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Correlation of C2 fractures and vertebral artery injury.

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Study design

Retrospective review

Background/Introduction

Vertebral artery injuries (VAI) are common occurrences with cervical spine and spinal cord injuries. To date, no study has examined the association between VAI and specific types of upper cervical spine fracture.

Objective/Purpose

To evaluate the incidence of VAI (as defined by MRI) in each different type of axis fracture, and the association between the incidence and the morphology and severity of fractures.

Methods

Patients admitted for axis fractures between October 2006 and December 2008 were identified through a prospectively maintained database. CT scan and MRA were then reviewed to evaluate the fracture and the occurrence of VAI. Fracture

displacement and angulation were measured with the digital rule on the electric radiological imaging system. Incidence of VAI was compared between different types and subtypes of fractures. The effects of displacement and angulation of fracture, morphology of foramen transversarium fracture, age and gender on VAI were also analyzed.

Result

101 patients were identified with C2 fractures, of which 18 (17.8%) VAI were diagnosed by MRA as having a VAI. There was no correlation between fracture types and VAI. However, in patients with TSA (traumatic spondylolisthesis of axis), those with more angulation had a greater risk of VAI ($p=0.0023$). Communion fracture and fragment within foramen transversarium were also more likely to have VAI ($P=0.0341$ and 0.0075). Multivariate logistic regression indicated that age, gender and the presence of fragments within foramen transversarium were also associated with greater risk of VAI.

Conclusion

Vertebral artery injuries are more likely to occur if the cervical fracture includes a foramen transversarium communion fracture, fragments within the foramen transversarium, or greater angulation. Male and older patients are also at greater risk. These risk factors should be considered when a patient presents with isolated axis fracture.

Key words

Vertebral artery, Axis fracture, Magnetic Resonance Angiography

Introduction

Incidence of VAI (Vertebral Artery Injury) associated with blunt cervical spine injury was initially thought to be rare but with improved imaging modalities this has been found to be quite common. There has been an evolution of the diagnostic method from conventional catheter angiography to non-invasive modalities such as Magnetic Resonance angiography (MRA) and computed tomography angiography (CTA).^{21,33}

VAI is usually asymptomatic; even after a complete thrombosis or cerebrovascular accident, the patient still remains neurological intact. However, vertebral injury and posterior circulation stroke have a high mortality rate. Furthermore, since most injured cervical arteries cannot reconstitute flow in the long-term,³⁴ there is decreased margin of safety against future injury or surgery in this area. Although some authors^{10,18,21} suggest aggressive screening for all blunt cervical spine injury patients, the cost-effectiveness remains uncertain. Therefore, an appropriate screening algorithm should evaluate potential patients according to high risk injury factors.

Some signs/symptoms and risk factors are thought to be associated with VAI include: cervical hematoma, neurologic deficit incongruous with head CT scan findings, infarct on head CT scan, massive epistaxis, Horner's syndrome, seatbelt sign above clavicle, severe facial fracture, cervical bruit or thrill, basilar skull fracture and

cervical spine injury. Among these, cervical spine fracture has been demonstrated an independent predictor⁴. Specific high risk patterns include facet dislocation/subluxation, fracture extending into foramen transversarium, and upper cervical spine fracture(C1-C3).^{9,10,15,19,24,35}

In upper cervical spine, the axis has a unique anatomy and isolated C2 fractures are common. Some studies^{9,10,30} have reported an association between upper cervical spine fracture and VAI, but did not consider axis fractures as an individual study group. Others^{22,29} reported VAI in patients with axis fracture but had a small cohort.

We performed a retrospective study of all patients admitted to Thomas Jefferson University Hospital (TJUH) with axis fractures, specifically examining the incidence of VAI in each different type of axis fracture, as well as the association between the incidence and the severity and subtype of fracture.

Method

Patients with axis fracture admitted to the level 1 tertiary care facility at Thomas Jefferson University Hospital, from October 2006 to December 2008, were identified. Cases were excluded if there was associated fracture or dislocation at other cervical levels; or if either MRA or CT imaging and reports could not be obtained.

According to the institutional trauma protocol, all patients had MRA performed in combination with a cervical MR imaging study on a 1.5T scanner (General Electric, Milwaukee, WI). The typical MRA acquisition consisted of 2-dimensional time-of-flight

pulse sequence, which was sufficient to observe all 4 segments of vertebral artery. The criteria for VAI were fulfilled by absence of time of flight images of V2 segment (C6-C2) in the expected location course, or narrowing adjacent to the C2 spine, that all confirmed on axial raw data. Reviews of MRA were performed without prior knowledge of the CT results; after reviewing MRA, plain films and CT were read. All imaging readings were confirmed with a radiologist.

Fractures were reviewed and classified on the basis of the appearance on the plain films and CT. Displacement and angulation were measured to describe the severity of fracture. The measurements were performed according to the method of Bono et al.⁷

Foramen transversarium fractures were identified on CT axial plane view, and assessed for three patterns as suggested by Oetgen et al²⁴: displacement, comminution fracture and fragments present within the foramen transversarium.

Statistical analysis was performed using JMP (version 7.0.2, SAS Institute, Cary, NC, USA). Chi-squared and Fisher's exact tests were used to determine association between incidence of VAI and each classification of fracture. Multivariate logistic regression was to estimate the association between VAI and all combined fracture categories along with the demographic variables age and gender. This study was approved by the institutional review board of TJU.

Result

Out of 195 patients with axis fracture in the period of interest, 94 patients were

excluded: 66 patients had fracture and/or dislocation at other cervical segments, 4 patients whose MRA or CT imaging information could not be reached, 24 patients MRA in poor quantity. Eligible subjects were 101 patients severed as the study group, 22 patients had TSA, 59 had odontoid fractures, and 20 sustained miscellaneous fractures.

Among the remaining 101, there were 45 male and 56 female. The average age was 69.7 with a standard deviation of 18.1 (range, 18-95). There were 18 VAI(17.8%) identified in study group, all of them occurred unilaterally: 6 of 22(27.3%) patients with TSA (Figure 1), 10 of 59(16.9%) patients with odontoid fractures (Figure 2), 2 of 20(10%) patients with miscellaneous fractures (Figure 3). VAI incidence did not significantly vary between these 3 types of fracture ($P=0.33$).

Odontoid fractures and TSA were classified using the categorization from Anderson et al ¹ and Effendi's et al ¹⁶, respectively, while miscellaneous fractures were classified according to Benzel. ² Incidence demography in each subtype of fracture is listed in Table 1. There was a significant difference ($P = 0.0077$) between patients with type I, type II and type IIa TSA; , the Chi-Square test is not completely reliable when there are low cell counts, but the visible trend in the data is striking. VAI incidence did not significantly vary among patients with type I, type II or type III odontoid fractures ($P=0.82$) or patients with coronal or sagittal C2 body fractures($P=1.0$). Angulation in TSA patients was significantly higher for VAI cases ($p=0.0023$), but this was not seen in odontoid patients ($p=0.1332$). In either type of

fracture, no association was found between VAI incidence and displacement (p=0.42-0.43).

In 36 patients, the fracture extended to foramen transversarium, unilaterally in 25 patients and bilaterally in 11, yielding 18 /47 (38.3%) fractured foramen transversarium with associated VAI. Occurrences of both comminution and fragment within foramen transversarium were statistically associated with VAI (P=0.0341 and 0.0075 respectively), but the displacement of foramen transversarium fracture was not (P=0.6259).

For the multivariate logistic regression analysis, the overall model fit was 0.0043, and the most significant fit was related to fragment within foramen transversarium (p=0.0060), age (p=0.0219) and gender (p=0.0039). The displacement of the fracture was of borderline statistical significance (p=0.0866), with larger displacement associated with lower risk of VAI (Odds Ratio < 1.0). Table 2 shows the variables and their associated odds ratios.

Discussion

The incidence of VAI associated with blunt cervical spine injury ranged from 10.5% to 88% in previous reports.^{3,8,25,33,36-38} This wide variation was probably due to underdiagnosis of asymptomatic VAI. Study group selection, sensitive and specificity difference in diagnostic methods, evaluation bias could also contribute to the variation.

With the development of non-invasive diagnostic methods, the VAI now

commonly detected in patients with blunt cervical spine injury. Prospective studies have shown that early reorganization and anticoagulation could improve the neurological outcome of VAI-caused stroke or embolism,²¹ encouraging the screening protocol based on injury pattern. A few signs/symptoms were thought to be associated with VAI, but in a five-year study by Miller,²⁰ only 12% of VAI were diagnosed because of ischemia symptoms. Injury patterns, especially cervical spine injury, were found predictive of VAI. Since Carpenter et al⁸ first reported the association between VAI and Cervical spine injury, several studies have been done on specific cervical spine injury patterns predicting VAI, mainly focusing on facet dislocation/subluxation^{9,10,15,34,35}, fractures extending into foramen transversarium,^{10,14,19,24,36,38} and upper cervical spine (C1-C3) fractures^{9,10,22,29}.

Because upper cervical fracture are often caused by high-speed energy force and associated with hyperextension or hyperflexion mechanism, which are thought to easily cause the stretching of vertebral artery, they are an obvious high risk factor for VAI. The axis has a unique anatomy, and isolated C2 fractures are common, which warrant independent consideration of its association with VAI.

In this study, VAI occurred in each type of axis fracture. According to the statistical results, none of these three types present greater risk for VAI. The subgroup analysis based on the classification/subtype in each type of axis fracture only showed significant differences between types in patients with TSA, not in those with odontoid fracture or miscellaneous fracture. Interestingly, a significantly increased

incidence of VAI with more angulation was found in the TSA patients but not for odontoid fracture. In either TSA or odontoid fracture patients, VAI incidence was not associated with more fracture displacement. We did find a correlation between comminution fracture of foramen transversarium and the incidence of ipsilateral VAI, as well as fragment presence within the foramen transversarium and the VAI. However, the displacement of foramen transversarium fracture was not associated with VAI in the univariate t-test, and was of only borderline significance ($p=0.0866$) in the final multivariate model. The multivariate result was also counter-intuitive in that larger displacement was associated with less risk of VAI.

The incidence of VAI in current study is relatively lower than in previous reports. This might relate to the chosen diagnostic method: MRA might miss some small disruption of intima and vessel spasm,^{27,28} and even grade 1-3⁶, although we feel dissection can be clearly identified unless in poor quantity imaging. Since Freidman, in 1995 firstly reported¹² the 2D TOF MRA used as noninvasive diagnostic method for VAI, most the authors have used it as a routine initial screening evaluation for VAI,^{6,27,28}. Conventional catheter cerebral angiography is the golden standard for screening VAI but it carries risk, like iatrogenic injury, stroke and even death.^{6 5,21}

The most initial injury mechanism of the artery is from either excessive stretching of vessel between two adjacent foramen transversarium, or direct lesion to the vessel wall. The mechanism of VAI was once thought to be hyperextension injury,^{31,32} but recently distractive flexion was identified as a likelier cause.^{4,13,17,26,34,35} Veras et al

reported 6 VAI patients injured in motor vehicle accidents; in all cases, the injury mechanism was flexion distraction.³⁵ In the study of Giacobetti et al¹³, 7 of 10 patients with vertebral artery occlusion had flexion distraction injuries. The classification scheme of TSA was described by Effendi,¹¹ which based on the mechanism of injury: Type I, axial loading and hyperextension; Type II, hyperextension and rebound flexion; Type III, primary flexion and rebound extension. Levin and Edward add Type IIA of which the mechanism is hyperflexion and distraction.¹⁶ We found the incidence of VAI presented a progressive increase from type I and from type II to type IIA, consistent with the opinion that distractive flexion is the more common injury mechanism. The association between VAI incidence and fracture angulation in patients with TSA was supported by the statistical results, which indicates that the fracture angulation might be a higher risk factor for VAI than fracture displacement, in patients sustaining TSA. Odontoid fractures are categorized according to the location fractures go through, the tip of the dens (type I), base (type II) or involve C2 body (type III)¹. Although some biomechanical and clinical study showed Type II odontoid fracture is caused by laterally-applied, medially-directed force vector, and Type III by flexion injury,²³ we found no difference on the incidence of VAI between different types of odontoid fracture. Likewise, the classification of miscellaneous fracture is based on the fracture line orientation, so each type can be caused by multiple mechanism; hence, VAI incidence was not found to be affected by type. Angulation is not a predictor in

odontoid fracture patient, of which the reason might be more angulation means more severe stretching of vessel in TSA, while it just describe the relationship between odontoid process and vertebral body, not necessarily mean the motion between two adjacent foramen transversarium in odontoid fractures.

Foramen transversarium fracture makes intuitive sense because the vertebral artery runs through the foramen transversarium of cervical spine. Since Woodring et al³⁸ suggested that foramen transversarium fracture may lead to VAI, several studies have documented the relationship between the foramen transversarium fracture and VAI.^{9,10,14,19,24,35,36} In two studies done by Cothren et al on aggressive screening for VAI, 16%¹⁰ -26%⁹ of patients with VAI had foramen transversarium fracture. Recently, Oetgen et al researched on the morphology of foramen transversarium fracture in cervical spine fracture patients and identified multilevel foramen transversarium fracture and foramen transversarium fracture comminution as high risk patterns for VAI.²⁴ Our result showed both the fracture comminution and fragment within the foramen transversarium correlated with VAI, nevertheless, during the multivariate logistic regression analysis, the overall model fit was not significant (P=0.0876) unless age and gender entered the model, and finally the most significant model removed the foramen transversarium comminution fracture. These differences from Oetgen's result, might result from the selection of patients: all segments of cervical fracture were included in Oetgen's study while we specifically studied the axis fracture, and Oetgen only inspected the incidence of VAI in patients with

foramen transversarium fracture while we included all axis fracture regardless of the foramen transversarium fracture. The entrance to the model of age and gender suggest that osteoporosis and angiosclerosis may also increase the chance of VAI.

There was little previous information about the VAI and axis fracture. Mirvis et al reported 14 of 27 patients with hangman's fractures had fracture extending to the foramen transversarium, one patient suffered cerebellar hemisphere infarction which showed by CT scan and was demonstrated by angiography.²² In Cothren's studies, 13 of 92⁹ and 42 of 107¹⁰ patients with VAI sustained upper cervical spine fracture, respectively. Previous studies neither specifically focused on the axis fracture pattern with VAI, nor included displacement and angulation as parameters either. Current study is the first report of the incidence of VAI in patients with axis fracture.

The limitations of this study should be acknowledged. Accuracy and objectivity of retrospective data cannot be guaranteed. There were no available medical records of type III TSA patients. The identification method for VAI we used was 2D TOF MRA, which is less accurate than traditional angiography. The results of this study do suggest that a prospective study, with appropriate screening protocol, is warranted.

Conclusion

This study specifically reviewed the incidence of VAI in patients with axis fracture. The vertebral artery was more likely to be injured in patients with foramen transversarium comminution fracture, with fragments within the foramen transversarium, or with greater fracture angulation. Male and older patients were

also at greater risk. These factors should be considered when patients present with isolated axis fracture.

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