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Original Article

Can the position of the vertebral artery be predicted on a lateral view X-ray of the craniovertebral junction? A radiological anatomy study

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Abstract

Background: The most feared complication while inserting C2 screws is vertebral artery injury. This article proposes predicting the position of the vertebral artery on a true lateral X-ray of the axis vertebra from the background information acquired from the computed tomography (CT) scan utilizing fluoroscopy.

Methods: Spiral CT scans of 33 C2 vertebrae were performed utilizing a 16-slice CT scanner lateral X-rays of C2 were then obtained before and after painting the vertebral artery grooves with barium. The space available for transarticular and C2 pedicle screw insertion above the vertebral artery groove in the isthmus was then calculated as a ratio for both X-rays and CT scans.

Results: There was no statistically significant difference between the (mean) ratios calculated by CT scan and X-rays regarding the space available for transarticular and C2 pedicle screw insertion (left side: 0.3894 vs 0.3897; right side: 0.3892 vs 0.3925; $P > 0.05$). The Kappa test revealed that CT scan and X-ray findings were in agreement in majority of the bones (left side: $n = 24$, 72.7%, right side: $n = 22$, 73.3%; $P < 0.05$).

Conclusion: A thorough understanding of a true lateral view X-ray based on background information extracted from three dimensional CT scans helps predict the highest point of the vertebral artery groove. This proves useful for placement of C2 transarticular and pedicle screws during regular "open" and "minimally invasive" spine surgery.

Key Words: C2 pedicle screw, fluoroscopy, transarticular screw, vertebral artery

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INTRODUCTION

The most feared complication while inserting C2 screws is vertebral artery injury.[9] The use of a computer-assisted neuronavigation system does decrease this complication considerably.[8] However, the technique still has some limitations and is still evolving. The aim of the study was to predict the position of the vertebral artery on a true lateral X-ray of the axis vertebra based on the background information achieved from the computed tomography (CT) scan. The information gained from the study may be useful for traditional "open" and/or "minimally invasive" application of C1–C2 transarticular and C2 pedicle screws.

MATERIAL AND METHODS

Thirty-three adult dry axis bones were obtained from the Department of Human Anatomy. The samples were inspected to ensure that all the axes were free from anomalies and pathological destructions. Spiral CT scans of these dry axis vertebrae were done on a 16-slice scanner (Brilliance Philips). Subsequently, they were subjected to lateral view X-rays in a digital subtraction angiography suite (Siemens).

X-ray protocol

First, a true lateral view [Figure 1] was obtained by ensuring that both inferior facets and isthmus were not visualized separately. Second, the wall of the left vertebral artery foramen was painted with barium sulfate (X-ray grade) and a true lateral X-ray was obtained. Finally, the wall of the right vertebral artery foramen was painted with barium sulfate and a true lateral X-ray was taken. A tangent was drawn from the highest part of the superior arc of the ring of the axis. Three perpendicular lines were dropped on this line from: lowest point of the body of axis; most superior point of the left vertebral artery foramen; and the most superior point of the right vertebral artery foramen. Ratios for left and right sides were obtained as shown in Figure 2.

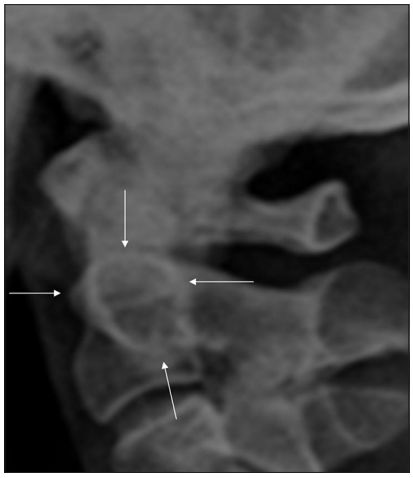

Figure 1: The normal ring of the axis (arrows). The highest point on the superior arc corresponds to the highest point of the superior articulating facets of the axis. The anterior curvilinear arc is composed of the anterior cortex of the axis at the junction of the body and its contiguous lateral structures. The superior arc is a distinct composite shadow consisting of the density produced by the cortex of the obliquely oriented superior articulating facets of the axis superimposed upon the superior cortex of the body between the dens and the superior facets. The posterior, vertical, straight arc is produced by the posterior cortex of the body of the axis. The characteristically discontinuous posteroinferior portion of the ring is caused by the foramen transversarium. The latter occasionally produces a distinct ring

Computed tomography protocol

Axial images were reconstructed (Brilliance Philips CT work station) parallel to the base of body of axis with a slice thickness of 0.5 mm. The slice that passed through the highest point of both superior facets was selected. On the workstation, the position of this cut on a midsagittal image was noted and the common denominator was measured as shown in Figure 3a and b. Coronal images were reconstructed parallel to the posterior border of the body of axis and perpendicular to its base.[7] On a parasagittal slice passing through the vertebral artery groove, the coronal cut passing through the highest point of the groove was selected individually on both sides. A tangent was passed from the highest point of the groove and the perpendicular distance from the highest point of the superior articular facet on the same side to this tangent was noted. The ratios were calculated as shown in Figure 3.

SPSS 15.0 software was used for statistical analysis. The level of significance was fixed at 0.05. Paired *t* test

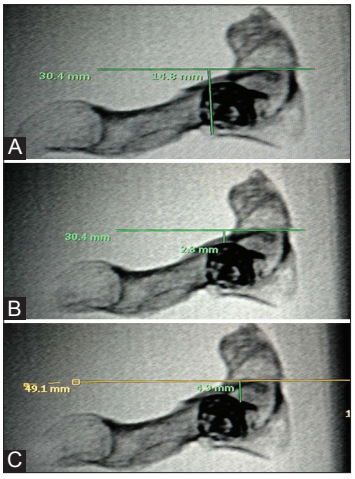

Figure 2: Lateral view X-ray taken after painting both vertebral artery grooves with barium sulfate. (A) Method of measuring common denominator (d): A perpendicular line is dropped from the posterior and inferior corner of the C2 body to a line that passes tangential to the highest point on the superior arc of the "ring of Axis". (B) A perpendicular is dropped to the same line from the top of left vertebral artery groove (outlined by barium sulfate). This is distance "a." (C) A perpendicular is dropped to the same line from the top of right vertebral artery groove (outlined by barium sulfate). This is distance "b." The X-ray ratio for left side is calculated by the formula: a/d; and on the right side by b/d

was used to compare the ratios. Kappa statistics was calculated to find out the agreement between X-ray and CT-based ratios.

RESULTS

There was no statistically significant difference between the ratios calculated by CT scan and X-rays [Table 1]. This shows that the ratio calculated by CT scan can be used to predict the highest point of the vertebral artery groove on a true lateral view X-ray individually on both sides with good accuracy [Table 1]. A kappa test was also used to look for agreement between the values. CT scan and X-ray findings were in agreement in majority of the bones (left side: n = 24, 72.7%; Table 2; right side: n = 22, 73.3%; Table 3).

Isthmus height is a universally acceptable CT parameter used to predict difficulty in inserting C1–C2 transarticular screws and C2 pedicle screws.[10] We measured this parameter on CT scan of all the 33 dry bones. On comparing the Isthmus height with the calculated ratios, we found that the mean ratios were larger when the Isthmus height was more than 5 mm [Table 4 and Figure 4]. The mean ratios as calculated by CT and X-rays were however comparable to each other in both the categories.

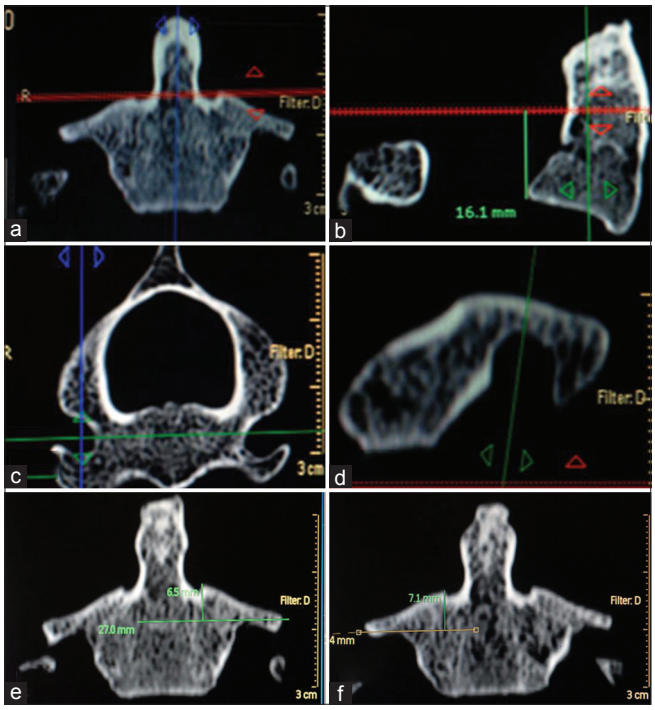

Figure 3: (a) In the coronal image, an axial slice that passes through the highest point of both superior facets is selected. On the workstation, the position of this cut on a midsagittal image (b) is noted and the common denominator is measured (z). (c) Proper coronal images are reconstructed parallel to the posterior border of C2 body as seen in axial slices.(d) A coronal image passing through the highest point of the vertebral artery groove as seen in a parasagittal cut is chosen. (e) In this selected coronal image, a tangent is drawn from the top of the left vertebral artery groove and a perpendicular (x) is dropped on it from the medial most point of the ipsilateral superior articular facet. (f) A tangent is drawn from the top of the right vertebral artery groove and a perpendicular (y) is dropped on it from the medial most point of the ipsilateral superior articular facet. Left side ratio is calculated by the formula: x/z and right side ratio by the formula: y/z

Table 1: Comparison of ratio as calculated by X-rays and CT scan (paired *t*-test)

	X-ray ratio (mean±SD)	CT ratio (mean±SD)	*P*
Left side (n=33)	0.3897±0.1059	0.3894±0.0989	0.985
Right side (n=30)*	0.3892±0.1105	0.3925±0.1237	0.750

*Ratio not available for three bones on right side

Table 2: Agreement between CT scan and X-rays-left side (Kappa: 0.405, *P*=0.018)

	CT ratio	
	<0.4 (n, %)	>0.4 (n, %)
X-ray ratio		
<0.4 (n, %)	17 (51.5)	3 (9.1)
>0.4 (n, %)	6 (18.2)	7 (21.2)

Table 3: Agreement between CT scan and X-rays-right side (Kappa: 0.429, *P*=0.018)

	CT ratio	
	<0.4 (n, %)	>0.4 (n, %)
X-ray ratio		
<0.4 (n, %)	15 (50)	5 (16.7)
>0.4 (n, %)	3 (10)	7 (23.3)

Table 4: Correlation between Isthmus height and ratios calculated on X-rays and CT

Isthmus height	X-ray ratio (n=63)	CT ratio (n=66)
≤5 mm (n=25)	0.3552±0.1191 (n=25)	0.3660±0.1207 (n=25)
>5 mm (n=41)	0.4120±0.0936 (n=38)	0.3992±0.1060 (n=41)
P (*t*-test)	0.039	0.246

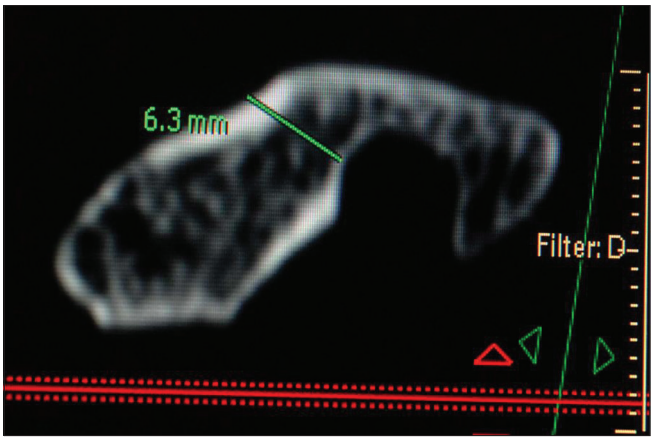

Figure 4: Isthmus height measurement

The transverse foramen of the axis was seen well on a true lateral view X-ray in the posteroinferior part of the ring in 36.4% (12/33) of the dry bones [Figure 1].

DISCUSSION

In this study, we proposed a new CT parameter in the form of a ratio, which can predict with good accuracy, the position of the highest point of the vertebral artery groove while using intraoperative fluoroscopy (separately for each side). The information can be extremely vital to avoid the feared complication of vertebral artery injury. While inserting a transarticular screw, the screw trajectory has to be superior to the vertebral artery groove. A C2 pedicle screw usually traverses superomedial or just superior to this groove.[10]

The use of spinal navigation has been shown to improve the accuracy of pedicle screw placement, also in the cervical spine.[4] However, spinal navigation is not perfect and intraoperative traction does not go very well with navigation.[2] Two large studies using lateral fluoroscopy reported 14% and 15% of screws were malpositioned.[3,6] Amiot *et al*.[1] demonstrated that 95% of pedicle screws placed with computer assisted image guidance were correctly positioned versus 85% of screws in correct position using conventional techniques. This study however shows that intraoperative fluoroscopy is probably underutilized as it could increase the accuracy of screw placement with understanding of the radiological anatomy.

Liu *et al*.[5] proposed a true lateral view of the C2 pedicle (isthmus) instead of a true lateral cervical spine view. For this, they angulated the X-ray beam 30 degrees with reference to the coronal plane to make it perpendicular to the C2 pedicle.

This study highlighted the significance of the "Ring of Axis" in inserting transarticular and C2 pedicle screws. We demonstrated that a true lateral view is a simple, reliable, and reproducible method to identify intraoperatively the position of the highest point of the vertebral artery groove at the C2 level based on assessment of 33 dry bones.

CONCLUSION

A thorough understanding of a true lateral view X-ray based on the background information extracted from a three dimensional CT scan can help to predict with good accuracy the highest point of the vertebral artery groove. This information can be very useful for regular and minimally invasive spine surgery in this region.

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Conflicts of interest
There are no conflicts of interest.

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