2-C6 levels); iii) upper cervical spine fractures (C1-C3) and hanging with anoxic injury; iv) fractures of transverse process and involving/extending into f. transversarium. An index case of a C5-C6 unilateral left sided facet joint dislocation with fracture of the articular process that is extending into foramen transversarium and raises an high index of suspicion warranting mandatory evaluation of Vertebral artery is depicted in Figure 1b-d. The

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Table 1. Fracture patterns of cervical spine and associated traumatic vertebral artery injuries incidence.

Author	Cervical spine fracture pattern	Cases	Traumatic incidence (%)
Kral *et al.*[11]	F. Transversarium	9/119	8
	Facet fracture + dislocation	25/119	21
Woodring *et al.*[12]	F. Transversarium	7/8	88
Miller *et al.*[13]	F. Transversarium	28/36	78
	Facet fracture + subluxation	6/36	17
	Occipito-atlantal dislocation	1/36	2.5
	Other minor C-spine fracture	1/36	2.5%
Vaccaro *et al.*[14]	F. Transversarium	1/12	8
	Facet joint dislocation	6/12	50
Cothern *et al.*[15]	Facet subluxation	38/92	41
	No spinal fracture	21/92	23
	F. Transversarium	18/92	20
	Upper spine fracture/dislocation	13/92	14
	Other minor C-spine fracture	2/92	2
Willis *et al.*[16]	F. Transversarium + facet subluxation	12/26	46
Louw *et al.*[17]	Facet fracture + dislocation	9/12	75
Parent *et al.*[18]	Lateral dislocation of C-spine	5/5	100

incidence of VAI with associated fracture patterns reported in literature by few independent researchers is summarized in Table 1.[11-18] Investigation for traumatic VAI: conventional catheter four vessel cerebral angiography or digital subtraction angiography (DSA) is considered to be an established gold standard for evaluation of tears, dissection and injuries to cerebral blood vessels.[19] However this is an invasive procedure and not without risks. Hence its routine use in evaluation for VAI in all trauma cases is discouraged. The complications rate ranges from 1-4%. The incidence of stroke is up to 0.5-1%. Other non-invasive imaging modalities described are magnetic resonance angiography (MRA) and computed tomographic angiography (CTA). They are associated with poor sensitivity in comparison to 4-vessel cerebral angiography. As most VAI occur in background of polytrauma warranting CT scans, MRA may be unsuitable given long scan times and limited additional information offered.[20] Duplex ultrasonography (USS) though least invasive and most readily accessible has the least sensitivity and is user dependent. One study reported its sensitivity to be 38.5% as the assessment of vertebral artery is obscured by bone, stiff necks and central venous catheters.[21] A new 16 slice high resolution CT angiography has been reported to have 99% specificity for angiographically proven VAI.[22] There was a 12-fold reduction in time to diagnosis and 4-fold reduction in stroke rate due to injury making it an attractive screening tool and investigation of choice for evaluating VAI.[23] Table 2 summarizes the sensitivities and specificities of USS, CTA and MRA in comparison with the *gold standard* (*i.e.* 4-vessel cerebral angiography) reported by researchers in published studies.[22,24]

The treatment options for traumatic VAI include:[24,25] i) *observation*, most commonly exercised option; ii) *anticoagulation*, following multidisciplinary input from neurologists, neurosurgeons and intensive care physicians after ruling out contraindications for anticoagulation and careful evaluation of risk benefit ratio. This thrombolytic therapy could be combined with endovascular stenting; iii) *surgery*, difficult surgical access associated with high mortality makes this least desirable. Surgical options include primary surgical repair, tamponade, embolization and endoluminal therapeutic interventions.

We have no personal experience in any of the above surgical treatment options. There exists no concrete evidence to support a specific surgical treatment as on today.[25] However therapeutic embolization is increasingly becoming an acceptable modality of treatment in contemporary era (especially in treatment of false aneurysms).[25] Two cases of surgical repair have been reported in literature and

Table 2. Sensitivity and specificity of duplex ultrasonography, computed tomography angiography and magnetic resonance angiography in detecting vertebral artery injuries.

Imaging modality	Sensitivity (%)	Specificity (%)
Duplex ultrasonography[22]	38.5	100*
Magnetic resonance angiography[24]	43	97
Computed tomography angiography[24]	53	99

*Duplex ultrasonography is not reliable for detection of intimal tears.

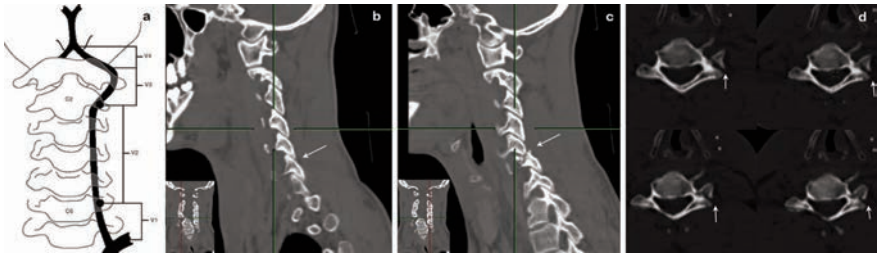

Figure 1. Index case of cervical spine unilateral (left sided) C5-C6 facet joint dislocation with fracture and vertebral artery's four parts. a) Line diagram representation of 4 parts of vertebral artery. b) Sagittal computed tomography (CT) scan of right sided facet joints showing normal alignment without any fracture. c) Sagittal CT of left sided facet joints revealing a C5-C6 dislocation with fracture of articular process. d) Axial CT images at C5 and C6 levels showing the fracture line extending into the foramen transversarium and vertebral artery potentially at risk. Such a fracture pattern warrants mandatory evaluation of vertebral artery by appropriate imaging (CTA/MRA).

open surgical ligation being reserved for uncontrolled hemorrhage. Bypass grafting maybe attempted and we are unaware of any successful outcome by this option. Endoluminal coil occlusion appears to be very promising in contemporary clinical practice and further studies are desired.[25]

Conclusions

Very little is known about traumatic VAI and they are best screened by high-resolution 16 slice CTA or MRA. Low grade and asymptomatic VAI could be treated by observation or anti-platelet agents. High grade and symptomatic VAI are best treated by endovascular approaches or thrombolytic therapy. There exists no consensus on standard of care in treating these complex pathologies. Follow-up CTA at two weekly intervals is recommended to assess response to therapeutic intervention (*i.e.* resolution or progression of injury).

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