Evaluating the V2 Segment of the Vertebral Artery with Computed Tomography to Assess Risks During Cervical Spinal Surgery: An Anatomic Study on Cadaver

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Abstract

Purpose: The second segment (V2) of the vertebral artery is located in the transverse foramen of the C6-2 cervical vertebrae. It is at risk of injury during anterior, anterolateral and posterior surgical approaches to the cervical spine. The aim of this study is to measure and evaluate the relationship between the V2 segment and bony landmarks of the cervical vertebrae.

Method: The vertebral arteries of 13 adult male cadavers were filled with a mixture of silicon and barium. Computed tomography (CT) imaging was done with Mx8000 Multi-slice System, Philips. Parameters were measured both directly on the cadaver and three-dimensionally on CT.

Results: The V2 horizontal diameters from C6 to C3 were measured as 4.6±0.7, 4.7±1.0, 4.6±0.7, 4.6±0.7 mm in CT; and as 4.4±0.5, 4.5±0.4, 4.4±0.6, 4.5±0.5 mm in direct measurements. Horizontal diameters of the transverse foramina from C6 to C3 were measured as 6.4±1.4, 5.9±1.2, 6.3±1.0, 6.5±0.8 mm in CT, and as 6.3±0.3, 6.0±0.4, 6.0±0.5, 6.5±0.5 mm in direct measurements. The distance between the V2 and the vertebral body midline from C6 to C3 in CT was 15.2±1.8, 13.9±1.4, 13.4±1.2, 13.4±1.3 mm. The distance between the V2 and the uncinate process from C6 to C3 was measured as 1.6±0.5, 1.6±0.4, 1.8±0.3, 1.7±0.3 mm in CT. In CT distance between the V2 and the anterior tubercle from C6 to C3 was measured as 3.3±2.8, 4.9±1.6, 4.3±2.1, 4.4±2.0 mm respectively. The V2 midline angle was 2.7±1.8º and 3.2±2.0º in CT and direct measurement, respectively.

Conclusion: This study confirmed the close relationship between the V2 segment and the adjacent bony structures. The results presented here demonstrated the correlation between the anatomic and CT measurements.

Keywords: vertebral artery, V2 segment

Introduction

The second segment of the vertebral artery, the V2, courses through the C6 transverse foramen (TF) to the C2 TF. (1-3) This location exposes the V2 to risk of injury during the anterior, posterior and anterolateral cervical spine surgical procedures. (4-6) This injury might occur during drilling with the aim of decompression, uncovertebral resection, foraminateomy or locked facet reduction, or during the cervical spine instrumentation. (1,4,7) The injury of the V2 may lead to dissection and resultant stroke, arteriovenous fistula, uncontrolled serious hemorrhage and subsequent hypovolemia. (6) Therefore, the knowledge regarding the anatomic relationship of the V2 with the neighboring structures is of vital importance. The aim of this study is to delineate the detailed anatomy of the V2 and its topographic relationship to the other structures of the cervical vertebrae on cadavers by making measurements both directly and with three-dimensional (3-D) computed tomography (CT) imaging.

Materials and Methods

Thirteen male cadavers were used for this study. The vertebral arteries of these cadavers were filled with a mixture of silicon and barium under fluoroscopic guidance in the angiography unit before CT. Details of preparing the mixture were mentioned in a previous study. (8) CT was obtained with a multi-slice scanner (Mx 8000 Multislice System, Philips) with four detectors. The cadavers were placed in the scanner in supine position and the images were obtained in the transverse plane. For CT scanning, a protocol similar to the cervical angiography protocol was used. Accordingly, the field of view was 250 mm, slice thickness was 1.3 mm, the increment...
was 0.6 mm, pitch 1.250, rotating time 0.75 s, power 120 kV, MAS/slice: 240, scanning angle: 180°, and acquisition matrix was 512. The scanning area was between the upper level of C2 vertebra and the lower level of C7. The mean scanning time was 40 seconds. After the scanning, all data were transferred to pacs. Both sagittal and coronal reformatted images were also produced on a post-processing console connected to pacs. Measurements were taken on the pacs viewing consoles (Figures 1, 2). The shape and course of the vertebral arteries were also studied with 3-D volume rendering and maximum intensity projection (MIP) image, which were produced from the original data.

Parameters measured on the CT include the V2 diameter, TF diameter (Figure 2) and the distance between the V2 and the vertebral components such as the uncinate process (UP), the anterior tubercle and the midline. The distance between the right and left V2 was also measured (Figure 3). After imaging and measurements with CT, the cadavers were carried to the anatomy department for direct measurements. The anterior walls of the transverse foramina were removed by Bromilow technique (9) and the vertebral arteries were exposed (Figure 4). Direct measurements were taken with a metal Vernier caliper sensitive to 0.1 mm and a goniometer sensitive to 1°. The CT and direct measurement results were analyzed using paired sample t-test and Pearson correlation test.

**Results**

The horizontal diameters of the V2 were measured from C6 to C3 at the vertebral body level. The V2 horizontal diameters were measured as: 4.6±0.7 mm, 4.4±0.5 mm at C6; 4.7±1.0 mm, 4.5±0.4 mm at C5; 4.6±0.7 mm, 4.4±0.6 mm at C4; and 4.6±0.7 mm, 4.5±0.5 mm at C3—on the CT and direct measurements, respectively.

The left V2 diameter was larger than the right in both methods. However, measurements of the V2 diameter in both CT and in direct measurements revealed no significant difference between the right and the left values (p>0.05) (Table I).

The CT and direct measurements of the horizontal diameters of the transverse foramina (TF) were, respectively: 6.4±1.4 mm, 6.3±0.3 mm at C6; 5.9±1.2 mm, 6.0±0.4 mm at C5; 6.3±1.0 mm, 6.0±0.5 mm at C4; and 6.5±0.8 mm, 6.5±0.5 mm at C3 (Table 1). The difference between the TF

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diameter and the V2 horizontal diameter was measured 1.8 mm at C6, 1.2 mm at C5, 1.7 mm at C4 and 1.9 mm at C3 on CT. The relationship between the V2 and the TF horizontal diameters is shown in Figure 5.

The TF anteroposterior (AP) diameters were measured as: 5.9±1.1 mm at C6, 5.6±1.0 mm at C5, 5.8±1.0 mm at C4 and 5.7±0.8 mm at C3 levels on CT (Table 1). The V2 AP diameters were measured as: 4.9±1.0 mm at C6, 4.6±1.0 mm at C5, 5.0±1.1 mm at C4, and 4.7±1.2 mm at C3 levels on CT (Table 1). The relationship between the V2 and the TF AP diameters is shown in Figure 6.

The distance between the V2 medial border and the vertebral body midline was 15.2±1.8 mm and 15.3±1.8 mm at C6, 13.9±1.4 mm and 14.4±1.8 mm at C5, 13.4±1.2 mm and 13.8±1.6 mm at C4, and 13.4±1.3 mm and 14.1±1.1 mm at C3 on CT and direct measurements, respectively. The distances decreased in all cases as the V2 ascends. There was no significant difference between the right and left both in CT and direct measurements (p>0.05) (Table 2).

The angle between the V2 and the midline at the C6-C3 levels on CT was 2.7±1.8º; on direct measurement was 3.2±2.0º.

The distance between the right and the left V2 was measured as 30.7±3.7 mm and 30.5±2.9 mm at C6, 28.1±2.5 mm and 28.4±2.7 mm at C5, 26.4±2.6 mm, and 26.6±2.6 mm at C4, and as 25.3±2.9 mm and 26.2±2.9 mm at C3 levels in CT and on direct measurements, respectively (Table 2).

The distance between the V2 and the uncinate process (UP) was measured as 1.6±0.5 mm at C6, 1.6±0.4 mm at C5, 1.8±0.3 mm at C4, 1.7±0.3 mm at C3 level on CT. The same distances were measured as 1.6±0.4 mm at C6, 1.6±0.4 mm at C5, 1.8±0.3 mm at C4, 1.7±0.3 mm at C3 level on CT and direct measurements, respectively.

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at C5, 1.7±0.2 mm at C4, 1.6±0.2 mm at C3 level on direct measurements (Table 2).

The distance between the V2 and the anterior tubercle in CT was measured as 3.3±2.8 mm at C6, 4.9±1.6 mm at C5, 4.3±2.1 mm at C4, 4.4±2.0 mm at C3 level (Table 2).

There was no significant difference between CT and direct measurements parameters (p>0.05) (Table 3).

**Conclusion**

The close proximity of the V2 to the cervical spine neural and bony structures exposes this segment of the VA to risk of injury during the cervical spine surgery, dictating knowledge regarding this segment of the V2. This study confirmed a good correlation between the CT and direct measurements; therefore, the use of CT seems to be safe in preoperative assessment of the V2 before cervical spine surgery.

### Table 1. Measured parameters I: V2 diameter measurements.

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<th>C: Right</th>
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**Table 2. Measured parameters II: V2 distance measurements.**

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A: V2 horizontal diameter; B: V2 antero-posterior diameter; C: Transverse foramen horizontal diameter; D: Transverse foramen antero-posterior diameter.

**Discussion**

There are some studies focusing on the morphology of the V2 in cadavers. This study is the first study comparing the CT and direct measurements parameters for V2 morphology. To obtain the best images in this study, we opacified the filling mixture with Barium. On the other hand, to increase the quality of anatomic images, a special 3D imaging software was used. This provided volume rendering, surface rendering and creation of endoscopic views of luminal structures.

This study confirmed the correlation between the CT and direct measurements, which was reported by others previously. (10, 11)

The V2 diameter was quite homogenous along its course. Both CT and direct measurements revealed a larger V2 in the left side (p<0.05) (Table 1). All these were in line with other previous reports. (2, 3, 6, 12-14)
The smaller distance in the current series may be attributed to the smaller size of the vertebral body.

The distance between the V2 and the anterior tubercle: The distance between the anterior tubercle of the transverse process and V2, according to the study on cadavers by Kawashima et al was 3.13±2.24 mm at C3-4, 2.94±2.41 mm at C4-5, 2.98±1.44 mm at C5-6, and 0.88±2.64 mm at C6-7 (16). In our study, it was measured as 4.4±2.0 mm at C3, 4.3±2.1 mm at C4, 4.9±1.6 mm at C5 and 3.3±2.8 mm at C6. The difference between our results and the results reported by Kawashima et al can be attributed to the level of measurements with respect to vertebral body versus intervertebral disc. Nevertheless, the surgeons should keep in mind the close proximity between anterior tubercle and V2 during anterolateral transforaminal approaches.

The distance between the V2 and the UP (uncinate process): The osteophytes originating from the UP are the major causes of radiculopathy, therefore they should be resected during cervical discectomy procedures.(21-25) Many authors have mentioned the potential risk of injury to the neurovascular structures during resection of UP.(18,25-28) Therefore, knowledge regarding the distance between the V2 and the UP is important.

The distance between the UP 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.(27) The same distance was found to be 1.6±0.5 mm at C6, 1.6±0.4 mm at C5, 1.8±0.3 mm at C4, and 1.7±0.2 mm at C3 level in CT and 1.6±0.4 mm at C6, 1.6±0.4 mm at C5, 1.7±0.2 mm at C4, and 1.6±0.2 mm at C3 level direct measurement in current study. In the current study, no significant difference was found between the right and the left in terms of the distance between the apex of the UP and medial border of the V2 (p>0.05).

Relation between diameters of the V2 and the transverse foramen (TF): The diameters of the V2 and the TF are important during approaches in terms of security. The VA arises from the plexiforme anastomoses between the intersegmental arteries embryologically and can be seen in the fifth intrauterine week. The TF is formed around the V2. Each half of the neural arch becomes wider from the center to the lateral, moves to anterior and surrounds the V2. It forms the TF with the vestigial ostigal element, which fuses to vertebral body.(29) In direct measurements by Ebraheim et al, on dry cervical vertebra, AP diameter of the TF was 4.7±0.6 mm on the right, 4.8±0.6 mm on the left at C3, 4.8±0.6 mm on the right, 5.0±0.6 mm on the left at C4, 5.0±0.6 mm on the right, 5.2±0.5 mm on the left at C5, 5.4±0.9 mm on the right, 5.6±1.0 mm on the left at C6.(18)

<table>
<thead>
<tr>
<th>p</th>
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<th>C4</th>
<th>C5</th>
<th>C6</th>
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<td>0.694</td>
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<tr>
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<td>0.303</td>
<td>0.084</td>
<td>0.393</td>
</tr>
<tr>
<td>Distance between right and left V2</td>
<td>0.424</td>
<td>0.984</td>
<td>0.799</td>
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</tr>
<tr>
<td>Distance between V2 and uncinate process</td>
<td>0.082</td>
<td>0.488</td>
<td>0.561</td>
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</table>

Unlike the reported series, there was no hypoplastic V2 in the current study. The hypoplastic VA (vertebral artery) was reported to be 8.6% (2 left, 4 right VA) by Matula et al,(15) 12% by Gabrielsen.(16) Golfinos et al, in their retrospective study on 1215 patients reported hypoplastic VA in 5.7% (left side) and 8.8% (right side), and aplastic VA 1.8% (left) and 3.1% (right side) of cases.(17)
TF AP diameter was studied on CT by some researchers.(25, 30) Vaccaro et al measured the TF AP diameter in CT sections of the patients as 5.85±0.85 mm at C3, 5.97±0.65 mm at C4, 6.30±0.73 mm at C5 and 6.63±0.85 mm at C6.(28) A similar result was reported by Ebraheim et al, in CT study of cadavers measured the TF AP diameter as 5.0±0.5 mm at C3, 5.6±0.6 mm at C4, 6.0±0.7 mm at C5 and 5.9±0.6 mm at C6.(30)

TF AP diameter was measured as 5.7±0.8 mm at C3, 5.8±1.0 mm at C4, 5.6±1.0 mm at C5, 5.9±1.1 mm at C6 in CT in current study. Our results are parallel to the results reported by Vaccaro (28) and Ebraheim.(30)

TF horizontal diameter was measured as 5.3±0.7 mm at C3, 5.4±0.8 mm at C4, 5.4±0.9 mm at C5, 5.2±1.3 mm at C6 (31) on direct measurements, and as 5.5±0.4 mm at C3, 5.7±1.0 mm at C4, 5.9±0.7 mm at C5, 5.7±0.7 mm at C6 on CT.(30) These are similar to our results.

Heary et al reported that left TF is generally larger than right TF.(14) In our study, both the V2 diameters and the TF diameters were larger on the left side (Table 1).

References
Editor’s Comment
Güvençer et al have provided anatomical information that correlates with imaging findings. The fact that such a correlation exists and that the authors have substantiated such is of great significance to us all. For this, the authors are to be congratulated.

Edward C. Benzel, MD
