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Journal of Craniovertebral Junction and Spine

Original Article

Optimal measurement for "posterolateral protrusion" of the vertebral artery at the craniovertebral junction using computed tomography angiography

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Journal of Craniovertebral Junction and Spine 2014, 5:38

Abstract

Purpose: Among extraosseous abnormalities of the vertebral artery (VA) at the craniovertebral junction (CVJ), available evidence regarding "posterolateral protrusion," the VA running distant from the groove over the superior surface of the posterior arch of the atlas, is limited. The purpose of this study was to determine the optimal measurement to indicate posterolateral protrusion of the VA. **Materials and Methods:** Computed tomography angiography (CTA) images of 40 consecutive patients with cervical disease were reviewed. Ultimately, 66 arteries were included in this study. Five parameters predicted to indicate posterolateral protrusion of the VA were defined (A–E) and measured by two surgeons twice over a 2-week interval. Intraclass correlation coefficients (ICC) were used to examine intra-observer reproducibility and inter-observer reliability. Receiver operating characteristic (ROC) curve analysis was performed to determine the most optimal parameter to predict posterolateral protrusion of the VA. **Results:** Excellent inter-observer reliability and intra-observer reproducibility were obtained for all parameters (ICC = 0.87-0.99). Among them, parameter A, defined as the maximal length from the outer surface of the VA to the outer surface of the posterior arch of the atlas, was most accurately described posterolateral protrusion of the VA. The optimal cut-off value of parameter A obtained with ROC curves was 8.3 mm (sensitivity 97.5%, specificity 100%). **Conclusions:** The measurement in this study can quantitatively evaluate the posterolateral protrusion of the VA. Before posterior surgery at the CVJ, pre-operative CTA can help surgeons detect anomalous VA and reduce the risk of intra-operative VA injury.

Key words: Atlas, computed tomography angiography, posterolateral protrusion, vertebral artery

Access this article online	
Quick Response Code:	Website: www.jcvjs.com
	DOI: 10.4103/0974-8237.147077

INTRODUCTION

Among extraosseous abnormalities of the vertebral artery (VA) at the craniovertebral junction (CVJ), available evidence regarding "posterolateral protrusion," the VA running distant from the groove over the superior surface of the posterior arch of the atlas, is limited.[1] The purpose of this study was to determine the optimal measurement to indicate posterolateral protrusion of the VA. We modified previously reported parameters to have greater clinical relevance and to quantitatively evaluate this condition. We also briefly present some cases of posterolateral protrusion of the VA.

MATERIALS AND METHODS

Data source

Computed tomography angiography (CTA) images of 40 consecutive patients with cervical disease that were collected in Yokohama Rosai Hospital between March 2006 and March 2013 were retrospectively reviewed. Four cases with injuries involving atlantoaxial lesions including fractures and traumatic atlantoaxial dislocation were excluded. Images from two patients were not adequate for assessment. Two VAs could not be measured due to their occlusion. Of the 80 arteries in 40 patients, 66 arteries were ultimately included in this study. The patients included 17 men and 17 women ranging from 15 to 79 years of age.

CTA imaging conditions

CTA was performed with a 64-slice computed tomography (CT) scanner (Aquillion; Toshiba Medical Systems, Tokyo, Japan). Imaging parameters were as follows: 0.5 mm slice thickness, 0.75 s/rotation, 120 kV, and 300 mA. Reconstruction was performed based on images with a slice thickness of 1.0 mm. Image scanning was acquired 15 s after intravenous injection of 53 ml non-ionic contrast medium at a rate of 4 ml/s. For measurement, reconstructed axial slices were created parallel to the line connecting the anterior and posterior arch of the atlas.

Definition of parameters

The five parameters predicted to reflect posterolateral protrusion of the VA were measured on reconstructed axial CTA images. These parameters were defined according to a modification of the parameters of Yamaguchi *et al.*,[1] as follows [Figure 1]: A) distance from the outer surface of the VA to the outer surface of the posterior arch of the atlas; B) distance from the midline of the atlas to the most protrusive part of the VA; C) distance from the midline to the intersection of the outer surface of the VA with the outer cortex of the posterior arch of the atlas; D) distance from the posterior tubercle of the posterior arch of the atlas to the intersection described for parameter C; E) distance from the posterior surface of the superior facet of the atlas to the posterior edge of the protrusion.

CTA measurements

Two observers measured the five parameters to evaluate inter-observer reliability. The second measurements were collected 2 weeks after the first, and the two sets were compared to evaluate intra-observer reproducibility. A spine surgeon diagnosed the posterolateral protrusion of the VA by reviewing CTA. Sensitivity and specificity were calculated for the accuracy of the five parameters. Receiver operator characteristic (ROC) analysis was performed for each group.

Statistical analysis

The intraclass correlation coefficient (ICC) was used to assess the inter-observer reliability and intra-observer reproducibility in evaluating the posterolateral protrusion. ICC less than 0.40 was defined as poor, 0.40-0.60 as fair, 0.60-0.74 as good, and 0.75-1.00 as excellent.[2] ROC curves and the corresponding area under the curve (AUC) were used to evaluate the performance of the prediction model using the CTA measurements. ROC curves plot the true-positive rate (sensitivity) vs. the false-positive rate (1-specificity) at a continuum of thresholds; participants were classified as having a posterolateral protrusion if their estimated probability of protrusion exceeded a particular threshold. Statistical Package for the Social Sciences (SPSS) version 20 (SPSS, Chicago, IL, USA) was used for all statistical analyses.

RESULTS

Measurements

Five parameters were measured in 66 arteries by two observers using CTA. The mean lengths of the five parameters are shown in Table 1.

Reliability and reproducibility of measurements

Intra-observer reproducibility between the two sets of measurements by the senior and junior observers and inter-observer reliability between measurements carried out by the two observers are shown in Table 2. Intra-observer reproducibility and inter-observer reliability for all parameters were excellent (ICC = 0.96-0.99 and ICC = 0.87-0.99, respectively).

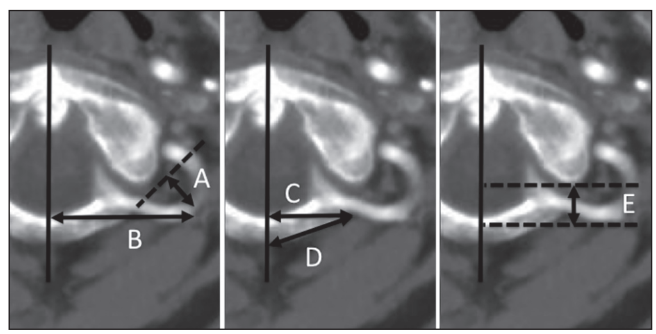

Figure 1: Reconstructed computed tomography angiography (CTA) at the atlas: Arrows in each panel represent the parameters. Five parameters (A, B, C, D, and E) are defined. See Methods for details on the definition of parameters

Table 1: Five parameters measured by the two observers in duplicate using computed tomography angiography (mm ± SD)

Parameters	Observer 1		Observer 2	
	Session 1	Session 2	Session 3	Session 4
Parameter A	7.6± 3.3	7.5± 3.3	8.2± 3.2	8.3± 3.4
Parameter B	29.6± 3.2	29.5± 3.2	29.8± 3.2	29.5± 3.1
Parameter C	19.3± 3.0	19.4± 3.3	19.2± 3.0	19.0± 3.0
Parameter D	21.4± 3.8	21.5± 3.7	21.5± 3.5	21.2± 3.9
Parameter E	8.6± 2.2	8.6± 2.2	8.0± 2.2	8.1± 2.3

SD = standard deviation

Relationships between parameters

Strong correlations were found between parameters A and B, and between parameters C and D [r = 0.78 and 0.81, Table 3]. Moderate correlations were found between parameters B and C, parameters B and D, and parameters A and E [r = 0.42 to 0.49, Table 3]. The correlations between A and C, A and D, B and E, C and E, and D and E were weak [r = -0.30 to 0.29, Table 3].

ROC analysis

ROC curves illustrated the accuracy of the five parameters measured using CTA to predict posterolateral protrusion of the VA [Figure 2]. The AUC for parameter A was 0.998 (95% confidence interval [CI], 0.99-0.9998). AUC comparison revealed that parameter A significantly differed from the other parameters, with AUC values of 0.81 (95% CI, 0.69-0.89) for B, 0.63 (95%CI, 0.50-0.74) for C, 0.57 (95%CI, 0.44-0.69) for D, and 0.75 (95%CI, 0.62-0.84) for E. The cut-off value of parameter A obtained with ROC analysis was 8.3 (sensitivity 97.5%, specificity 100%). Cut-off values of the other parameters were 30.6 for B (sensitivity 77.5%, specificity 85.0%), 19.0 for C (sensitivity 60.0%, specificity 75.0%), 25.1 for D (sensitivity 17.5%, specificity 100%), and 8.2 for E (sensitivity 75.0%, specificity 72.5%).

CASE PRESENTATION

Case 1

An 81-year-old woman with incomplete spinal cord injury due to subaxial cervical spine fracture underwent fusion surgery. Pre-operative axial reconstruction CTA showed posterolateral protrusion of the bilateral VA [Figure 3a], which differed from the well-known imaging finding of bilateral VA contained in the groove of the posterior arch of the atlas [Figure 3b]. Parameter A measured using axial reconstruction CTA was 12.3 mm for the right VA and 11.9 mm for the left VA.

Case 2

A 65-year-old woman presented with progressive myelopathy secondary to atlantoaxial instability. Axial reconstruction CTA revealed bilateral VA running posterolaterally [Figure 4a]. The 3D reconstruction images from CTA also showed that the posterolateral portion of the bilateral VA deviated from the groove of the posterior arch of the atlas. Particularly, left dominant VA was recessed, caught between the posterior arch of the atlas and occipital bone [Figure 4b]. Pre-operative CTA revealed that the left VA, running slightly caudally, could suffer intra-operative injury during the procedure to insert a left C1 lateral mass screw. The results of measurement for parameter A were 11.0 mm for the right VA and 14.3 mm for the left VA.

Case 3

A 70-year-old man presented with myelopathy in association with atlantoaxial instability. Axial and 3D reconstruction CTA showed posterolateral protrusion of the right VA, whereas the left side was in the groove [Figure 5a and b]. Parameter A of the right VA was 9.4 mm, whereas on the left it was 2.7 mm. Atlantoaxial fusion surgery was performed successfully, with attention to VA injury on exposure of the posterior arch of the atlas, especially in the right lateral direction.

Table 2: Intra-observer reproducibility and inter-observer reliability: ICC values regarding posterolateral protrusion of the VA evaluated for each parameter (ICC, 95% CI)

ICC values	Intra-observer		Inter-observer	
Parameter A	0.99	(0.98-0.997)	0.99	(0.96-0.99)
Parameter B	0.98	(0.96-0.99)	0.89	(0.75-0.97)
Parameter C	0.96	(0.91-0.98)	0.87	(0.70-0.95)
Parameter D	0.96	(0.91-0.98)	0.87	(0.71-0.95)
Parameter E	0.97	(0.93-0.99)	0.87	(0.71-0.95)

ICC = intraclass correlation coefficient; CI = confidence interval

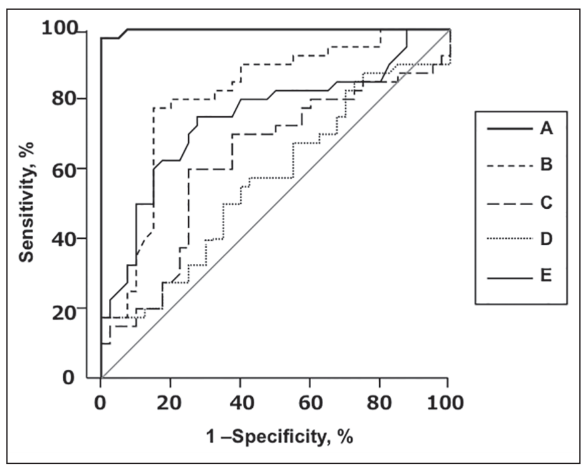

Figure 2: Receiver operator characteristic (ROC) curves demonstrated the relative ability of the five parameters to predict posterolateral protrusion of the vertebral artery (VA). Area under the curve (AUC) for parameter A was 0.998, whereas 0.81 for B, 0.63 for C, 0.57 for D, and 0.75 for E

Table 3: Matrix of correlations between each parameter: R values after the pearson test (r, 95% CI)

R values	Parameter B		Parameter C		Parameter D		Parameter E	
Parameter A	0.78	(0.67-0.85)	0.02	(−0.20-0.24)	0.29	(0.08-0.48)	0.48	(0.29-0.63)
Parameter B			0.42	(0.22-0.58)	0.49	(0.30-0.64)	0.18	(−0.04-0.38)
Parameter C					0.81	(0.71-0.87)	−0.30	(−0.49-0.08)
Parameter D							−0.24	(−0.44-0.02)

CI = confidence interval

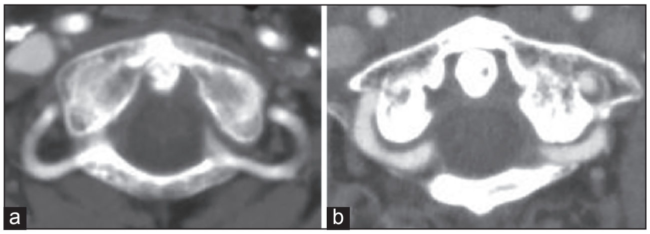

Figure 3: Axial computed tomography angiography (CTA) in Case 1 (a) showing posterolateral protrusion of bilateral vertebral artery (VA), which was differentiated compared to CTA in a different patient (b), whose bilateral VA was contained in the groove of the posterior arch of the atlas

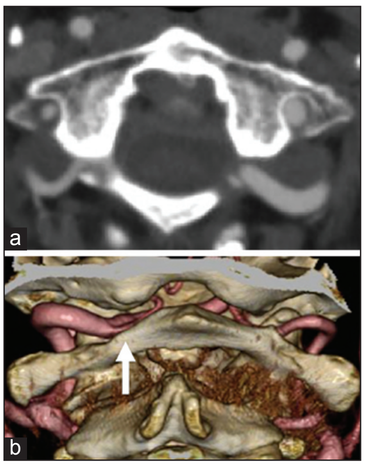

Figure 4: Axial computed tomography angiography (CTA) in Case 2 (a) showing posterolateral protrusion of bilateral vertebral artery (VA). 3D CTA images in Case 2 (b) showing left dominant VA recessed by being caught between the posterior arch of the atlas and occipital bone (white arrow)

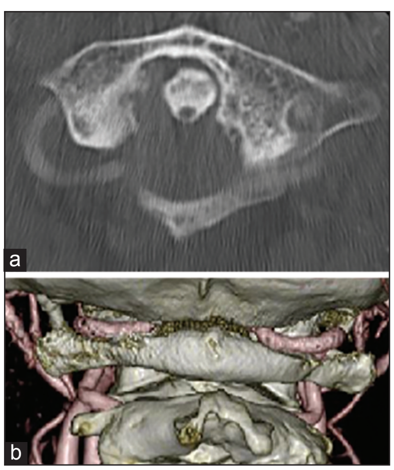

Figure 5: Axial and 3D computed tomography angiography (CTA) in Case 3 (a, b) showing posterolateral protrusion of the right vertebral artery (VA), whereas left VA was in the groove of the posterior arch of the atlas

DISCUSSION

This study is the first report regarding quantitative measurements to detect posterolateral protrusion of the VA using image examination. Although instrumentation surgery for cervical disorders has become widespread, these surgical procedures may carry the risk of VA injury. Intraoperative VA injury can cause severe complications such as cerebral infarction, massive bleeding, and even death.[3-7] Therefore, preoperative evaluations to determine the route of the VA at cervical vertebrae are of great significance to prevent VA injury and subsequent consequences. In this study, five parameters predicted to represent this condition were measured, and all parameters were assessed with excellent agreement with respect to inter-observer reliability and intra-observer reproducibility. ROC curve analysis revealed the predictive accuracy of the parameters, and the AUC for parameter A in particular was excellent and significantly greater than those of the other parameters. The findings of this study established a quantitative measurement strategy to identify posterolateral protrusion of the VA.

Extraosseous parts of the VA, as well as the intraosseous parts, are exposed to a high risk for VA injury. First, fusion surgery using screws at C1 or C2 requires wide exposure at the craniovertebral junction, which can cause VA injury to the extraosseous region during posterior exposure.[8] Also, a case of VA injury due to superior tap deviation during C1 lateral mass screw fixation has been reported.[9] Thus, surgeons should also exercise great caution against extraosseous VA injury when inserting such devices. Moreover, novel navigation system-based techniques for cervical instrument insertion cannot prevent injury to the extraosseous VA, although they can help surgeons insert instrumentation without injury to the intraosseous VA.[10,11] A recent large-scale study demonstrated the timing of VA injury during operative procedures and revealed that 20% of VA injuries occurred during surgical exposure.[12] In particular, posterior exposure was reported to be a relatively common situation of VA injury following posterior instrumentation of the upper cervical spine and anterior corpectomy. These findings suggest that surgeons should also pay attention to extraosseous abnormality of the VA, which carries the risk for VA injury during exposure, in addition to intraosseous abnormality such as high-riding VA, which should be a focus of attention during instrumentation. Because VA anomalies in the extraosseous region, including posterolateral protrusion, cannot be detected intra-operatively even with a navigation system, pre-operative evaluation of the VA course is important.

Although recent studies on extraosseous abnormality of the VA at the CVJ have been reported,[8,13,14] available evidence regarding posterolateral protrusion is limited. A few cadaver studies described lateral protrusion of the VA. Cassiola *et al.*, reported that the VA did not occupy the entire vertebral artery groove on the inferior surface of the superior articular facet and over the posterior arch of the atlas in their cadaver study.[15] Previous cadaveric and angiographic study demonstrated that the VA of elderly patients and the dominant VA had a tendency to be ectatic, bulging out from the C-1 groove, and therefore carried greater risk of injury during lateral exposure of the posterior skull base.[16] However, available studies on image findings quantitatively evaluating this phenomenon are limited. Yamaguchi *et al.*, termed a VA adopting a protrusive course posterolaterally over the posterior arch of the atlas as posterolateral protrusion of the vertebral artery.[1] Although measurements for this condition in their study using CTA included five parameters, two of those parameters were similar, reflecting the distance from the midline to the intersection of the VA outer surface with the cortex of the posterior arch of the atlas. The only difference was whether outer or inner cortex of the posterior arch of the atlas was considered. However, the latter is not significant clinically, because exposure of the craniovertebral junction is performed through the outer side of the atlas. Therefore, we omitted this parameter and added two additional parameters, parameter D and E in this study, representing a view of the surgical field from posterior approach and the posterior component of protrusion. Finally, we identified five relatively more clinically important parameters.

The measurements of posterolateral protrusion were quantitatively evaluated in this study. The interobserver reliability and intraobserver reproducibility of quantitative posterolateral protrusion measurements in this study were excellent for all parameters, exceeding the ICC threshold of 0.75 indicating acceptability.[17] Previous studies have not evaluated the reliability and reproducibility of measurement parameters. Some parameters demonstrated strong associations upon analysis of correlation coefficients. Such strong correlations may result from measuring the same aspect of the VA protrusion. Parameter B measured the distance from midline to the posterolateral edge of the protrusion defined by parameter A. Additionally, parameters C and D measured the distance from a certain point to the intersection of the outer surface of the VA and outer cortex of the posterior arch of the atlas. These results suggested that measuring similar parameters that represent the same aspect appears unnecessary.

The accuracy of the five parameters to predict posterolateral protrusion of the VA on CTA was evaluated using ROC analysis. Parameters A, B, and E were above the threshold for acceptability (AUC >0.7),[18] whereas parameters C and D were not. Among the acceptable parameters, parameter A predicted posterolateral protrusion of the VA with the highest accuracy, and a cut-off value of 8.3 mm (sensitivity 97.5%, specificity 100%) was determined as the most useful to define this condition on CTA.

The measurement of posterolateral protrusion in this study using CTA is relatively easy because CTA has already become a routine tool before surgical treatment at the CVJ based on the superiority of CTA over MRI in terms of accurate depiction of the VA, surrounding osseous tissue, and their reciprocal anatomy, which aids in spatial analysis with unrestricted image reconstruction.[8,14] Surgeons should evaluate the directionality of the VA with preoperative imaging and be well versed in various VA anomalies at the CVJ.[8] When considering surgery at the CVJ in patients with Down syndrome, pre-operative CTA was reported to be of further importance for precisely identifying abnormal courses of the VA, which are more prevalent in patients with some congenital disease.[14] However, whether posterolateral protrusion of the VA is associated with a specific disease condition remains unknown.[1] We believe that the measurements in this study provide a basis for future research to examine the association between this phenomenon and disease conditions.

This study has several limitations. First, our sampling strategy may cause selection bias, because CTA was used to assess patients with cervical disease. However, such bias may be unavoidable considering that the inclusion of healthy participants in this study would have ethical problems due to the invasiveness of contrast radiography. Second, the two observers were able to identify the presence of this phenomenon in appearance while measuring the parameters using CTA, which can lead to diagnostic suspicion bias. Such bias could not be prevented in a quantitative evaluation using image examination such as the present study, because no blind method was available. Finally, observers measured the parameters on two-dimensional reconstructed axial slices. In some cases, the VA ran caudally in addition to posterolaterally distant from the groove of the atlas. For more accurate measurement of posterolateral protrusion of the VA, three-dimensional images may be effective.

In conclusion, the measurement in this study can evaluate one extraosseous abnormality of the VA, posterolateral protrusion, quantitatively. Before posterior surgery with instrumentation or wide exposure at the CVJ, preoperative CTA should be performed to detect this VA anomaly and reduce the risk of intraoperative VA injury.

REFERENCES

1. Yamaguchi S, Eguchi K, Kiura Y, Takeda M, Kurisu K. Posterolateral protrusion of the vertebral artery over the posterior arch of the atlas: Quantitative anatomical study using three-dimensional computed tomography angiography. J Neurosurg Spine 2008;9:167-74.
2. Fleiss JL. Reliability of measurement. In: Fleiss JL, editor. The Design and Analysis of Clinical Experiments. Toronto: Wiley; 1986. p. 1-32.
3. Burke JP, Gerstzen PC, Welch WC. Iatrogenic vertebral artery injury during anterior cervical spine surgery. Spine J 2005;5:508-14.
4. Neo M, Fujibayashi S, Miyata M, Takemoto M, Nakamura T. Vertebral artery injury during cervical spine surgery: A survey of more than 5600 operations. Spine (Phila Pa 1976) 2008;33:779-85.
5. Russo VM, Graziano F, Peris-Celda M, Russo A, Ulm AJ. The V (2) segment of the vertebral artery: Anatomical considerations and surgical implications. J Neurosurg Spine 2011;15:610-9.
6. Park HK, Jho HD. The management of vertebral artery injury in anterior cervical spine operation: A systematic review of published cases. Eur Spine J 2012;21:2475-85.
7. Wang M. Death due to extensive cervicomedullary infarction following iatrogenic vertebral artery occlusion. Forensic Sci Med Pathol 2012;8:334-7.
8. Yamazaki M, Okawa A, Furuya T, Sakuma T, Takahashi H, Kato K, *et al*. Anomalous vertebral arteries in the extra- and intraosseous regions of the craniovertebral junction visualized by 3-dimensional computed tomographic angiography: Analysis of 100 consecutive surgical cases and review of the literature. Spine (Phila Pa 1976) 2012;37:E1389-97.
9. Aota Y, Honda A, Uesugi M, Yamashita T, Baba N, Niwa T, *et al*. Vertebral artery injury in C-1 lateral mass screw fixation. Case illustration. J Neurosurg Spine 2006;5:554.
10. Ishikawa Y, Kanemura T, Yoshida G, Matsumoto A, Ito Z, Tauchi R, *et al*. Intraoperative, full-rotation, three-dimensional image (O-arm)-based

navigation system for cervical pedicle screw insertion. J Neurosurg Spine 2011;15:472-8.
11. Uehara M, Takahashi J, Hirabayashi H, Hashidate H, Ogihara N, Mukaiyama K, *et al*. Computer-assisted C1-C2 transarticular screw fixation "Magerl Technique" for Atlantoaxial instability. Asian Spine J 2012;6:168-77.
12. Lunardini DJ, Eskander MS, Even JL, Dunlap JT, Chen AF, Lee JY, *et al*. Vertebral artery injuries in cervical spine surgery. Spine J 2014;14:1520-5.
13. Hong JT, Lee SW, Son BC, Sung JH, Yang SH, Kim IS, *et al*. Analysis of anatomical variations of bone 1 and vascular structures around the posterior atlantal arch using three-dimensional computed tomography angiography. J Neurosurg Spine 2008;8:230-6.
14. Yamazaki M, Okawa A, Hashimoto M, Aiba A, Someya Y, Koda M. Abnormal course of the vertebral artery at the craniovertebral junction in patients with Down syndrome visualized by three-dimensional CT angiography. Neuroradiology 2008;50:485-90.
15. Cacciola F, Phalke U, Goel A. Vertebral artery in relationship to C1-C2 vertebrae: An anatomical study. Neurol India 2004;52:178-84.
16. Ulm AJ, Quiroqa M, Russo A, Russo VM, Graziano F, Velasquez A, *et al*. Normal anatomical variations of the V_3 segment of the vertebral artery: Surgical implications. J Neurosurg Spine 2010;13:451-60.
17. Portney LG, Watkins MP. Part II: Concepts of Measurement, 5. Reliability of Measurements. In Portney LG, Watkins MP. Foundations of Clinical Research: Applications to Practice. 3rd ed. Upper Saddle River. 2009.
18. Hosmer DW, Lemeshow S. Assessing the fit of the model. In: Hosmer DW, Lemeshow S, editors. Applied logistic regression, 2nd edn. New York: Wiley; 2000. p. 143–202

How to cite this article: Ohya J, Miyoshi K, Oka H, Matsudaira K, Fukushima M, Nagata K. Optimal measurement for "posterolateral protrusion" of the vertebral artery at the craniovertebral junction using computed tomography angiography. J Craniovert Jun Spine 2014;5:151-6.

Source of Support: Nil, **Conflict of Interest:** None declared.