Exploring the atlantic part of the vertebral artery in the South Indian Population and its implications in spine surgery

Rohini Punja\textsuperscript{1}, Aamna Kausar\textsuperscript{2}, Girish R Menon\textsuperscript{3}, Mamatha Hosapatna\textsuperscript{1}

\textsuperscript{1}Department of Anatomy, Kasturba Medical College (Manipal), Manipal Academy of Higher Education, Manipal, India
\textsuperscript{2}Division of Anatomy, Department of Basic Medical Sciences, Manipal Academy of Higher Education, Manipal, India
\textsuperscript{3}Department of Neurosurgery, Kasturba Medical College (Manipal), Manipal Academy of Higher Education, Manipal, India

Received Jan 30, 2024; Revised Mar 22, 2024; Accepted Mar 27, 2024
Corresponding author: Mamatha Hosapatna
Department of Anatomy, Kasturba Medical College (Manipal), Manipal Academy of Higher Education, Karnataka, 576104 India
Tel: +91-820-2922327, Fax: +91-0820-2571927, E-mail: Mamatha.h@manipal.edu

Study Design: A descriptive, quantitative cross-sectional study of the atlantic part (V3) of the vertebral artery (VA).

Purpose: This study aimed to bridge the research gap in the morphometry of the V3 segment of the VA in the South Indian population.

Overview of Literature: The microsurgical anatomy of this segment of the VA has been explored in various populations, and a thorough understanding of the anatomy and course of the VA, particularly the V3 segment, is essential to prevent iatrogenic complications. Several computed tomography studies but a few cadaveric studies have explored the V3 segment of the VA in the South Indian population.

Methods: This study examined 40 VAs from 20 embalmed cadavers that were obtained from the voluntary donation program, and Institutional Ethical Clearance was obtained before the study. The length, diameter, and angle of the vertical, horizontal, and exit parts of the V3 segment of the VA were documented after its exposure.

Results: The mean lengths of the right and left VAs on each part were nearly similar, except for the mean length of the horizontal part (right: 38.937 mm, left: 40.237 mm) and total length of the V3 segment (right: 66.870 mm, left: 70.350 mm).

Conclusions: These morphometric parameters are essential to spine surgeons who intend to operate on a small part (vertical, horizontal, or exit part) of the V3 segment of the VA. The mean values of the parameters obtained in this study give average measurements or safe limits to surgeons for safe surgical procedures such as the occipital condyle screw technique and C1 laminectomy.

Keywords: Vertebral artery; Regional anatomy; Posterior cranial fossa; Cervical vertebrae; Laminectomy

Introduction

The vertebral artery (VA) arises as a branch of the posterior–superior aspect of the first segment of the subclavian artery. It then traverses through the transverse foramina of each cervical vertebra, except for the transverse foramina of the seventh cervical vertebrae. This justifies that the diameter of the VA is not more than the diameter of the cervical foramina. Later, this artery turns medially behind the lateral masses of the atlas and enters the skull through the foramen magnum. At the level of the lower border of the pons, which is the pontomedullary junction, the VA from the opposite side unites with its fellow artery to form the basilar ar-
tery. This defines the typical course of the VA. In some instances, the artery enters the foramen transversarium of the fourth, fifth, or seventh cervical vertebrae [1].

Despite some ambiguities proposed by different authors in understanding the segmental limits of its course, this study designated four segments based on their position: (1) preforaminal (V1) segment, which runs from its place of origin in the subclavian artery to the foramen transversarium of the sixth cervical vertebrae (C6) [2]; (2) foraminal (V2) segment, which stretches from the C6 foramen transversarium to the C2 foramen transversarium; (3) atlantic/extradural/extraspinal (V3) segment, which lies at the craniovertebral junction, commencing from the C2 foramen transversarium and extends to the foramen magnum [3,4]; and (4) intradural/intracranial (V4) segment, which is entirely intracranial and runs from the dura at the lateral edge of the posterior atlantooccipital membrane to the pontomedullary junction [5-7].

Among the aforementioned segments, this study focused on the third segment (V3), the atlantic part of the VA. This segment extends from the transverse foramen of the second cervical vertebrae to the foramen magnum at the craniovertebral junction [2,4]. It exits slightly lateral from the foramen transversarium of the axis (C2) to enter the foramen transversarium of the atlas (C1). Then, this segment curls backward and medially to the lateral masses of the atlas to lie horizontally in a groove on the posterior arch of the atlas. Finally, the lateral margin of the atlanto-occipital membrane and dura mater are pierced before the artery passes through the foramen magnum and enters the cranial cavity [3]. The entire atlantic segment lies in the suboccipital triangle, bounded by the suboccipital muscles. In addition to the anatomical complexity of the VA that is in the suboccipital region, it also comprises the periarterial neural plexus, its branches, and the adjacent spinal nerves, which are cushioned in the venous plexus. Vascular, neoplastic, degenerative, congenital, or traumatological diseases could develop in this region; thus, a detailed understanding of this complex anatomical system is crucial for appropriate surgical management [8].

Because of the clinical importance of the V3 segment, many authors have studied its microsurgical anatomy [5,9]. VA damage will result in life-threatening complications because this artery is closely related to the floor of the posterior cranial fossa. Before attempting surgery at the posterior cranial fossa and the craniovertebral junction, a thorough understanding of the anatomy and course of the VA, particularly the V3 segment [10], is necessary to prevent iatrogenic complications [3]. Numerous studies have examined the suitability of the bone structure of the C1 and C2 vertebrae for screw insertion; however, few studies have documented the importance of knowledge on the vascularity around the suboccipital region, that is, the atlantic segment of the VA [11]. Cadaveric studies of this region are scarce in comparison to imaging studies. Thus, this study aimed to fill the research gap on the morphometry using cadavers such as the length, diameter, and angle to facilitate safe exposure of the atlantic part of the VA during neurosurgical procedures.

**Materials and Methods**

This study was conducted in the anatomy department in association with neurosurgery after obtaining the Institutional Ethical Committee of Kasturba Medical College and Kasturba Hospital (IEC674/2021). Forty VAs from 20 embalmed (10% formalin) cadavers that were used for first-year medical students during routine dissection classes were analyzed. The cadavers were initially positioned prone, with a wooden block placed under the neck region. The skin was reflected in layers down to the VA using microsurgical instruments. The C7 spine, acromion process, and external occipital protuberance were all felt before making the incision. With these bony reference points, three incisions were taken, which included two horizontal incisions (first from the midline with the external occipital protuberance as the reference till the acromion process laterally along the highest nuchal above and second from the C7 spine to the acromion process below) and a vertical midline incision (from the external occipital protuberance up to the C7 spinous process). The skin flaps, superficial fascia, and thickened deep fascia were exposed, and the posterior (superficial and deep) muscles of the neck were then identified, dissected, and exposed downward. The deep muscles included the semispinalis capitis, semispinalis cervicis, and longissimus capitis, and the superficial muscles included the trapezius, levator scapulae, and splenius capitis.

The following suboccipital triangle muscles were exposed: rectus capitis posterior major, rectus capitis posterior minor, obliquus capitis inferior, and obliquus capitis superior. At this stage in the dissection process, the triangular space housed a portion of the atlantic (V3) part of the VA (Fig. 1). These suboccipital muscles forming the boundaries of the triangle were detached from their bony attachments to observe and measure the various parameters of the V3 segment of the VA. To facilitate the visibility of the VA, the suboccipital
venous plexus in this area was completely removed. Using blunt forceps and a periosteal elevator device, the region around the atlantoaxial joint, C1 posterior arch, C1 tubercle, and C2 spine, and the transverse processes of C1 and C2 were exposed. The entire course of the V3 segment of the VA and the second cervical nerve (its rami and ganglion) became visible after the dissection (Figs. 1, 2).

The V3 segment of the VA was further subdivided into three parts for the feasibility of the study. These parts were labeled as the vertical (V), horizontal (H), and exit (E) parts. The V part is the portion of the VA extending from the level where the artery leaves from the foramen transversarium of the axis (C2) vertebrae up to the level where it leaves the foramen transversarium of the atlas (C1) vertebrae. The H part lies horizontally in the groove for the VA on the posterior arch of the atlas. It extends from the level where the artery leaves the foramen transversarium of the atlas (C1) vertebrae to the point at which it turns slightly upward (the medial-most end of the groove in the posterior arch of the atlas). The E part is the portion that extends from the medial end of the groove in the posterior arch of the atlas to the level at which the artery exits behind the atlantooccipital membrane to continue as the V4 segment (Fig. 2). Parameters denoted as pair 1 to pair 9 were included in the study:

- **Length of various parts of V3 segment of VA**
  - Pair 1: length of the V part on the right (LVR) and left (LVL) sides (Fig. 3)
  - Pair 2: length of the posterior arch of C1 corresponding to the V3 segment on the right (LPR) and left (LPL) sides (Fig. 3); total length of the V part + length of the posterior arch of the atlas
  - Pair 3: length of the H part on the right (LHR) and left (LHL) sides
  - Pair 4: length of the E part on the right (LER) and left (LEL) sides
  - Pair 5: length of the total V3 segment on the right (LTR) and left (LTL) sides.

- **Diameter of V3 segment of VA (at the mid-length of each part)**
  - Pair 6: diameter of the V part on the right (DVR) and left (DVL) sides
  - Pair 7: diameter of the H part on the right (DHR) and left (DHL) sides
  - Pair 8: diameter of the E part on the right (DER) and left (DEL) sides
  - Pair 9: diameter of the total V3 segment on the right (DTR) and left (DTL) sides.
- Pair 7: diameter of the H part on the right (DHR) and left (DHL) sides (Fig. 3)
- Pair 8: diameter of the E part on the right (DER) and left (DEL) sides (Fig. 3)
- Pair 9: average diameter (average diameter of the V, H, and E parts): on the right (DAR) and left (DAL) sides

Angle between vertical and horizontal part of V3 segment: on right (AR) and left side (AL) (Fig. 4)

The aforementioned parameters were measured using a Aerospace Digital Vernier calipers (Halamanee Aerospace Pvt. Ltd., Bangalore, India), except for the angle. This parameter was measured using ImageJ software (https://imagej.net/ij/). To get accurate values of the angle through ImageJ, appropriate photographs were taken by maintaining a predetermined distance between the dissected area and the camera.

At the final stage, data collected were analyzed using the IBM SPSS Statistics ver. 26.0 (IBM Corp., Armonk, NY, USA). Descriptive statistical analyses were performed, reporting the mean and standard deviation. Pearson's correlation test was also performed to determine the relationship between the two variables.

## Results

The descriptive analysis of the length and diameter of 40 VAs (right and left) is presented in Table 1. The mean lengths on the right and left sides of each part were nearly comparable, except for the mean length of the H part (right: 36.86 mm, left: 38.09 mm) and the total length of the V3 segment (right: 66.87 mm, left: 70.35 mm). The total length depicts that the left VA is longer than the right VA. The mean diameters for each part of the right and left VAs were comparable.

To check the simultaneous relationship between two parameters, the correlation of the total length (LTR and LTL) and average diameters (DAR and DAL) of the VA were analyzed using Pearson's correlation test. Pearson's r-value was weakly positive for the right (+0.003) and left (0.021) (Figs. 5, 6).

The angle between the V and H parts on the right and left sides of all cadavers was measured, and descriptive analysis was performed. The analysis revealed that the mean angle on the right side (AR) was greater (80.8°) than that of the left (AL, 78.5°) with standard deviations of 24.45° and 22.43° on the right and left sides, respectively.

The correlation between the AR and AL was also analyzed using Pearson's correlation test, and Pearson's r-value was 0.911, which indicates strongly positive correlation. The p-value in the correlation analysis was <0.001, which represents a significant correlation between AR and AL (Fig. 7). The correlation between the total length (LTR and LTL) and average diameter (DAR and DAL) was not significant (r-values of 0.003 and 0.021, respectively).

### Table 1. Represents morphometric measurements of length and diameter of the various segments: descriptive analysis in 40 vertebral arteries

<table>
<thead>
<tr>
<th>Pair</th>
<th>Category</th>
<th>Length/diameter (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pair 1</td>
<td>LVR</td>
<td>23.72±4.98</td>
</tr>
<tr>
<td></td>
<td>LVL</td>
<td>23.45±4.76</td>
</tr>
<tr>
<td>Pair 2</td>
<td>LPR</td>
<td>6.40±1.87</td>
</tr>
<tr>
<td></td>
<td>LPL</td>
<td>6.72±1.79</td>
</tr>
<tr>
<td>Pair 3</td>
<td>LHR</td>
<td>36.86±6.71</td>
</tr>
<tr>
<td></td>
<td>LHL</td>
<td>38.09±6.83</td>
</tr>
<tr>
<td>Pair 4</td>
<td>LER</td>
<td>2.07±0.11</td>
</tr>
<tr>
<td></td>
<td>LEL</td>
<td>2.14±0.13</td>
</tr>
<tr>
<td>Pair 5</td>
<td>LTR</td>
<td>66.81±13.15</td>
</tr>
<tr>
<td></td>
<td>LTL</td>
<td>70.35±8.94</td>
</tr>
<tr>
<td>Pair 6</td>
<td>DVR</td>
<td>3.55±1.16</td>
</tr>
<tr>
<td></td>
<td>DVL</td>
<td>3.54±0.97</td>
</tr>
<tr>
<td>Pair 7</td>
<td>DHR</td>
<td>3.63±1.40</td>
</tr>
<tr>
<td></td>
<td>DHL</td>
<td>3.69±1.40</td>
</tr>
<tr>
<td>Pair 8</td>
<td>DER</td>
<td>3.41±1.26</td>
</tr>
<tr>
<td></td>
<td>DEL</td>
<td>3.45±1.37</td>
</tr>
<tr>
<td>Pair 9</td>
<td>DAR</td>
<td>3.69±1.29</td>
</tr>
<tr>
<td></td>
<td>DAL</td>
<td>3.56±1.12</td>
</tr>
</tbody>
</table>

Values are presented as mean±standard deviation. LVR/LVL, length of vertical part right and left side; LPR/LPL, length of posterior arch of C1 corresponding to V3 segment right and left side; LHR/LHL, length of horizontal part right and left side; LER/LEL, length of exit part right and left side; LTR/LTL, length of total V3 segment right and left side; DVR/DVL, diameter of vertical part on right and left side; DHR/DHL, diameter of horizontal part on right and left side; DER/DEL, diameter of exit part on right and left side; DAR/DAL, diameter average (average diameter of V, H, and E parts) on right and left side.
A few previous studies have examined the morphometry of the atlantic segment of the VA. Confining to the parameter length of the atlantic part of the VA, the analogous studies were as follows (Table 2).

As seen in Table 2, this study measured the length of the three parts of the atlantic segment of the VA (V, H, and E) and the total length of the whole V3 segment and compared the morphometric values for both the right and left sides, unlike the previous cadaveric studies [10,12]. The total length depicts that the left VA is longer than the right VA. Moreover, the larger sample size validates the results of the present study. The mean length documented for each part of the V3 segment could be of value to surgeons performing surgeries involving this segment.

However, a few studies that measured the diameter of the atlantic segment of the VA were compared, and the results are presented in Table 3 [2,12-17].

Table 3 reflects the limited number of cadaveric studies with a good sample size that measured the diameter of the V3 segment. For example, in 2015, Khanfour and El Sekili [14] measured the diameter of the V and H parts but not the E part. Moreover, Duan et al. [15] in 2009 measured the diameter of the E part only. Thus, to our knowledge, the present study is the only anatomical study that measured the diameter of all three parts (V, H, and E) along with the average diameters on the right and left sides in 40 VAs. In addition, all the mean diameter values ranged between 4.95 mm and 5.70 mm, and the maximum diameter among all was 6.0 mm. Unlike the other studies mentioned above, the present study also compared the diameters on either side and found a correlation between the average diameter and total length of the V3 segment of the VA. These mean diameter values and the results of the correlation test performed will assist surgeons in acquiring a better approach during skull base surgeries. Internal fixation with cervical plates promotes immediate stability and decreases graft-related complications; thus, knowledge

**Table 2.** Represents the comparison between the analogous previous studies along with the current study for the parameter: length of VA.

<table>
<thead>
<tr>
<th>Author (year)</th>
<th>No. of VA/population</th>
<th>Mean length (mm)</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Lang et al. [10] (1991)</td>
<td>65/German</td>
<td>38.91±5.53</td>
<td>44.3±6.27</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Muralimohan et al. <a href="2009">12</a></td>
<td>21/South Indian</td>
<td>15.0±1.53</td>
<td>35.6±2.44</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Current study</td>
<td>40/South Indian</td>
<td>LVR: 30.12±6.855</td>
<td>LHR: 36.86±6.71</td>
<td>LER: 2.07±0.11</td>
<td>LTR: 66.810±13.15</td>
</tr>
<tr>
<td></td>
<td></td>
<td>LVL: 30.175±6.775</td>
<td>LHL: 38.09±6.83</td>
<td>LEL: 2.14±0.13</td>
<td>LTL: 70.350±8.94</td>
</tr>
</tbody>
</table>

Values are presented as mean±standard deviation.

VA, vertebral artery; V, vertical part; H, horizontal part; E, exit part; LVR/LVL, length of vertical part right and left side; LPR/LPL, length of posterior arch of C1 corresponding to V3 segment right and left side; LHR/LHL, length of horizontal part right and left side; LER/LEL, length of exit part right and left side; LTR/LTL, length of total V3 segment right and left side.
of various segments of the VA is crucial during such spine surgeries [18]. The diameters and angles have affected the turbulent blood flow supplying the brain and spinal cord, which could trigger an ischemic stroke; similarly, defects in the vessel wall might lead to aneurysmal defect with aging [16]. Moreover, the angle measured in the present study was compared with those reported in previous studies (Table 4) [11,16].

Compared with other studies, the present study stands distinctive because it measured the angles between the V and H parts of the V3 segment of the VA (Table 4). This study used ImageJ software to measure the angle compared with other studies that used a protractor [8]. This software was used to maintain high accuracy of angle measurements. The correlation of the angles measured, AR and AL, was analyzed using Pearson’s correlation test. Pearson’s r-value was 0.911, and the p-value of the correlation was <0.001, representing a significant correlation between AR and AL (Fig. 7). This may mean that the distribution of the blood supply to the brain is dependent on the angle formed between the V and H part on the right and left sides. However, a limitation of this study was that the analysis results were based on cadavers, and there might be a slight change in morphometric values compared with living individuals.

Studies conducted on the basilar artery have shown a

<table>
<thead>
<tr>
<th>Author (year)</th>
<th>Type of study</th>
<th>No./population</th>
<th>Segment of VA</th>
<th>Angle between V part and H part</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patel et al. [16] (2020)</td>
<td>Brain specimen</td>
<td>10 Brain specimens/American</td>
<td>V4 at vertebrobasilar junction: 51°–91°</td>
<td>-</td>
</tr>
<tr>
<td>Cengiz et al. [11] (2009)</td>
<td>14 Cadavers and 48 CT images/Turkish</td>
<td>Angle at dural entry point (cadaveric)</td>
<td>Right: 82.42°±10.34°</td>
<td>No correlation test done</td>
</tr>
<tr>
<td>Current study</td>
<td>40 VA/South Indian</td>
<td>V3</td>
<td>AR: 80.8°±24.45°</td>
<td>Difference in diameter with angle was insignificant.</td>
</tr>
</tbody>
</table>

Values are presented as mean±standard deviation. VA, vertebral artery; V, vertical part; H, horizontal part; CT, computed tomography; AR/AL, angle on the right side with that on the left side.
correlation between arterial dilatation and elongation, and this is attributed to dolichoectasia. Thus, we analyzed the correlation between the diameter and length of the V3 segment (Figs. 5, 6), which was seen to be clinically insignificant because dolichoectasia preferentially affects the basilar artery [19-21].

The anatomy of the VA must be critically evaluated before performing upper cervical spine surgeries, from C3 spine [22-25]. VA had an increased risk for injury during transarticular screw placement if the C2 isthmus is too small to accommodate the screw. Studies have further stated that variations in the V3 segment of the VA could lead to its injury during C1 lateral mass screw placement [22-25].

Through this study, we have attempted to collect the morphometric data pertaining to the V3 segment of the VA for the South Indian population because this VA segment is less frequently explored, and data obtained could aid spine surgeons when performing surgeries for a specified population.

**Conclusions**

In contrast to earlier studies, the present morphometric investigation evaluated the length, diameter, and angle of each of the three parts of the atlantic segment of the VA. This study will be of great importance to spine surgeons who intend to perform surgery on a limited segment (any of the three parts) of the atlantic portion of the VA. The mean values of the parameters give an average measurement as a reference for surgeons during microsurgical procedures such as occipital condyle screw technique and C1 laminectomy for vascular pathologies involving the VA.

**Key Points**

- First comprehensive cadaveric study of V3 segment of vertebral artery in South Indian population, measuring length, diameter, and angle of all three parts.
- Left-sided vertebral artery longer than right (mean total length: 70.35 mm vs. 66.81 mm); mean diameters ranged 4.95–5.70 mm.
- Strong positive correlation between right and left side angles (80.8° and 78.5°, respectively), suggesting dependency for balanced blood supply.
- Morphometric data provides valuable reference for spine surgeons performing procedures in the atlantoaxial region.

**Conflict of Interest**

No potential conflict of interest relevant to this article was reported.

**Acknowledgments**

We would like to acknowledge body donors without whom this type of research would not be possible.

**ORCID**

Rohini Punja: https://orcid.org/0000-0003-0732-5468;  
Aamna Kausar: https://orcid.org/0009-0006-7620-9830;  
Girish R Menon: https://orcid.org/0000-0002-1849-0453;  
Mamatha Hosapatna: https://orcid.org/0000-0002-7150-1369

**Author Contributions**


**References**

7. Zhu SW, Yang Y, Liu YG, Cao JW, Li F. Anatomical features and clinical significance of radiculomuscular artery variants involving the suboccipital segment of vertebral...