A safe approach to explore/identify the $V_2$ segment of the vertebral artery during anterior approaches to cervical spine and/or arterial repairs: anatomical study

Laboratory investigation

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Object. The purpose of this study was to find a landmark according to which the surgeon can dissect the cervical spine safely, with the lowest possibility of damaging the vertebral artery (VA) during anterior approaches to the cervical spine or the VA.

Methods. The “safe zone” for each level of the cervical spine was described as an area where the surgeon can start from the midline in that zone and dissect the soft tissue laterally to end up on the transverse process and cross the VA while still on the transverse process. In other words, safe zone signifies the narrowest width of the transverse process at each level. In such an approach, the VA is protected from the inadvertent deep penetration of the instruments by the transverse process. The surgical safe zone for each level was the common area among at least 95% of the safe zones for that level. For the purpose of defining the upper and lower borders of the safe zone for each level, the line passing from the upper vertebral border perpendicular to the midline (upper vertebral border line) was used as a reference.

Cervical spines of 64 formalin-fixed cadavers were dissected. The soft tissue in front of the transverse process and intertransverse space was removed. Digital pictures of the specimens were taken before and after removal of the transverse processes, and the distance to the upper and lower border of the safe zone from the upper vertebral border line was measured on the digital pictures with Image J software. The VA diameter and distance from the midline at each level were also measured. To compare the means, the authors used t-test and ANOVA.

Results. The surgical safe zone lies between 1 mm above and 1 mm below the upper vertebral border at the fourth vertebra, 2 mm above and 1 mm below the upper vertebral border at the fifth vertebra, and 1 mm above and 2 mm below the upper vertebral border of the sixth vertebra. The VA was observed to be tortuous in 13% of the intertransverse spaces. There is a positive association between disc degeneration and tortuosity of the VA at each level (p < 0.001). The artery becomes closer to the midline (p < 0.001) and moves posteriorly during its ascent.

Conclusions. Dissection of the soft tissue off the bone along the surgical safe zone and removal of the transverse process afterward can be a practical and safe approach to avoid artery lacerations. The findings in the present study can be used in anterior approaches to the cervical spine, especially when the tortuosity of the artery mandates exposure of the VA prior to uncinate process resection, tumor excision, or VA repair. (DOI: 10.3171/2009.7.SPINE08504)

Key Words • cervical spine • vertebral artery • transverse process • uncinate process • cadaver dissection

 Abbreviations used in this paper: LCM = longus colli muscle; VA = vertebral artery; VB = vertebral body.
structures difficult to identify. Moreover, the uncinate process can be in close proximity to the VA due to cervical spondylosis. The LCM has also been used as a landmark for the VA; however, comparison of the results of different studies has shown that there is considerable variability in the location of the LCM in relation to the midline. Additionally, most of these studies have a limited sample size, and the results cannot be extrapolated.

Tortuosity and anomalies of the VA, and loss of intraoperative landmarks have been identified as the main reasons for VA lacerations. The purpose of this study was to find a landmark according to which the surgeon can dissect the cervical spine safely, with the least possibility of damaging the VA during anterior approaches. Exposure of the VA is necessary in a variety of conditions, including resection of hard discs compressing the nerve roots/VA, tumor excision, and VA repair. We speculated that if the artery can be exposed fully at certain points of its course, then the surgeon can expose the artery by careful dissection between these points. The purpose of this study was 1) to find out where in the cervical spine the VA is at higher risk of being damaged, and 2) to find certain spots where the artery is at low risk of damage during dissection and exposure.

To our knowledge, none of the previous articles analyzed the images of the VA in a cadaveric study. Additionally, this study had the largest sample size to date among the studies delineating the course of the VA.

Methods

The “safe zone” for each level of the cervical spine was described as an area in which the surgeon can start from the midline and dissect the soft tissues off the bone laterally, to end up on the transverse process and cross the VA while still dissecting on the transverse process. In other words, the safe zone is the area along which the surgeon can expose the artery by careful dissection between these points. The purpose of this study was 1) to find out where in the cervical spine the VA is at higher risk of being damaged, and 2) to find certain spots where the artery is at low risk of damage during dissection and exposure.

To our knowledge, none of the previous articles analyzed the images of the VA in a cadaveric study. Additionally, this study had the largest sample size to date among the studies delineating the course of the VA.

<table>
<thead>
<tr>
<th>Authors &amp; Year</th>
<th>No. of Specimens</th>
<th>C-3</th>
<th>C-4</th>
<th>C-5</th>
<th>C-6</th>
<th>C-7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lu et al., 1998¹²</td>
<td>54</td>
<td>19.3 ± 1.5</td>
<td>20.5 ± 1.9</td>
<td>21.2 ± 1.6</td>
<td>23.0 ± 1.8</td>
<td>25 ± 2</td>
</tr>
<tr>
<td>Güvençer et al., 2006</td>
<td>12</td>
<td>23.7 ± 3.2</td>
<td>24.0 ± 3.1</td>
<td>25.5 ± 3.0</td>
<td>28.3 ± 4.5</td>
<td></td>
</tr>
</tbody>
</table>

* All values are in millimeters (mean ± SD).

Because the artery is protected by the transverse process from inadvertent penetration by instruments while the soft tissue around the VA is being dissected. We used the upper vertebral border in the midline as a reference for describing the safe zone of the corresponding vertebra. Because the height of the disc may decrease with senescence/spondylotic changes, the lower vertebral border of the upper vertebra does not seem to be a reliable landmark.

To define the safe zone, a line perpendicular to the midline of the cervical spine was drawn to pass from the upper vertebral border of each vertebra, as shown in Fig. 1a (upper vertebral border line). The safe zone on each image was identified as the area between the highest (labeled “d”) and the lowest (labeled “e”) lines perpendicular to the midline that did not cross the artery at any point. In other words, “safe zone” signifies the narrowest width of the transverse process at each level. The area confined between these 2 lines (“d” and “e”) can provide a safe dissection route to the VA. The distances of the upper (“a”) and lower (“b”) boundaries of this zone from the upper vertebral border (“f”) were evaluated subsequently. The surgical safe zone for each level was the common area among 95% of the safe zones for that level. The distances of the upper and lower borders of the surgical safe zone from the upper vertebral border line were calculated using SPSS software and rounded subsequently (Table 3). Because the results were rounded, they were again tested to find out how often the artery is covered by the transverse process between these 2 lines.

Sixty-four formalin-fixed cadavers were dissected in the anatomy laboratory between November 2007 and January 2008. The cadavers were decapitated at the level of C1–2, but the rest of the cervical spine and its muscular attachments remained intact. The prevertebral fascia, LCM, and the soft tissue in front of the transverse process and intertransverse space (Fig. 1c) were removed. After removing the intertransverse ligament, the VA was exposed from C-7 to C-2 while still running in the transverse foramina. A digital camera (Panasonic, 3.2-megapixel) was used to take a picture from the anterior aspect.
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After that, the transverse processes were removed carefully so that the VA was not damaged. Pictures from the anterior, left, and right lateral aspects of the cervical spine were taken. The camera was held at the same level as the cervical spine in lateral pictures.

Based on the fact that the VA and the bone structure in its vicinity are 3D objects, we decided that the most accurate way to measure the artery indexes was to analyze images taken from the dissected cervical spine. The accuracy of such a method is higher than when using a caliper or ruler, which are basically designed for measuring 2D objects.

The pictures were analyzed using Image J software (1.39 m, National Institutes of Health). The measurements were calibrated according to the number of pixels per millimeter on the ruler image. The results were reported in millimeters, with an accuracy of 3 decimal digits. All the measured indexes were then entered into SPSS version 15 (SPSS, Inc.) and analyzed. To compare the means we used either the t-test or ANOVA, and for testing the correlations the chi-square test was used. A $p$ value was considered significant if it was $< 0.05$.

Besides the safe zone, we also investigated the following: 1) the anatomy of the VA, including its tortuosity, diameter (Fig. 1b), entry level into the transverse foramen, distance of the medial border of the artery to the midline of the cervical spine in the anterior images; and 2) the distance from the anterior border of the VA to the anterior vertebral border at the middle of the vertebrae in the lateral images.

**TABLE 3: Distance to upper and lower borders of the final and surgical safe zone from the upper vertebral border**

<table>
<thead>
<tr>
<th>Level</th>
<th>Safe Zone Borders</th>
<th>Area Covered by 95% of Safe Zones at Each Level</th>
<th>Surgical Safe Zone Borders</th>
<th>% of Cases w/ VA Completely Covered by Transverse Process in Surgical Safe Zone</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-3</td>
<td>upper -1.17</td>
<td>-1</td>
<td>-1</td>
<td>94</td>
</tr>
<tr>
<td></td>
<td>lower -1.42</td>
<td>-1</td>
<td>-1</td>
<td>96</td>
</tr>
<tr>
<td>C-4</td>
<td>upper 0.8</td>
<td>1</td>
<td>1</td>
<td>95</td>
</tr>
<tr>
<td></td>
<td>lower -1.12</td>
<td>-1</td>
<td>-1</td>
<td>96</td>
</tr>
<tr>
<td>C-5</td>
<td>upper 2.06</td>
<td>2</td>
<td>2</td>
<td>96</td>
</tr>
<tr>
<td></td>
<td>lower -0.8</td>
<td>-1</td>
<td>-1</td>
<td>95</td>
</tr>
<tr>
<td>C-6</td>
<td>upper 1.06</td>
<td>1</td>
<td>1</td>
<td>96</td>
</tr>
<tr>
<td></td>
<td>lower -2.27</td>
<td>-2</td>
<td>-2</td>
<td>98</td>
</tr>
</tbody>
</table>

* Positive and negative numbers mean that the line is above and below the upper vertebral border, respectively. All measures are in millimeters.
Results

Four specimens were excluded from the study due to previous surgery (1 specimen) or damage to the cervical spine while decapitating the cadaver (3 specimens). The mean age of the cadavers was 77 years, and 34 of the cadavers were males and 30 were females. Osteoarthritis was observed in 26% of all cervical spine levels, especially from the C-4 to the C-7 disc spaces.

Table 3 shows the results of the analysis for the upper and lower borders of the final and surgical safe zones for each level. There was no surgical safe zone identified for the third cervical vertebra, although the area between the upper vertebral border and 1 mm below it was the safest area to dissect (93% of arteries are covered by the transverse process in this zone). For the fourth vertebra, the surgical safe zone was between 1 mm above and 1 mm below the upper vertebral border. Two millimeters above and 1 mm below the upper border for the fifth vertebra was considered to be a surgical safe zone; and for the sixth vertebra, 1 mm above and 2 mm below the upper vertebral border was the safest area to dissect from the midline toward the lateral aspect.

Tortuosity of the VA was identified in 13.4% of all intertransverse spaces. Most of the artery tortuosities were observed in the third to fifth intertransverse spaces (Table 4). Finding a tortuous VA at the second intertransverse space was significantly less likely compared with other levels ($p = 0.004$). Table 5 shows the correlation between disc degeneration (decreased disc space and osteophyte formation) and tortuosity ($\chi^2 = 40.2$, $p < 0.001$). In 9.7% of intertransverse spaces, inward looping of the tortuous artery was observed at the level of the uncinate process. Inward looping of the VA at the level of the uncinate process was higher at the fourth (17%), fifth (16%), and sixth (14%) level than at the second (0), and seventh (4%) levels ($p < 0.001$). Two percent of the transverse processes had a defect. These defects were identified at all levels, and the average size of the defects was 5.35 mm$^2$.

Ninety-six percent of arteries entered the transverse foramen at the level of the sixth vertebra, and 4.3% at the level of the fifth vertebra. The distance from the medial border of the artery to the midline was not significantly different on either the right (15.35 ± 3.44 mm) or the left side (15.09 ± 3.05 mm) of the cervical spine ($p = 0.318$). Table 6 shows the distance of the medial border of the VA from the midline at different levels. From the third to the seventh intertransverse spaces there was a significant lateral deviation of the artery from the midline. As Table 7 shows, from the second vertebral level downward the VA became more superficial. This change was significant in transition from the second to the third ($p < 0.001$) and also from the third to the fourth vertebral levels ($p = 0.05$). However, from the fourth level downward no significant change was observed.

The diameter of the artery was larger at the higher levels of the cervical spine than at the lower levels, although the difference was not statistically significant (Table 6). The average diameter of the artery between C-2 and C-7 on the left side was 4.72 ± 0.88 mm, and it was

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### Table 4: Tortuosity of VA at different levels of the cervical spine*

<table>
<thead>
<tr>
<th>Level</th>
<th>Rate of VA Tortuosity (%)</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>2nd intertransverse space</td>
<td>2 of 112 (2)</td>
<td>0.004</td>
</tr>
<tr>
<td>3rd intertransverse space</td>
<td>14 of 120 (12)</td>
<td>0.21</td>
</tr>
<tr>
<td>4th intertransverse space</td>
<td>24 of 120 (20)</td>
<td>0.90</td>
</tr>
<tr>
<td>5th intertransverse space</td>
<td>27 of 120 (23)</td>
<td>0.18</td>
</tr>
<tr>
<td>6th intertransverse space</td>
<td>18 of 120 (15)</td>
<td></td>
</tr>
</tbody>
</table>

* The p value shows the significance of the difference between each level and the lower level.

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### Table 5: Association of degeneration and tortuosity

<table>
<thead>
<tr>
<th>Artery Type</th>
<th>Degenerative (%)</th>
<th>Nondegenerative (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>tortuous artery</td>
<td>48 (27.6)</td>
<td>44 (8.6)</td>
</tr>
<tr>
<td>nontortuous artery</td>
<td>126 (72.4)</td>
<td>467 (91.4)</td>
</tr>
<tr>
<td>total</td>
<td>174</td>
<td>511</td>
</tr>
</tbody>
</table>

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### Table 6: Distance from VA medial border to midline of cervical spine at each level, and diameter of VA at the middle of the intertransverse space*

<table>
<thead>
<tr>
<th>Level</th>
<th>Distance From Medial Border of VA to Midline</th>
<th>p Value</th>
<th>VA Diameter†</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>2nd intertransverse space</td>
<td>13.33 ± 2.18</td>
<td>0.54</td>
<td>4.84 ± 1.05</td>
<td>0.68</td>
</tr>
<tr>
<td>3rd intertransverse space</td>
<td>13.16 ± 1.96</td>
<td>&lt;0.001</td>
<td>4.78 ± 0.92</td>
<td>0.72</td>
</tr>
<tr>
<td>4th intertransverse space</td>
<td>14.09 ± 1.7</td>
<td>&lt;0.001</td>
<td>4.78 ± 0.92</td>
<td>0.69</td>
</tr>
<tr>
<td>5th intertransverse space</td>
<td>15.22 ± 2.11</td>
<td>&lt;0.001</td>
<td>4.69 ± 0.93</td>
<td>0.15</td>
</tr>
<tr>
<td>6th intertransverse space</td>
<td>17.53 ± 2.76</td>
<td>&lt;0.001</td>
<td>4.51 ± 0.88</td>
<td>0.5</td>
</tr>
<tr>
<td>7th intertransverse space</td>
<td>19.83 ± 3.9</td>
<td></td>
<td>4.42 ± 0.95</td>
<td></td>
</tr>
</tbody>
</table>

* The p value shows the significance of the difference between each cell and the lower cell. All measures are in millimeters (mean ± SD).
† Diameter at the middle of the intertransverse space.
4.62 ± 1 mm on the right side (p = 0.21). In 3 cases VAs penetrated and made a loop inside the VB (Fig. 2). The shortest distance between the VA and the midline in these 3 cases (5%) was 4.8 mm.

**Discussion**

Most arterial lacerations are associated with unco-vertebral joint resection, anterior cervical decompression, foraminotomies, vertebrectomy for reduction of a locked facet, and direct injury by a drill. If the course of the artery is tortuous (13%) (Fig. 3a), then the anterior approach for uncosectomy and uncoforaminotomy can predispose the artery to a considerable risk of injury, because it can run in close proximity to the uncinate process. As our study showed, in 10% of levels there is inward looping of the VA at the level of the uncinate process. The artery and the nerve root are encased in a fibroligamentous band, which is attached to the uncinate process. This band places the VA at risk for laceration during uncosectomy and uncoforaminotomy. It has also been demonstrated that the VA is at risk for injury at the lateral extent of the decompression. According to our study, the VA can penetrate the vertebrae (5%) and run as close as 4.8 mm to the midline.

**Anatomical Features of the VA**

**Distance to the Midline.** The distance between the medial artery border to the midline increased from the third to the seventh intertransverse spaces. There was no difference between the mean distance of the artery to the midline in the second and third space (p = 0.54). Thus, corpectomy of the upper vertebrae imposes a higher risk of laceration to the VA than the same operation on the lower vertebrae. The same results were inferred by Vaccaro et al. in their study focusing on the distance of the posterior border of the foramen transversarium from the ventral border of the spinal canal (from 2.16 ± 1.18 mm at C-3 to 3.53 ± 1.56 mm at C-6). Our results were also compatible with the findings of Güvençer et al. The distance of the VA to the midline was always > 8 mm, except in 1 level (1 in 360 cervical levels), which shows that a standard corpectomy (16 mm of vertebral bone removal) is a reasonably safe procedure (Fig. 4). The lateral border of the vertebra cannot be considered a safe margin for corpectomies for 2 reasons: 1) in

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**TABLE 7: Distance from anterior border of VA to anterior vertebral border at the middle of each vertebra**

<table>
<thead>
<tr>
<th>Level</th>
<th>Distance</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-2</td>
<td>11.38 ± 2.7</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>C-3</td>
<td>9.75 ± 2.5</td>
<td>0.05</td>
</tr>
<tr>
<td>C-4</td>
<td>9.08 ± 2.65</td>
<td>0.51</td>
</tr>
<tr>
<td>C-5</td>
<td>8.84 ± 2.8</td>
<td>0.18</td>
</tr>
<tr>
<td>C-6</td>
<td>8.30 ± 3.16</td>
<td></td>
</tr>
</tbody>
</table>

* The p value shows the significance of the difference between each cell and the lower cell. All measures are in millimeters (mean ± SD).

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3 specimens the artery entered the vertebra at 1 level (Fig. 2); and 2) the lateral border of the vertebra may encroach on the VA in the process of osteoarthrosis.

**Diameter and Tortuosity.** Although the diameter of the VA changed at different levels, none of the p values comparing the VA diameter at adjacent levels was significant (Table 6). The results of the VA diameter were compatible with findings in the study by Kawashima et al. In a study of 12 cadavers, the internal diameter of the VA measured on the angiographic images was found to be almost 1 mm smaller than our results. Güvençer et al. also found no significant difference between the diameters of the VA on either the left or right side. The anteroposterior diameter of the transverse process foramen decreases from C-6 to C-3 according to the study by Ebraheim et al. Both of the aforementioned results match our results with the VA diameter.

Tortuosity of the artery was observed mostly in the fourth (20%) and the fifth (23%) intertransverse spaces. The rate of degeneration in these spaces was 31 and 43% for the fourth and fifth space, respectively. The rates of degeneration and tortuosity were 6.3 and 2% at the second intertransverse space, respectively, which was significantly lower than at all the other levels (p = 0.004). The association of degeneration and VA tortuosity can...
be explained by the fact that the artery is fixed to the nerve root by a fibroligamentous band behind the anterior rim of the transverse process. Reduction of the disc space height in the process of degeneration makes the intertransverse portion of the artery (which is not fixed by the fibroligamentous band) more tortuous. Because 9% of nondegenerative cervical spine levels showed VA tortuosity, there should also be other reasons involved as the cause of tortuosity.

A less tortuous course of the VA at both sides of the odontoid and the fact that the minimum distance of the VA from the midline at this level is 8.7 mm should be considered in anterior screw fixation of the odontoid and odontoidectomy. This becomes even more important during endoscopic resection of the odontoid, in which exposure of the VA is not feasible.

Distance to the Anterior Border of the Cervical Spine. The VA moves anteriorly during its descent in the cervical spine. The study conducted by Lu et al. on 28 cadavers and also that by Oh et al. on 10 cadavers showed that the average distance from the anterior border of the artery to the anterior margin of the VBs decreased from C-3 to C-6, which was in line with our findings. This finding is in line with the previously completed studies by Oh et al. and Ebraheim et al. As was mentioned before, the artery is also more tortuous at the fourth and fifth intertransverse spaces. Thus, the artery is more vulnerable during dissections in the intertransverse space of the caudal cervical spine. This should especially be considered during tumor resection in the vicinity of the VA.

Inward Looping. The rate of the inward looping of the VA at the level of the uncinate process is higher at the level of the fourth to the sixth cervical vertebrae (14–17%). The fact that the VA is more anteriorly located at these levels makes it more prone to injury during resection of the uncinate process. This underscores the importance of imaging and VA exposure, if indicated, prior to uncinate process resection. Although in 3 cases the VA entered the vertebrae as a consequence of inward looping, the artery came closer than 8 mm to the midline at only 1 level (Fig. 4).

Level of Entry Into the Foramen Transversarium. All the levels of entry were at the level of C-6 or C-5. Bruneau et al. did a radiological study on 250 MR images of the cervical spine. According to their results, in 93% of all cases the VA entered the transverse foramen at C-6, whereas the percentages for entry at levels C-3, C-4, C-5, and C-7 were 0.2, 1, 5, and 0.8%, respectively. This signifies that a high variation exists in the level of entry of the VA into the transverse foramen. This variability merits consideration while operating on the lower cervical spine vertebrae.

Transverse Process. The transverse process consists of an anterior and posterior rim in the cervical spine. The two are attached by a costotransverse bar laterally. The VA runs in the foramen transversarium, which lies between the lateral border of the vertebra medially, the costotransverse bar laterally, and the anterior and posterior rims of the transverse process. The intertransverse space lies between the lower edge of the upper transverse process and the upper edge of the transverse process below. Vertebral artery, spinal nerve root, and a venous plexus are located in this space. The intertransverse space is anteriorly covered by the intertransverse ligament, which lies in close proximity to the VA and consists of irregular, scanty fibers. According to our results, 2% of transverse processes have defects at the anterior rim.

Safe Exposure. To expose the VA, the surgeon can use either the approach through the intertransverse space or removal of the transverse process. According to the following facts, sectioning of the intertransverse ligament at the intertransverse space may not always be a safe approach to the VA. 1) Exposure of the VA through the intertransverse space mandates removal of the intertransverse ligament (Fig. 1c), which covers the VA in the intertransverse space. In our study we found that removal of this ligament is not always easy to perform without...
Safe approach to the V₂ segment of the vertebral artery

laceration of the VA, because the artery lies immediately beneath it. 2) Because 13% of the intertransverse spaces proved to have a tortuous artery, the VA can easily be injured while the surgeon is trying to remove the intertransverse ligament. 3) Exposure of the artery through the intertransverse space mandates dissection along the lateral border of the vertebra. This border may encroach over the intertransverse space and VA (Fig. 3b) due to osteoarthritis.

For the following reasons, removal of the transverse process as a window to expose the VA can provide a safe route. 1) The transverse process can provide protection for the VA while the surgeon is dissecting the prevertebral soft tissue and LCM prior to exposing the artery, so inadvertent deep penetration of instruments will be halted by the transverse process without damaging the artery. 2) Removing the anterior rim of the transverse process with rongeur and Kerrison devices provides a proper exposure of the whole diameter of the VA. 3) According to our results, there is a landmark for safe extension of dissection laterally onto the transverse process and VA.

Thus, we concluded that dissection of the soft tissue off the bone along the safe zone and removal of the transverse process afterward can be a practical approach to avoid VA lacerations. The transverse process can be very thin and, if fractured, its bone flakes can lacerate the VA underneath it. According to Kawashima et al., in a study of 10 cadavers, 40% of the transverse processes were either < 1 mm thick or paper-thin. Careful use of the Kerrison instrument to remove the transverse process can prevent such injuries. It is safer to remove the transverse process starting from its inferior edge because the fibroligamentous tissue is easier to dissect from the anterior rim of the transverse process in this area. Following removal of the transverse process, the fibroligamentous band can be dissected and the VA can be mobilized. This approach can be used for exposure of the VA prior to laceration repairs, removal of tumors in the vicinity of the VA (like dumbbell-shaped tumors), and uncovertebral joint resection. The distance between the VA and the midline (Table 6) can provide further information on where the artery can be found in the intertransverse space.

According the results depicted in Table 3, in 2–6% of cases the VA is not covered by the transverse process in the surgical safe zone. This is due to the variability in the location and diameter of the transverse process in the cervical spine. Another landmark for identification of the VA is the anterior tubercle of the transverse process. It has been mentioned by Kawashima et al., that the distance between the VA and the anterior tubercle is similar from C-3 to C-6 and is a more reliable landmark than the LCM or the lateral border of the VB for locating the VA.

A tortuous VA can be close to the midline (it may even penetrate the VB), and the level of VA entry into the transverse foramen can be variable. The anterior rim of the transverse process can also be very thin or, rarely, defective. Due to all the aforementioned facts, review of the MR images or CT scans obtained with contrast is absolutely necessary prior to surgery in the vicinity of the VA.

The VA is at a higher risk of injury at the level of the third vertebra for the following reasons: 1) it runs very close to the midline; 2) the VA diameter is higher here than at the lower levels; 3) the anterior rim of the transverse process is thin; and 4) a reliable surgical safe zone does not exist at this level. Injury to the artery can be more disastrous at the higher levels because its vascular branches are largest in the upper cervical segments. In spite of the greater height of the intertransverse space at the upper levels of the cervical spine, the VA occupies a larger portion of these spaces than at the lower levels, which may be a predisposing factor to VA injury.

The fact that a surgical safe zone could not be found at the level of C-3 may be due to the fact that the transverse processes of C-3 are smaller than those of the lower cervical vertebrae. The VA becomes more superficial during its descent in the cervical spine, but it is smaller and also lies at a relatively greater distance from the midline.

Conclusions

In this cadaveric study we defined a surgical safe zone for approaching the V₂ segment of the VA. This surgical safe zone lies between 1 mm above and 1 mm below the upper vertebral border at the fourth vertebra, 2 mm above and 1 mm below the upper vertebral border at the fifth vertebra, and 1 mm above and 2 mm below the upper vertebral border of the sixth vertebra. The results can be used in anterior approaches to the cervical spine. This is especially true when the tortuosity of the artery mandates exposure of the VA prior to uncovertebral joint resection, tumor resection, and VA repair. Based on the high incidence of tortuosity of the VA, preoperative MR imaging or contrast-enhanced CT scans are absolutely necessary before operating in the vicinity of the VA.

Disclaimer

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.
References


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