The V2 segment of the vertebral artery in anterior and anterolateral cervical spinal surgery: A cadaver angiographic study

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Abstract

Objective: The second segment of the vertebral artery is under the risk of injury during anterior and anterolateral cervical spine procedures. To avoid such a risk, one needs to be familiar with the regional anatomy. The aim of this study was to measure the distance between the vertebral artery and the uncinate process, midline, and the medial side of the longus colli muscle using vertebral artery angiograms at the level of C6, C5, C4, and C3 vertebrae.

Materials and methods: In 12 human cadavers, the vertebral arteries were first irrigated with water. Then the arteries were filled with silicon and barium, and finally their angiographic images were obtained.

Results: The transverse diameter of the vertebral artery was measured at C6, C5, C4, and C2 level. The values on the left were bigger than the values on the right (p > 0.05).

The distance between the vertebral artery and the midline decreased from C6 (17.2 ± 5.6 mm on the right, 17.2 ± 2.3 mm on the left) to C3 (15.8 ± 5.3 mm on the right, 13.8 ± 2.1 mm on the left) (p > 0.05).

The distance between the apex of the uncinate process and the medial side of the vertebral artery was found to be longer at C4 (2.7 ± 1.0 mm on the right, 2.5 ± 1.0 mm on the left) and C5 (2.5 ± 1.1 mm on the right, 2.5 ± 1.0 mm on the left) vertebral levels on the right side (p = 0.539 at C4, p = 0.862 at C5).

The distance between the medial side of the longus colli muscle and the medial side of the vertebral artery was measured as 9.7 ± 2.1 mm at C6 level, 9.2 ± 2.6 mm (9.8 ± 2.6 mm on the left) at C6 level, 9.2 ± 2.6 mm (8.6 ± 2.4 mm on the right, 9.8 ± 3.1 mm on the left) at C5, 9.4 ± 1.9 mm (9.2 ± 2.1 mm on the right, 9.5 ± 2.0 mm on the left) at C4, and 10.4 ± 2.7 mm (10.5 ± 3.0 mm on the right, 10.1 ± 2.6 mm on the left) at C3 vertebral level. No significant difference was found between the right and the left (p > 0.05).

The angle between the vertebral artery and the midline was measured as 4.0 ± 1.9° on the right and 2.2 ± 1.4° on the left side (p = 0.030).

Conclusion: It was considered that the values obtained could be useful in anterolateral and anterior cervical approaches in terms of evaluating the position of the vertebral artery and its relation to vertebral structures. It is also concluded that the risk of injury in upper subaxial cervical spine is higher than in the lower part of the subaxial cervical spine. © 2005 Elsevier B.V. All rights reserved.

Keywords: Cervical spine; Vertebral artery; Longus colli muscle; Uncinate process

1. Introduction

The vertebral artery is classically divided into four segments. The first segment extends from its origin on the subclavian artery to the C6 transverse process. The second segment extends from C6 to C2 transverse processes. The third segment extends from C2 to the foramen magnum. The fourth segment extends intradurally from the foramen magnum dura to verteobasilar junction [1]. The second segment of the vertebral artery is also known as the V2 [2]. The close relation between the V2 and the subaxial cervical spine exposes this part of the vertebral artery at the risk of complication during both anterior and posterior cervical spine surgery.
Anterior cervical disectomy and corpectomy are the main anterior cervical spine surgery procedures. These procedures are used for decompression and/or stabilization of degenerative, traumatic, infectious, neoplastic and iatrogenic disorders of the cervical spine [3,4]. The V2 may be injured during these surgical procedures. Technically, the V2 injury may occur during the uncovertebral joint resection by high-speed drill, during the foraminotomy, during decompression for reduction of the locked facet, and as a result of malposition of the cervical spine implants [1]. On the other hand, posterior cervical spine instrumentation using lateral mass or pedicle screws may injure the V2, too. A posterior or anterior vertebral artery injury may cause a vertebral artery fistula or a serious vertebral artery laceration resulting in uncontrollable rapid bleeding, hypovolemia, and in turn, high morbidity and mortality [5–7]. Therefore, the knowledge regarding the V2 anatomy is of vital importance, and may decrease the possibility of the V2-related complications. The aim of this study is to reveal the distances between the V2 and the surrounding constant structures.

2. Materials and methods

Twelve human cadavers fixed with formaldehyde were used for this study. All the cadavers were adult male cadavers with an average age of 50 years. Prior to the current study, the cadavers had been decapitated at C1–2 levels, and the tissues superficial to the prevertebral fascia had been removed.

A branul was placed into the vertebral artery close to its origin from the subclavian artery. From the puncture site the branul was pushed forward approximately 1.5 cm toward the head. In order to prevent the retrograde flow of the injected liquid, the artery was sutured with silk at a point somewhere between the puncture site and the branul tip.

A water tank was placed three meters high from the floor. After a line was produced between the water tank and the branul, the water was given into the vertebral artery with gravity. After completing irrigation process, the angiographic visualization of the vertebral arteries was done in the angiography unit of our institution.

The mixture to be injected into the vertebral artery was consisted of 5 ml of Dow Corning, 3110 RTV silicone rubber, 3 ml of catalasts S, 10 ml of thinner, and 30 g of barium sulphate in one unit. The freezing time for the mixture was measured and found to be 36 h. The mixture was slowly given (1 ml/s) into the vertebral artery through the branul.

Angiographic imaging: The imaging was done in a “C” arm angiography unit (Multi Diagnost 4, Phillips). The available image intensifier diameters were 38, 25, and 17 cm. Usually, 25 and 17 cm were chosen in the study. The image matrix was 512 × 512. The angiographic images were obtained at a rate of one image per second. The first series of images were obtained in the frontal plane with digital subtraction angiography. The following series were obtained without subtraction and included 45° right and left anterior oblique projections and the lateral projection. A 10-mm-long marker was placed in the imaging plane in all series. The measurements were done using this marker as the reference length. All measurements were done in AP angiograms, between C2 and C6 levels for both right and left sides. The other projections were used to view the course of the artery and to check for any anomaly. For each vertebra, the midline was defined as the line that coincides with the spinous process. The measurements related to the V2 diameter, and those related to the distance between the right and left V2 were performed at the midpoint level of the height of the vertebral body. The axis of the V2 was defined as a line connecting the midpoints of the V2 at the levels of C3 and C6 vertebrae. For measurement of the distance between the medial border of the longus colli muscle and medial border of the V2, the medial border of longus colli muscle was marked by a metal marker under fluoroscopy at each cervical level, and the distance between the marker and the medial side of the vertebral artery was measured.

The angiographic measurements were made by using the software provided on the unit.

![Fig. 1. The measured parameters: (a) The transverse diameter of the V2, (b) The distance between the medial side of the V2 and the midline, (c) The distance between the uncinate process and the V2, (d) The distance between the right and the left uncinate processes, (e) The distance between the medial sides of the right and the left V2 (UP, uncinate process, ML, midline).]
Fig. 2. The angle between the V2 (a) and the midline (b).

Statistically, the right and the left side measurements were compared with Mann-Whitney U-test. The following parameters were evaluated:

1. The entrance level of the vertebral artery to the transverse foramen.
2. The transverse diameter of the V2 at the level of C2, C3, C4, C5, and C6 vertebrae (Fig. 1).
3. The distance between the medial border of the V2 and the midline at the level of C2, C3, C4, C5, and C6 vertebrae (Fig. 1).
4. The distance between the uncinate process apex and medial border of the V2 at the C3, C4, C5, and C6 levels (Fig. 1).
5. The distance between the right and left uncinate process at the C3, C4, C5, and C6 levels (Fig. 1).
6. The distance between the medial borders of the right and the left V2 at the level of C2, C3, C4, C5, and C6 vertebrae (Fig. 1).
7. The angle between the V2 and the midline (sagittal plane) (Fig. 2).
8. The distance between the medial border of the longus colli muscle and medial border of the V2 (Fig. 3).

3. Results

The vertebral artery entered the transverse foramen at the level of C6 vertebra on both sides of all cadavers. The V2 was larger in diameter on the left side \( (p > 0.05) \). The diameter of the V2 from C6 to C2 was measured as 3.5 ± 0.8, 3.3 ± 0.7, 3.6 ± 0.7, 3.5 ± 0.9, and 3.6 ± 0.9 mm (Table 1).

The distance between the right and the left V2 medial side and the distances between the apices of the right and the left uncinate processes were measured. The distances between the medial borders of the right and the left V2 decreased as the V2 ascended from C6 to C3 level. The V2 medial side on the right and on the left was measured as 32.2 ± 3.3, 30.5 ± 2.7, 29.6 ± 3.4, and 28.0 ± 3.2 mm; the distances between the apices of the right and the left uncinate processes were measured as 28.3 ± 4.5, 25.5 ± 3.0, 24.0 ± 3.1, and 23.7 ± 3.2 mm from C6 to C3, respectively. Similarly, the distances between the apices of the uncinate processes decreased in the upper subaxial cervical spine (Table 1). The angle between the V2 and midline (sagittal plane) was found to be 4.0 ± 1.9°, 2.2 ± 1.4°, and 3 ± 2°, on the right and left sides, and in total, respectively. The right side angles were larger than the left side angles \( (p = 0.030) \).

Table 1

<table>
<thead>
<tr>
<th>parameter</th>
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<td>Left</td>
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<td>p</td>
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<td>0.434</td>
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<td>B</td>
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<td>C</td>
<td>21.7±3.2</td>
<td>24.0±3.1</td>
<td>25.5±1.0</td>
<td>28.3±4.5</td>
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A, the transverse diameter of the V2; B, the distance between the medial sides of the right and the left V2; C, the distance between the right and left uncinate processes.
The results of measurements of the distances between the V2 and the landmark structures are as follows:

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<th>C3</th>
<th>C4</th>
<th>C5</th>
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<tr>
<td>Right</td>
<td>17.6±6.1</td>
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<td>0.902</td>
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<tr>
<td>C</td>
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<td>Right</td>
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</tr>
<tr>
<td>Total</td>
<td>10.4±2.7</td>
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<td>9.2±2.6</td>
<td>9.7±2.7</td>
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<td>p</td>
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<td>0.862</td>
<td>0.752</td>
<td>0.833</td>
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</table>

A, the distance between the medial side of the V2 and the midline; B, the distance between the apex of the uncinate process and the medial side of V2; C, the distance between the medial side of the longus colli muscle and the medial side of the V2.

The distances between the V2 and the landmark anatomic structures, such as midline, uncinate process and the longus colli muscle were measured (Table 2).

The distance between the medial border of the V2 and the midline was observed to decrease from C6 to C3. Totally, it was measured as 17.2 ± 6.1 mm at C2, 18.8 ± 5.3 mm at C3, 15.6 ± 3.9 mm at C4, 16.0 ± 4.3 mm at C5, and 17.2 ± 5.6 mm at C6. The main reason of decreasing distance between the V2 and the midline is the loss of the midline by surgical manipulation.

The incidence of the vertebral artery injury during anterior cervical spine procedures has been reported as 0.22–2.77% [7,9–11]. The iatrogenic V2 injuries most commonly arise from the shift of the decompression process to the lateral, because of the losing of the midline by surgeon [7,5,11,16]. To avoid this risk, one needs some reference points for surgical orientation. These reference sites include the distance between the V2 and some landmarks, such as the midline, the uncinate process and the longus colli muscle. The data including the distance between right and left vertebral arteries, the distance between right and left uncinate processes, and the angle of the V2 are also important in terms of recognition of the anatomy of this region. Each reference point has its advantages and disadvantages in practice.

Determination of the midline during the corpectomy is the easiest way to avoid the vertebral artery injury. In the study reported by Xu, the distance between the midline and the medial borders of the first segment of the vertebral artery was found to be 22.3 ± 2.9 mm at T1, and 17.5 ± 1.8 mm at C7 [17]. Our study revealed that the distance between the medial border of the V2 and the midline decreased from C6 to C3. According to the current study the distance between the medial border of the V2 and the midline was measured as 17.2 ± 4.1, 16.0 ± 3.4, 15.3 ± 3.0, 14.8 ± 4.1, and 16.2 ± 4.7 mm, at the levels of C6, C5, C4, C3, C2, respectively. One can observe the similar differences in the distance between right and left vertebral arteries. The distance between right and left V2 was found to be 32.2 ± 3.3 mm at C6, 30.5 ± 2.7 mm at C5, 29.6 ± 3.4 mm at C4, 28.0 ± 3.2 mm at C3, and 29.2 ± 3.1 mm at C2 in the current study. This is almost parallel with the results reported in the literature [16].

A comparison between the V2 and midline at the level of C6 (our study) and C7 (Xu’s study) suggests that the V2 may be under risk of injury even at C7 level though the V2 is out to foramen transversarium. This fact needs to be taken into consideration during C7 level surgery.

The decreasing distance between the V2 and the midline, and the decreasing distance between right and left vertebral arteries can cause an upward convergent angle between the V2 and the midline. According to Lu and Ebarghen, the V2 moves upward making an angle of 4.3 ± 2.6° with the midline [9,18]. The direct measurements by Lu et al., showed that the angle between the V2 and midline was 3.5 ± 3.0° on the left, 5.1 ± 2.0° on the right and the general average was 4.3 ± 2.6° [9]. In our study, the angle between the V2 and the midline was 4.0 ± 1.9° on the right, and 2.2 ± 1.4°, on the right and left sides, respectively.

The main reason of decreasing distance between the V2 and the midline is the shorter distance between the left and the right V2 in the upper subaxial cervical spine due to the smaller sized vertebral body in upper subaxial cervical spine. Both the shorter distance between the V2 and the midline in the upper subaxial cervical spine and the resultant V2 injury was observed in 2.2% of 185 corpectomy cases [3,12].
angle should be taken in mind during anterior cervical spine surgery. The uncinate process forms the lateral border of the corpectomy. The distance between the right and the left uncinate process form the width of the corpectomy. The distance between the right and the left uncinate processes decreases gradually from C6 to C3 [18–20]. In our radiographic study, the distance between the right and the left uncinate process was measured 28.3 ± 4.5 mm at C6, 25.5 ± 3.0 mm at C5, 24.0 ± 3.1 mm at C4, and as 23.7 ± 3.2 mm at C3. The distances determined in our study are shorter than the distances reported by Lu et al. The measurement done by Lu et al. revealed that the distance between the right and left uncinate processes was 25.2 ± 2.0 mm at C7, 23.4 ± 1.9 mm at C6, 21.4 ± 1.7 mm at C5, 20.5 ± 1.8 mm at C4, and 19.4 ± 1.3 mm at C3 [20].

The distance between the uncinate process and the medial border of the V2 is of vital importance during the uncinctomy procedure. An aggressive uncinctomy using high-speed drill may cause V2 injury. The distance between the uncinate process and the medial border of the V2 was reported to be 1.0 mm at C7, 1.4 mm at C6, 1.6 mm at C5, 1.3 mm at C4, and 0.8 mm at C3, in a cadaveric study by Pait et al. [21]. The same distance was found to be 2.1 ± 1.2 mm at C6, 2.5 ± 1.0 mm at C5, 2.4 ± 1.0 mm at C4, and 1.8 ± 1.3 mm at C3 level in our angiographic study. In the current study, no significant difference was found between the right and the left in terms of the distance between the lateral border of the uncinate process and medial border of the V2, angiographically (p > 0.05). The presence of difference between the results reported by Pait et al. [21] and results of current study may be explained by the methodology of the current study. This is so, because the angiographic study reflects the inner diameter of the V2 and the cadaveric study reflects the outer diameter of the V2. The addition of the V2 wall thickness to the inner diameter may give us the outer diameter. The critical short distance between the uncinate process and V2 dictates surgeon to be extremely careful during the subaxial cervical spine foraminotomies.

The medial border of the longus coli muscle is an important reference in determining the lateral borders in anterior cervical surgery [16]. The distance between the medial border of the longus coli muscle and the medial border of the V2 was reported as 11.5 ± 1.0 mm at C6, 10.7 ± 0.6 mm at C5, 9.9 ± 0.8 mm at C4, and 9.03 ± 1.3 mm at C3, by Lu et al., in a cadaveric study [9]. This distance was reported as 12.48 ± 2.21 mm at C2–3 intervertebral space, 9.89 ± 2.09 mm at C3–4 intervertebral space, 8.74 ± 2.14 mm at C4–5 intervertebral space, 9.46 ± 2.64 mm at C5–6 intervertebral space and 12.05 ± 3.01 mm at C6–7 intervertebral space by Kawashima et al., in a cadaveric study [22]. In our study, we measured the distance between the medial border of the longus coli muscle and the medial border of the V2 as 9.7 ± 2.7 mm at C6, 9.2 ± 2.6 mm at C5, 9.4 ± 1.9 mm at C4, and 10.4 ± 2.7 mm at C3. Our results are in line with the results reported by Lu et al. We agree with Lu et al. that the existence of a 5-mm-long bone structure between the V2 and the burr could be suitable for the safety.

All the aforementioned results suggest that the vertebral artery is under more risk of injury in the upper levels of the subaxial cervical spine. Some anatomical factors contribute to the aforementioned risky situation of the vertebral artery, such as the distance between the right and the left uncinate processes, and the width of the vertebra body.

5. Conclusion

In summary, this study revealed the distances between the V2 and consistent anatomical markers, such as the midline, the uncinate process, and the longus colli muscle. This study also revealed that the V2 converges as it ascends. This is due to the bony anatomical reasons. It is concluded that the upward convergent aspect of the V2 may expose this segment to the higher injury risk in the upper subaxial cervical spine than the lower subaxial cervical spine. This should be taken into consideration during the anterior cervical spine surgery. Additionally, the determination of the midline in the level adjacent to the decompression level may help midline orientation, and in turn, reduce the risk of the V2 injury.

References


