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Cervical Computed Tomography Angiography Rarely Leads to Intervention in Patients With Cervical Spine Fractures

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Abstract

Study Design: Retrospective cohort study.

Objectives: To evaluate the impact of computed tomography angiography (CTA) in the management of trauma patients with cervical spine fractures by identifying high-risk patients for vertebral artery injury (VAI), and evaluating how frequently patients undergo subsequent surgical/procedural intervention as a result of these findings.

Methods: All trauma patients with cervical spine fractures who underwent CTA of the head and neck at our institution between January 2013 and October 2017 were identified. Patients were indicated for CTA according to our institutional protocol based on the modified Denver criteria, and included patients with cervical fractures on scout CT. Those with positive VAI were noted, along with their fracture location, and presence or absence of neurological deficit on physical examination. Statistical analysis was performed and odds ratios were calculated comparing the relationship of cervical spine fracture with presence of VAI.

Results: A total of 144 patients were included in our study. Of those, 25 patients (17.4%) were found to have VAI. Two patients (1.4%) with VAI underwent subsequent surgical/procedural intervention. Of the 25 cervical fractures with a VAI, 20 (80%), were found to involve the upper cervical region (4.2 OR, 95% CI 1.5-12.0; $P = .007$). Of the 25 who had a VAI, 9 were unable to undergo reliable neurologic examination. Of the remaining 16 patients, 5 (31.3%) had motor or sensory deficits localized to the side of the VAI, with no other attributable etiology.

Conclusions: Cervical spine fractures located in the region of the C1-C3 vertebrae were more likely to have an associated VAI on CTA. VAI should also be considered in cervical trauma patients who present with neurological deficits not clearly explained by other pathology. Despite a finding of VAI, patients rarely underwent subsequent surgical or procedural intervention.

Keywords
cervical fracture, trauma, vertebral artery injury, computed tomography angiography, cervical spine, neurologic deficit

Introduction

Blunt cerebral vascular injury (BCVI) is a major concern when evaluating patients with cervical spine fractures as it has been estimated that 17% to 46% of these patients have an associated vertebral artery injury (VAI).[1,2] Computed tomography angiography (CTA) of the head and neck has been standardly used to identify VAI in these patients that may require urgent medical and surgical intervention in concert with other necessary medical treatments. However, there is controversy surrounding the utility of this advanced

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imaging study to screen patients with cervical trauma. VAIs can be asymptomatic and sometimes considered to be clinically insignificant due to the cerebral circulation being composed of a network of redundant vasculature. The rate of stroke due to VAI is also variable ranging between 0% and 25%.[3-7] Further complicating this topic is the lack of consensus regarding the association of specific cervical spine fracture morphology and VAI in the trauma setting, a relationship that is important in determining an appropriate protocol for obtaining CTA in these patients.[2,8-10]

CTA has been used to better assess any potential cervical arterial or venous flow abnormalities. However, it exposes patients to extra radiation, increases potential for radiation-induced malignancy, contrast-related nephropathy and allergic reactions, and may prevent patients from receiving appropriate time-sensitive treatment for other acute injuries. The procedure is also costly, and unnecessary usage not only wastes resources but can potentially delay other indicated patients from receiving the diagnostic procedure. The usefulness of CTA in the setting of cervical trauma has often been described by the prevalence of VAIs diagnosed as opposed to by the change in clinical management of these patients.[1] Because trauma patients may be indicated for the recommended anticoagulation therapy despite the diagnosis of VAI, or contraindicated due to hemorrhage or surgery in the near future, the value of frequent CTA screening is of debate.[7] In order to set and evaluate a given protocol for obtaining CTA of the head and neck in the trauma patient, it is imperative to consider the physical examination and imaging findings that most strongly correlate to changes in clinical management.[11] Furthermore, certain types of cervical injuries may pose a higher risk of VAI, which may play a role in the decision to obtain CTA.

There is little evidence describing the proportion of patients who undergo a procedure as a result of a positive VAI finding on CTA in association with cervical fractures. Therefore, the purpose of this study was to evaluate the clinical impact of CTA in cervical fractures by (1) identifying patients who sustained cervical fractures who underwent CTA and grouping them by presence or absence of VAI, and subsequent interventional procedures, (2) examining patients with VAI for presence or absence of unexplained neurological deficit, and (3) describing the fracture location of those that were found to have a VAI in the upper cervical region and compare with those in the same location that did not have a VAI.

Methods

A retrospective review of our academic institution's database was performed to identify all patients who had undergone CTA of the head and neck from January 2013 to October 2017. Of the identified patients, those who also underwent CT imaging of the cervical spine and had a confirmed cervical fracture in the setting of traumatic events were identified and included in the study cohort. Therefore, the final study population consisted of patients who underwent CTA of the head and neck as a result of traumatic cervical spine fracture. The decision to obtain a CTA for evaluation of BCVI was made according to an institutional protocol based on the modified Denver criteria.[12] During the study period, any patient who was found to have a cervical spine fracture on scout CT was triaged for evaluation with a CTA. This resulted in a unique population that is poorly defined in the literature. All medical records, imaging, and operative notes were thoroughly reviewed by two fellowship-trained orthopedic spine surgeons (AE and MR). Institutional review board exemption was obtained for this study.

Each patient's official radiologist CTA report was reviewed for the presence of VAI, which was defined as any vertebral artery abnormality in the vicinity of the cervical spine fracture. Patients were divided into 2 groups, those with the diagnosis of VAI, and those without. Demographics, including age and gender of each group, were assessed. Patients were also stratified into 3 groups: (1) those with a positive finding of VAI on CTA who subsequently underwent further surgical/procedural intervention as a result of this diagnosis, (2) those who had a positive finding on CTA but did not undergo surgical/procedural intervention, (3) and those who had negative findings of VAI on CTA.

The clinical note and physical examination for patients with VAI were reviewed and abnormalities were noted where present. VAIs were stratified as symptomatic or asymptomatic by the presence or absence of an unexplained neurologic deficit on physical examination. Asymptomatic patients were those who had 5/5 motor examination grading with intact sensation in both the upper and lower extremities with 2+ reflexes, unless there was a documented explanation in the patient's history for a deficit.

The fracture location of patients with positive findings of VAI on CTA were compared with that of patients with negative findings. For the purposes of this study, upper cervical fractures were classified as those primarily involving the C1, C2, or C3 vertebrae. The upper 3 cervical vertebrae have a unique anatomical relationship to the lower 4 vertebrae as their lateral articular processes and pedicles protrude more anteriorly.[12] This also allowed injuries extending to, and involving the C2-C3 disc space to be considered an upper cervical injury. The number of fractures at each location with VAI was compared with the total number of fractures at the same location in our study population (ie, C1 fractures with VAI/all C1 fractures etc). Odds ratios (OR) were calculated for each cervical fracture in relation to all cervical fractures.

All data, including patient demographics, fracture location and morphology, intervention (or absence of), and neurological status were tabulated into an Excel spreadsheet (Excel, Microsoft Corporation, Redmond, WA) for statistical analysis. The statistical software Graph Pad Prism version 5.01 (GraphPad Software Inc, La Jolla, CA), was used to perform all statistical calculations.

Results

Overall, 958 patients with CTA of the head and neck were identified, of whom 144 had presented after a traumatic event and had a confirmed cervical spine fracture on CT imaging of the cervical spine. There were 89 men (62%) and 55 women

Table 1. Age and Gender of Patients With Vertebral Artery Injury on CTA and Those Without.

Demographic	CTA+	CTA−	*P*
Male/female (male %)	18/7 (72)	71/48 (48)	.2691
Age, years, mean (SD)	57 (21)	51 (25)	.2650

Abbreviations: CTA, computed tomography angiography; SD, standard deviation.

Table 2. Neurologic Condition of Patients With Vertebral Artery Injury (VAI).

	Neurologic Deficit	Neurologically Intact
VAI and responsive (n = 16)	5 (31.3%)	11 (68.7%)

(38%), with a median age of 55 years (range, 16-92 years). Of those 144 patients, 25 (17.4%) patients had positive findings of a VAI. Although patients with evidence of VAI on CTA were older and more predominantly male compared to patients without VAI, these differences were not statistically significant (Table 1).

Of the 25 patients who had a VAI, 9 were unresponsive, intubated, and unable to undergo a complete and reliable neurologic examination for motor and sensory function. Of the remaining 16 patients, 5 (31.3%) had motor or sensory deficits localized to the side of the VAI (Table 2). The other 11 had an unremarkable neurologic examination, with 5/5 gross motor function to upper and lower extremities with sensation intact bilaterally. Fourteen of the 16 patients were placed on antiplatelet therapy with 81 mg aspirin. Antiplatelet therapy was contraindicated in the remaining 2 patients and therefore they underwent procedural intervention for VAI. There were no documented cases of stroke among patients diagnosed with VAI. No patients developed any new neurologic symptoms attributable to VAI subsequent to diagnosis.

Two patients (1.4%) with VAI underwent an acute surgical/procedural intervention due to diagnosis of VAI (group 1, Table 3). One patient had a comminuted fracture of the C2 body, including the posterior elements, and was also found to have a dissection of the left vertebral artery at the junction of the brachiocephalic and aortic arch. The patient subsequently underwent surgical treatment with stent placement by an interventional radiologist. Another patient had left C6 and C7 facet, comminuted transverse process, and foramen fractures who was found to have left arm weakness on physical examination. This patient was found to have a left vertebral artery laceration and underwent an open exploration and catheterization of the left vertebral artery.

Out of the 25 patients with cervical fractures and VAI, 20 (80%) were found to mainly involve the upper cervical region (C1-C3). There was a total of 8 fracture pathologies mainly involving C1, 9 involving C2, and 3 involving C3 in which there was also a VAI on CTA (Table 4). Of the 119 patients who had a cervical fracture without a VAI, 58 (49%) had fractures mainly involving the upper cervical region (C1-C3). Nineteen of which involved C1 (33%), 26 C2 (45%), 13 C3 (22%). Therefore, 8 of 27 (30%) of C1, 9 of 35 (26%) C2, and 3 of 16 (19%) C3 were identified to have VAI. In our cohort, upper cervical fractures (C1-C3) were significantly more likely to be associated with the presence of VAI compared with lower cervical fractures (C4-C7; Table 4). There was no significant difference between each upper cervical fracture location (C1, C2, C3) however, there was a trend toward significance from C3 upward to C1 (Table 4).

Table 3. Subgroups of Patients Determined by Presence or Absence of Vertebral Artery Injury (VAI) and Subsequent Intervention.

Total patients (n = 144)	VAI	Intervention
Group 1 (n = 2, 1.7%)	+	+
Group 2 (n = 23, 16%)	+	−
Group 3 (n = 119, 83%)	−	−

Table 4. Vertebral Artery Injury by Level of Cervical Spine.

Fracture Location	VAI (% of Total VAI, n = 25)	OR (95% CI), *P*
C1 (n = 27)	8 (30)	2.5 (0.9-6.6), .067
C2 (n = 35)	9 (26)	2.0 (0.8-5.1), .139
C3 (n = 16)	3 (19)	1.1 (0.3-4.2), .876
C1 through C3 (n = 78)	20 (80)	4.2 (1.5-12.0), .007

Abbreviations: VAI, vertebral artery injury; OR, odds ratio; CI, confidence interval.

Discussion

There is a paucity of literature describing the role of CTA of the head and neck in the management of the trauma patient with cervical spine fractures, especially with regard to subsequently undergoing a surgical or procedural intervention. One CTA of the head and neck exposes the patient to approximately 4000 mGy/cm and can increase the risk of radiation-induced malignancies, whereas the effective doses for AP and lateral cervical radiographs are 0.12 and 0.02 mSv.[13-15] The intravenous contrast medium administered is another risk that has to be considered in patients undergoing CTA as it can induce acute kidney injury and allergic reactions in certain patients.[16] Furthermore, the time it takes to undergo a CTA can delay intervention for other acute injuries that are time sensitive in nature, while also preventing other patients indicated for the diagnostic procedure from utilizing the CT machine. Additionally, CTA of the head and neck is an expensive invasive procedure that can result in further financial burden on the patient. The use of CTA to evaluate for BVCI in the trauma setting has been increasing in the past decade, regardless of the aforementioned patient risks, and with little difference in stroke likelihood.[17] The purpose of this study was to analyze the role of

CTA in the management of trauma patients with cervical spine fractures, information that can be useful in reducing undue risks and cost to such patients.

Despite its common use in the workup of the trauma patient with a cervical fracture, CTA rarely plays a role in changing the acute clinical management of these patients. In this study, we found that only 2 (1.4%) of the CTAs performed on patients with a cervical fracture led to a surgical or interventional procedure, despite 25 (17.4%) of the 144 patients examined having a positive finding of traumatic VAI (such as dissection, laceration and occluded flow). In 2014, Hagedorn et al[13] elucidated the issue of evaluating the use of CTA in the trauma setting of cervical fracture by the incidence of VAIs found by the procedure. They found a similar rate of positive findings on CTA to ours at 20%. Those findings only changed the surgical management of the patient's cervical fracture in 1 case out of 126 evaluated, similar to our results. Furthermore, Tobert et al[18] performed a propensity matched analysis comparing patients who underwent CT alone to those who underwent both CT + CTA. In their CT + CTA cohort of 644 patients, they found a rate of VAI (17.5%) that was almost identical to our 17.4%. They also found a comparably low rate of posterior stroke (0.9%) and adverse bleeding events.

According to the protocol utilized by Hagedorn et al,[13] in the setting of the trauma patient with a cervical fracture, it is only necessary to obtain an urgent CTA in those patients who have a neurologic deficit or fracture pattern previously described as high risk for traumatic VAI such as subluxations or dislocations, C1-C3 fractures, or any fracture involving the foramen transversarium. Our series found, similarly, that 20 of the 25 (80%) diagnosed VAIs were found to involve the C1-C3 region. Furthermore, 5 of the 16 (31.3%) patients with VAI that were able to be examined had new neurologic deficits found on physical examination.

It is interesting to note the locations of the cervical spine fractures in the 2 patients that underwent intervention for their VAI. One patient had a fracture involving the C2 body and posterior elements, and the other had a fracture involving the C6 and C7 facet, transverse process and foramen. As noted previously, upper cervical fractures have been described as high risk injuries for VAI.[13,19] However, fractures involving the foramen transversarium, particularly at the C6 level where the vertebral artery enters the vertebrae (or C7 in some individuals), have been described as a high-risk region for VAI as well.[7] Because of its natural anatomic course, the vertebral artery may be more vulnerable at these locations, where it enters and exits the cervical spine, as it is not contained within the bony vertebrae and lacks rigid support (Figure 1).

In a review of the literature performed by Fassett et al[2] in 2008, the authors found that 70% of all traumatic VAIs were found to have an associated cervical spine fracture. Therefore, cervical CTA may be considered to evaluate for VAIs in patients with cervical fractures, however the utility of this diagnostic test remains controversial. They further concluded that there is a lack of class 1 evidence to support strong guidelines for the treatment of asymptomatic VAIs. In 2014, Hagedorn et al[13] reviewed their institution's practice of ordering CTAs retrospectively in patients with cervical fractures and compared it with their protocol in a study involving 126 patients. They found CTAs ordered off protocol had a very low likelihood of having a VAI, the incidence of CTA changing the surgical intervention of the patient was likewise low (1 of 126, 0.8%), and C1-C3 spine injuries have an increased association with VAI. Similarly, in a retrospective study ranging 10 years and encompassing 732 patients, Lockwood et al[20] found that C1 and C2 fractures along with those involving the foramen transversarium and subluxation injuries, were associated with an increased risk of VAI. Additionally, they found that only 7.8% (4 of 51) of these VAIs and 0.6% (10 of 732) of all CTAs conducted, ended up with a posterior stroke. Thus, the clinical information of gained from CTA in the acute setting is called into question by this finding. More recently, a study in 2017 by Dreger et al[21] involving 108 patients found that only 4 (3.7%) received treatment.

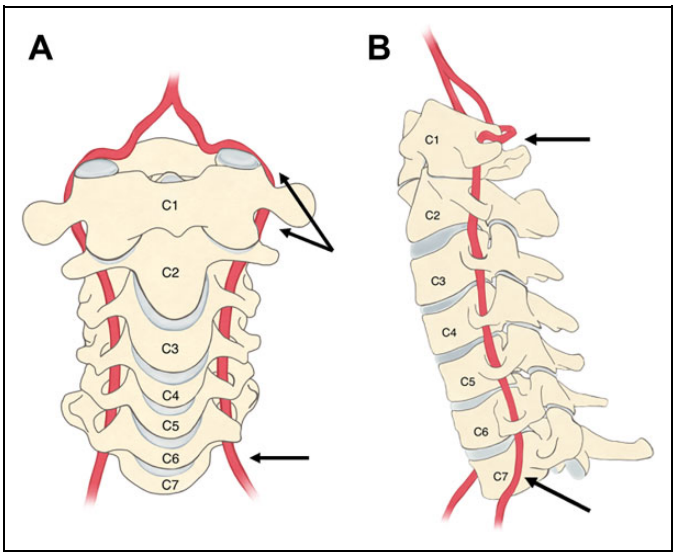

Figure 1. Illustrations of both (A) anteroposterior (AP), and (B) lateral views of the cervical spine demonstrating the anatomic course of the vertebral artery. The vertebral artery is exposed before it enters the cervical spine via C6 transverse foramen and as it exits the cervical spine (shown by arrows), areas where it may be more vulnerable to injury.

While most studies suggest that observation or anticoagulation are safe options in the acute setting of asymptomatic VAI, rarely is endovascular intervention necessary and thus, the positive finding often does not change the acute management of the patient's cervical fracture, or other acute injuries.[22] Furthermore, due to concomitant injuries, anticoagulation must often wait until after other issues, such as subdural bleeds and surgical intervention, resolve. Although CTA may increase identification of VAIs, stroke, and other preventable adverse events in these patients remain low.[18] The consistency of findings by these studies, in addition to our own, highlights the necessity of an established protocol at institutions that involves consideration of orthopedic literature to

create a patient specific and cost-effective evaluation. We theorize that the lack of clinical importance issued by the findings of this time-consuming procedure can delay the initiation of time sensitive treatment for the cervical fracture or other acute injuries in the trauma setting.

There were several limitations of this study. Our review was retrospective and took place at a single institution. Our search could not evaluate patients with fatal injuries that did not reach our hospital with VAIs. It is also possible that traumatic VAI findings on CTA of the head and neck altered the decision making of a treating surgeon, influencing them to delay or prefer non-operative treatment over surgical intervention of cervical fractures. In this case, the CTA would have provided valuable information and changed the clinical management of the patient directly. Furthermore, although our study population showed a high incidence of VAIs associated with upper cervical spine fractures (C1-C3), these are not the only high-risk injuries for VAIs.[23] Future studies should be directed in a prospective and multicenter manner at level-1 trauma centers in order to evaluate protocols by their effect on the change in clinical management of patients with cervical fractures.

Conclusions

CTA of the head and neck may be overutilized in the setting of a diagnosed cervical fracture. Patients with upper cervical fractures (C1-C3) were more likely to sustain a traumatic VAI; however, they were rarely treated with an invasive procedure. There may also be an association between VAI and neurological deficits localized to the side of the injury. Therefore, VAI should be considered in patients with cervical spine fractures who present with unexplained neurologic deficits. We recommend that CTA of the head and neck should be reserved for high-risk patients. Institutions should self-evaluate their utilization of CTA in the setting of cervical fracture in order to create a judicious protocol based on the clinical outcomes of these patients with input from the orthopedic/neurosurgical team.

Authors' Note

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References

1. Bromberg WJ, Collier BC, Diebel LN, et al. Blunt cerebrovascular injury practice management guidelines: the Eastern Association for the Surgery of Trauma. *J Trauma*. 2010;68:471-477.
2. Fassett DR, Dailey AT, Vaccaro AR. Vertebral artery injuries associated with cervical spine injuries: a review of the literature. *Clin Spine Surg*. 2008;21:252-258.
3. Biffl WL, Moore EE, Ryu RK, et al. The unrecognized epidemic of blunt carotid arterial injuries: early diagnosis improves neurologic outcome. *Ann Surg*. 1998;228:462-470.
4. Eskander MS, Drew JM, Aubin ME, et al. Vertebral artery anatomy: a review of two hundred fifty magnetic resonance imaging scans. *Spine (Phila Pa 1976)*. 2010;35:2035-2040.
5. Miller PR, Fabian TC, Croce MA, et al. Prospective screening for blunt cerebrovascular injuries: analysis of diagnostic modalities and outcomes. *Ann Surg*. 2002;236:386-395.
6. Park JH, Kim JM, Roh JK. Hypoplastic vertebral artery: frequency and associations with ischaemic stroke territory. *J Neurol Neurosurg Psychiatry*. 2007;78:954-958.
7. Scott WW, Sharp S, Figueroa SA, Madden CJ, Rickert KL. Clinical and radiological outcomes following traumatic Grade 1 and 2 vertebral artery injuries: a 10-year retrospective analysis from a Level 1 trauma center. *J Neurosurg*. 2014;121:450-456.
8. Ding T, Maltenfort M, Yang H, et al. Correlation of C2 fractures and vertebral artery injury. *Spine (Phila Pa 1976)*. 2010;35:E520-E524.
9. Inamasu J, Guiot BH. Vertebral artery injury after blunt cervical trauma: an update. *Surg Neurol*. 2006;65:238-245.
10. Oetgen ME, Lawrence BD, Yue JJ. Does the morphology of foramen transversarium fractures predict vertebral artery injuries? *Spine (Phila Pa 1976)*. 2008;33:E957-E961.
11. Even J, McCullough K, Braly B, et al. Clinical indications for arterial imaging in cervical trauma. *Spine (Phila Pa 1976)*. 2012;37:286-291.
12. Biffl WL, Moore EE, Offner PJ, et al. Optimizing screening for blunt cerebrovascular injuries. *Am J Surg*. 1999;178:517-522.
13. Hagedorn JC 2nd, Emery SE, France JC, Daffner SD. Does CT angiography matter for patients with cervical spine injuries? *J Bone Joint Surg*. 2014;96:951-955.
14. Samartzis D, Nishi N, Hayashi M, et al. Exposure to ionizing radiation and development of bone sarcoma: new insights based on atomic-bomb survivors of Hiroshima and Nagasaki. *J Bone Joint Surg*. 2011;93:1008-1015.
15. Simpson AK, Whang PG, Jonisch A, Haims A, Grauer JN. The radiation exposure associated with cervical and lumbar spine radiographs. *J Spinal Disord Tech*. 2008;21:409-412.
16. Saljoughian M. Intravenous radiocontrast media: a review of allergic reactions. *US Pharm*. 2012;37:HS14-HS16.

17. Newhall K, Gottlieb DJ, Stone DH, Goodney PP. Trends in the diagnosis and outcomes of traumatic carotid and vertebral artery dissections among Medicare beneficiaries. *Ann Vasc Surg*. 2016; 36:145-152.
18. Tobert DG, Le HV, Blucher JA, Harris MB, Schoenfeld AJ. The clinical implications of adding CT angiography in the evaluation of cervical spine fractures: a propensity-matched analysis. *J Bone Joint Surg Am*. 2018;100:1490-1495.
19. Cothren CC, Moore EE, Ray CE Jr, Johnson JL, Moore JB, Burch JM. Cervical spine fracture patterns mandating screening to rule out blunt cerebrovascular injury. *Surgery*. 2007;141:76-82.
20. Lockwood MM, Smith GA, Tanenbaum J, et al. Screening via CT angiogram after traumatic cervical spine fractures: narrowing imaging to improve cost effectiveness. Experience of a Level I trauma center. *J Neurosurg Spine*. 2016;24:490-495.
21. Dreger T, Place H, Mattingly T, Piper C, Brechbuehler J. Analysis of cervical angiograms in cervical spine trauma patients, does it make a difference? *Clin Spine Surg*. 2017; 30:232-235.
22. Miller PR, Fabian TC, Bee TK, et al. Blunt cerebrovascular injuries: diagnosis and treatment. *J Trauma*. 2001;51: 279-286.
23. Lebl DR, Bono CM, Velmahos G, Metkar U, Nguyen J, Harris MB. Vertebral artery injury associated with blunt cervical spine trauma: a multivariate regression analysis. *Spine (Phila Pa 1976)*. 2013;38:1352-1361.