

Is the Vertebral Posterior Line a Safety Landmark for Cervical Posterior Screw Insertion? – Radiological Study of the Vertebral Artery in the Cervical Spine

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Abstract

At posterior cervical fixation, iatrogenic injury of the vertebral artery (VA) must be avoided. As the VA is usually located in front of the posterior line of the vertebral body, intraoperative lateral fluoroscopy is used to identify the line. We investigated in how many of 105 patients (210 VAs) this line is a safe marker. We also inspected the original cervical magnetic resonance angiograms (MRA) of 105 consecutive patients who had been treated for other than cervical spine diseases to study some anatomical characteristics of the VA in the cervical spine. The distance from the posterior line of the vertebral body to the posterior VA surface was classified as safe, as requiring attention, and as unsafe. Among the 210 VAs, four hypoplastic vessels were excluded from this study; consequently, 206 VAs were available for assessment. The average distance exceeded 6 mm, it was shorter at the upper cervical level. Although in at least 200 VAs (97.1%) the distance between C4 and C7 was safe, in only 170 VAs (82.5%) was it safe at C3. We observed a total of 31 tortuous loops in 17 VAs; their presence had a significant negative effect on the usefulness of the safety line. Although the posterior line of the vertebral body may be useful for safe screw insertion at the C4–C7 level, it may be less useful at C3. In the presence of tortuous VA loops, close attention must be paid to the reliability of the safety line during cervical spine surgery.

Key words: cervical spine, cervical posterior fusion, complication, vertebral artery

Introduction

In patients undergoing cervical spine surgery, iatrogenic vertebral artery (VA) injury must be avoided. Posterior cervical fixation using lateral mass- or transarticular screws is a common technique for treating instability of the cervical spine due to trauma, degenerative spondylosis, or neoplasms. Although the risk for VA injury is lower than upon the insertion of pedicle screws, when lateral mass- or transarticular screws are too long or incorrectly directed, the VA may be injured because the vessel is located close to the front of the lateral mass.^{1–3)} Intraoperative lateral

fluoroscopy shows the sagittal direction and depth of the screws but not the direct distance to the VA (Fig. 1).²⁾ Although lateral mass screws, inserted in a slightly lateral direction, are recommended to avoid VA injury, we used the posterior line of the vertebral body as one landmark because the VA is usually located in front of this safety line.

Anatomical VA variations, e.g. an anomalous VA entry into the transverse foramen and tortuous VA loops with or without bony erosion have been reported.^{4–7)} To prevent VA injury during cervical anterior fusion, the presence of tortuous VA loops must be ruled out.^{4,5,8–11)} The effect of anatomical VA variations on the safety of screw insertion for cervical posterior fixation needs attention.

To ascertain the usefulness of this safety line in the general population, we inspected magnetic resonance imaging (MRI) scans and measured the

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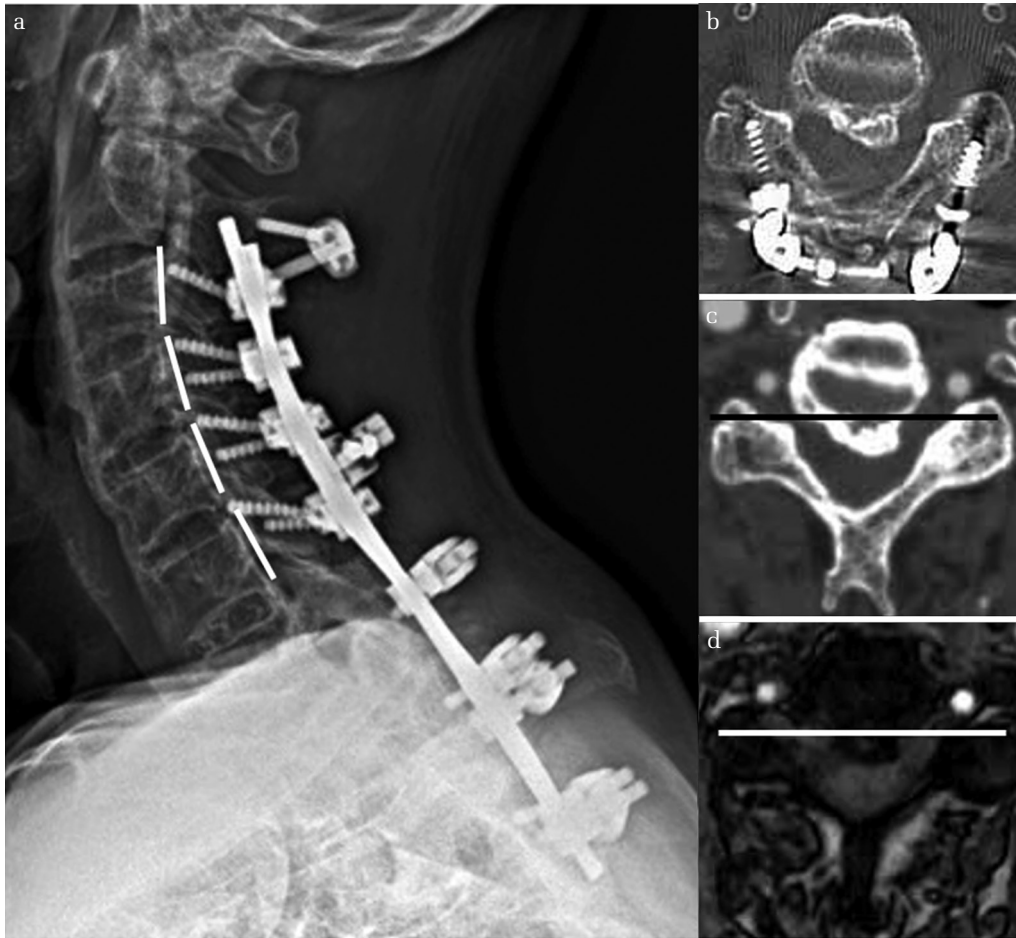


Fig. 1 A 71-year-old male with a C7 unstable fracture and diffuse idiopathic skeletal hyperostosis. We performed posterior fusion from C3 to T2 by inserting bilateral lateral mass screws into C4, C5, and C6 and unilateral lateral mass screw into C3. (a) Post-operative X-ray, lateral view. The bars show the vertebral posterior line. (b) CT, axial view, at the C5 level. (c) Preoperative CTA. (d) MRA, original image. The vertebral artery is anterior to the vertebral posterior line. To prevent VA injury, no lateral mass screws are inserted anterior to this line. CTA: Computed tomography angiography, MRA: magnetic resonance angiography.

perpendicular distance between the posterior VA surface and the posterior line of the vertebral body in 105 patients. We also examined the impact of VA anomalies on the usefulness of the safety line in patients subjected to the insertion of cervical posterior lateral mass- or transarticular screws.

Materials and Methods

Patients

Between January 2016 and December 2018, 105 consecutive patients (210 VAs) underwent cervical magnetic resonance angiography (MRA) to diagnose other than cervical spine diseases at Chiba Shintoshi Rurban Clinic. Informed consent was obtained from all participants included in the study. They were 53 men and 52 women; their average age was 65.0 years (range 21–95 years).

MRI was performed on a 1.5-T GE scanner (Brivo MR355, GE Healthcare, Chicago, IL, USA). A sagittal localizer was used to position the MRA field of view (FOV) to include all cervical levels between C3 and C7. The parameters for 3D time-of-flight MRA images of the neck were repetition

time (TR) = 24 ms, echo time (TE) = 6.8 ms, flip angle = 20°, bandwidth = 19.23 kHz, slice thickness = 2.2 mm, axial FOV = 260 × 260 mm².

Measurement methods and factors

Using the original MRA images, we examined anatomical characteristics of the VA at the cervical spine at each vertebral body- and intervertebral disc level. They were the entrance level to the transverse foramen of the VA, the VA diameter, and the perpendicular distance from the posterior margin line in the spinal canal of the vertebral body to the posterior VA surface (Fig. 2). The distance between the posterior line of the vertebral body to the posterior VA surface was classified as safe (>2 mm to the anterior VA surface), as needing attention (2 mm ≥ the distance to the anterior VA surface) and as unsafe (0 mm ≥ the distance to the posterior VA surface). All measurements were performed by KK and MN.

Statistical analysis

Statistical analysis was performed with the Fisher exact test using SPSS for Windows (version 25.0; IBM Corp., Armonk, NY, USA). To evaluate the

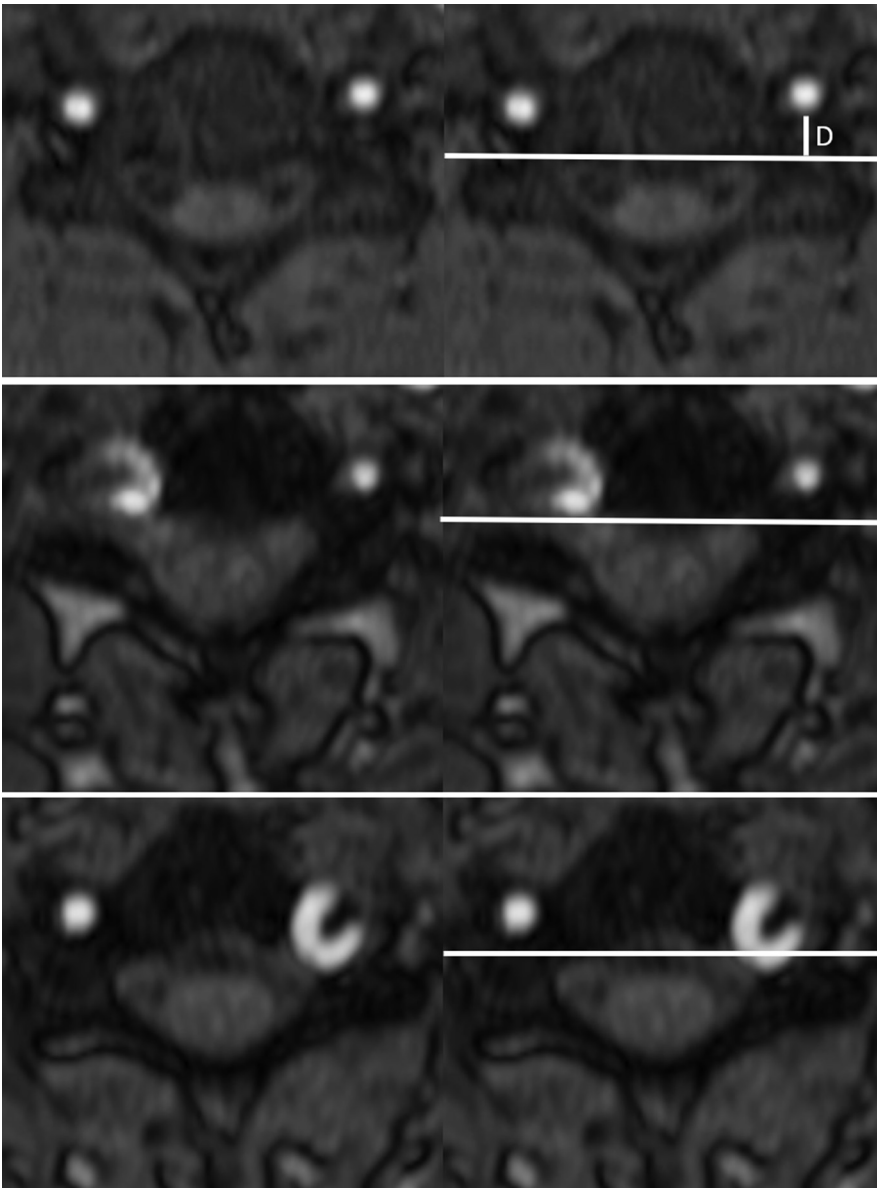


Fig. 2 Using the original axial MRA images, we recorded the perpendicular distance (*D*) from the posterior margin line of the vertebral body (*horizontal white line*) to the posterior surface of the vertebral artery as safe, as needing attention, and as unsafe. (Upper) Representative axial MRA image at C5. The distance on left side is classified as safe (>2 mm). (Center) Representative axial MRA image at C3. The distance on the right side is classified as needing attention (distance on the right 2 mm \geq , distance to the anterior VA surface >0 mm). (Lower) Representative axial MRA image at C4. The distance on left side is classified as unsafe (0 mm \geq to the posterior VA surface). MRA: magnetic resonance angiography.

intra- and inter-observer reliability of the measurements they were recorded twice in 35 patients and the intra- and inter-class correlation coefficient was calculated.¹²⁾ As it was greater than 0.98 for all measurements we considered it to be excellent. Differences of $P < 0.05$ were considered statistically significant.

Results

Anatomical VA characteristics

As MRA failed to show blood flow in three VAs on the right and one the left due to hypoplasia, 206 of the 210 VAs were evaluable.

Of the 206 VAs, 188 (91.3%) entered the transverse foramen of the cervical spine at the C6 level.

Among 18 of the 206 VAs (8.7%), entry was at C4 ($n = 6$, 2.9%, at C5 ($n = 9$, 4.4%), or at C7 ($n = 3$, 1.5%). In 92 of the 105 patients (87.6%), entry of the bilateral VA was at the same level. The mean diameter of the right and left VA was 3.7 ± 0.7 and 3.8 ± 0.8 mm, respectively and not significantly different at the different cervical levels (Table 1). There were 17 VAs (8.3%) harboring a total of 31 tortuous loops.

Distance between the posterior surface of the VA and the posterior line of the vertebral body

In these patients, the perpendicular distance averaged 6.3 ± 3.3 mm on the right and 6.7 ± 3.1 mm on the left (Table 2). On both sides it was shorter at the upper than the lower level and shorter on the

Table 1 Diameter of the vertebral artery at C3–C7

	C3	C3/4	C4	C4/5	C5	C5/6	C6	C6/7	C7	Mean
Right (mm)	3.8	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.6	3.7 ± 0.7
Left (mm)	3.8	3.7	3.9	3.8	3.9	3.9	4.1	3.8	3.9	3.8 ± 0.8

Table 2 Perpendicular distance between the posterior VA surface and the posterior line of the vertebral body

	C3	C3/4	C4	C4/5	C5	C5/6	C6	C6/7	C7	Mean
Right (mm)	3.5	5.1	4.8	5.5	5.5	5.8	6.2	8.8	11.5	6.3 ± 3.3
Left (mm)	4.1	5.8	5.3	6.3	6.0	6.8	6.0	8.5	11.6	6.7 ± 3.1

right than the left side. Based on our classification, the distance between C4 and C7 was safe in at least 200 of 206 VAs (97.1%) (Table 3). The distance to C3 was safe in 170 VAs (82.5%). It was not safe at seven sites [C3: $n = 3$ (1.5%), C3/4, C4, C4/5 and C6/7: $n =$ one each (0.5% each)]. At these seven sites, the safety line was not a safety landmark; in five of these sites, tortuous VA loops were involved (Table 4). Our observations revealed that the presence of tortuous VA loops had a statistically significant negative effect on the reliability of the safety line ($P < 0.05$).

Discussion

Iatrogenic VA injury during cervical spine surgery

For posterior stabilization of the lower cervical spine, lateral mass- and/or transarticular screw fixation is performed. As the placement of such screws may result in VA injury, the location of the VA in the cervical spine must be identified. Although Nishinome et al.³⁾ examined the safety zone for lateral mass screws in 13 cadavers, they did not address the safe distance between the posterior VA surface and the anterior aspect of the lateral mass. Ebraheim et al.²⁾ reported that VA injury can be avoided by screwing perpendicular to the posterior aspect of the lateral mass at C3–C5 and 10° lateral to the sagittal plane at C6 starting at the lateral mass midpoint. Using cadavers, they measured the vertical distance between the posterior midpoint of the lateral mass and the posterior surface of the VA foramen. However, there is a gap between the transverse foramen and the VA^{12,13)} because the vessel occupies only 30% of the transverse foramen.¹³⁾ We think that for the evaluation of the transverse foramen, neither cadaver nor CT studies are appropriate and CT angiography (CTA) or MRA is required. We inspected original axial MRA images because their acquisition is less invasive and the blood flow in the VA is visualized on cervical axial views.

Usually the VA is located anterior rather than posterior to the line of the vertebral body. Lateral mass- or transarticular screws are placed with the aid of a lateral fluoroscope; to prevent VA injury, the screws tend to be not inserted farther than anterior to that line. However, it is not known whether the line is a safety landmark. In our study of 105 patients who underwent imaging evaluations to diagnose other than cervical spine diseases, we found that the mean distance between the posterior VA surface and the posterior line of the vertebral body exceeded 6 mm and that it was shorter at the upper- than the lower cervical level. At C4–C7, 97% of the VAs in the safe distance group were located more than 2 mm anterior to the safety line. At the C3 level, the distance was safe in only 82.5% of the VAs, suggesting that use of the safety line may be appropriate at C4–C7 but not at the C3 level.

Relationship between VA anomalies and the VA location in the cervical spine

In patients with VA anomalies such as fenestration, tortuous loops with/without bony erosion, and abnormal VA entries into the transverse foramen,^{4–7)} care must be taken to avoid iatrogenic VA injury during cervical spine surgery. In 90.0–95.6% of cases, the VA entered the transverse foramen of the cervical spine at the C6 level.^{4,7,14,15)} Alternative entry sites were at C3 (0.2%), C4 (0.5–1.6%), C5 (3.1–5.0%), and C7 (0.3–0.8%).^{4,6,7,15)} The VA entry site may affect the treatment strategy in patients scheduled for cervical posterior surgery. In our series, 186 of 206 VAs (90.3%) entered the transverse foramen of the cervical spine at the C6 level. Our findings are as documented in earlier reports.

The VA course is usually straight or slightly looped. The incidence of tortuous VA loops is 1.0–7.5%^{4,5,8,11,16,17)} and their presence may result in significant medial or a lateral artery displacement. The mechanisms underlying their formation remain unclear although an association with cervical

Table 3 Classification based on the distance between the posterior VA surface and the posterior line of the vertebral body

Classification (%)	C3	C3/4	C4	C4/5	C5	C5/6	C6	C6/7	C7
Safe (>2 mm)	82.5	98.5	97.1	99	99.5	98.5	98.5	99.5	100
Needing attention (2 mm \geq)	16.0	1.0	2.4	0.5	0.5	1.5	1.5	0	0
Unsafe (0 mm \geq)	1.5	0.5	0.5	0.5	0	0	0	0.5	0

Table 4 Relationship between 17 tortuous VA loops and safety classification

Classification*	C3	C3/4	C4	C4/5	C5	C5/6	C6	C6/7	C7	Total
Safe (>2 mm)	3	2	2	1	3	4	5	2	3	25
Needing attention (2 mm \geq)	1	0	0	0	0	0	0	0	0	1
Unsafe (0 mm \geq)	1	1	1	1	0	0	0	1	0	5

*Number of VAs.

spondylotic changes, hemodynamic stress, high pulsatile arterial pressure, VA elongation due disc space narrowing, and cervical trauma has been proposed.^{9,16,18)} While tortuous VA loops tend not to elicit symptoms, they may affect surrounding structures and elicit bony erosion, cervical radiculopathy or myelopathy, neck or shoulder pain, and vertebrobasilar insufficiency.^{8,16,18,19)} Ekşi et al.¹⁶⁾ reported that patients with tortuous VA loops were significantly older than patients with a straight VA and that most loops were located at the C5 and C6 level.

Of our 206 VAs, 17 (8.3%) manifested tortuous loops. This higher rate than in earlier reports may be explicable by the older age of some of our patients. The presence of such loops raises the risk for arterial complications in patients undergoing anterior cervical surgery.^{4,5,8-11)} At seven sites in our series, the safety line was not an appropriate landmark; in five of these sites, tortuous VA loops were involved. Consequently, the presence of tortuous VA loops may affect the location of the VA in the cervical spine and be a statistically significant risk factor in patients scheduled for posterior cervical fusion.

Study limitations

The population in our retrospective study was relatively small. The purpose of this study was to investigate only the relationship between the VA and the posterior line of the vertebral body, a line representing one safety line on lateral fluoroscopy images acquired during surgery. We did not attempt to discover a new screw insertion method.

Two modalities, MRA and CTA, can be used to evaluate the VA in the cervical spine. MRA is inferior to CTA with respect to bone evaluation. Drawing the posterior vertebral line on MR images

may yield less accurate results than drawing it on radiograms and CT scans, as it does not involve radiation or contrast media. Although MRA scans are useful to inspect the VA location in the cervical spine to detect VA anomalies preoperatively and to reduce the risk of complications, CTA provides more useful information when detailed pre-operative examination is required to identify, for example, bone deformation and VA anomalies.

Conclusion

The posterior line of the vertebral body may be a useful landmark for the safe insertion of screws at the C4–C7 level. However, in only 170 (82.5%) of our 206 VAs was it useful at the C3 level. The presence of tortuous VA loops increases the risk for iatrogenic VA injury in patients undergoing cervical spine surgery.

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Conflicts of Interest Disclosure

The authors declare they have no conflicts of interest and no commercial relationships and received no support from pharmaceutical or other companies. All authors, except M.N, who are members of The Japan Neurosurgical Society (JNS) have completed the Self-reported COI Disclosure Statement Forms available at the website for JNS members.

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