The V₂ segment of the vertebral artery and its branches

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Objective. The goal of this study was to demonstrate the origins, courses, anastomoses, and target tissues of the arterial branches that arise from the V₂ segment of the vertebral artery.

Methods. Ten adult cadaveric necks (20 V₂ segment specimens) were examined (magnification × 40) after injection of colored silicon. The branches at each cervical level were classified in a new system according to anatomical features and target tissues—anterior, posterior, medial, and lateral. Incidence with which each branch category was observed at each cervical level was calculated.

Anterior branches were observed at C-3 in all 20 V₂ segment specimens. The incidence with which the posterior branch was present at C-4 was 45%, whereas the corresponding rates at segments superior and inferior were lower. The medial V₂ segment branches were assessed in four subcategories. The anterior spinal artery was present at C-3 in all specimens, whereas the mean incidence at the C4–6 level was 46.7%. The posterior spinal artery was most frequently detected at C-3 (60%). The anterior radicular artery (RA) was present at C-5 in 50% of the specimens, whereas the posterior RA was detected at C-5 in only 35%. Lateral branches were most frequently detected at C-3.

Conclusions. The authors provide detailed anatomical information about the origins, courses, anastomoses, and target tissues of the vessels that arise from the V₂ segment. This new classification allows for better understanding of the vasculature of the C3–6 region.

KEY WORDS • vertebral artery • V₂ segment • cervical spine • cadaver

Increased clinical interest in spinal derangements combined with advancements in spinal procedures underscores the need for more precise knowledge of structural and functional relationships of the anatomy in the healthy spine. Only a few studies have provided comprehensive information about the vascularization of the cervical spine. Although the V₂ segment of the VA is the major supplier of blood in this region, no investigators have provided a detailed anatomical description of the branches that arise from this segment of the VA in humans. The V₂ segment is the transverse portion of the VA. It extends from the site where the VA enters the transverse foramen at the C-6 level to the point where it enters the C-2 transverse foramen. The tissues supplied by the V₂ segment are potential sites of vascular, neoplastic, degenerative, and trauma-induced disease, and the operative management of such conditions demands in-depth understanding of the complex vascular anatomy.

In this study we provide the anatomical details of the branches of the V₂ segment and discuss how these branches contribute to the vascularization of the cervical spine. To provide a better understanding of the arterial branches that originate from this segment, we propose a new classification system in which the different branches are grouped according to anatomical features and target tissues.

Abbreviations used in this paper: ASA = anterior spinal artery; PSA = posterior spinal artery; RA = radicular artery; VA = vertebral artery; VB = vertebral body.

Materials and Methods

Spinal Specimens

The cervical spines of 10 cadavers (20 VAs) were removed en bloc. By definition the V₂ segment comprises the transverse segment of the VA that extends from the C-6 transverse foramen to the C-2 transverse foramen. Accordingly, we attempted to identify both VAs in each specimen at the normal entry point at C-6. Entry of the VA at a level other than C-6 was grounds for exclusion from the study; however, none of the specimens exhibited this pattern.

Inspection of the V₂ Segments

The cadavers had been embalmed in a formalin solution. We cannulated both VAs in each specimen and irrigated them with saline to remove any residual blood clots. Colored latex material (Carolina Biological Supply Co., Burlington, NC) was then injected at the proximal opening of each vessel. To ensure adequate perfusion of the microcirculation, each segment was perfused individually under pressure by clamping the distal part of the VA at the atlas. Forty hours after injection, the cadavers were ready for dissection. In each specimen, the distance between the medial borders of the longus colli muscles, the diameters and lengths of the V₂ segments, and the distances between the medial borders of the transverse foramina of the cervical spine were measured. All dissections were performed using a surgical microscope (magnification × 40), and measurements were made in millimeters using a steel ruler.

A cervical level was defined as the region from the lower margin of the transverse foramen of one vertebra to the lower margin of the transverse foramen of the adjacent vertebra. For example, the C-5 level was identified as the region extending from the lower margin of the C-4 transverse foramen to the lower margin of the C-5 transverse foramen. The branches were identified and recorded (was this structure a direct branch off of the VA and/or was it part of a common trunk?). The branches of each of the 20 V₂ segment specimens
were classified as anterior, posterior, medial, and lateral, according to their site on the parent vessel and their course (Table 1). For each individual branch, the origin, course, anastomosis, and final target tissues were noted. For each branch type and each subcategory (as in the case of medial branches and lateral branches) we calculated the incidence with which each cervical level was occupied by each of the 20 specimens.

**Results**

The distance between the medial borders of the longus colli muscles increased in a rostrocaudal direction. The mean distances were 7 mm at C-3, 12 mm at C-4, 15.6 mm at C-5, and 17.2 mm at C-6. The mean length of the V2 segment of the 20 VAs was 78.2 mm; the mean diameters of the left and right VAs were 4.6 and 4.2 mm, respectively. The distance between the medial borders of the transverse foramina was greatest at the base of the neck (mean 32 mm at the C-6 level) and narrowed as the vessel ascended (mean 24 mm at the C-3 level). Table 2 provides a summary of origin/course of each branch in each specimen according to location (anterior, posterior, medial, or lateral) on the V2 segment.

**Anterior Branches of the V2 Segment**

We identified anterior V2 segment branches as 1) those supplying the anterior surface of the VB; and 2) those forming the arterial network beneath the longus colli muscle, superficial to the costal processes. These anterior branches run in rostral and caudal directions, and they form discrete longitudinal arterial chains along the medial margins of the longus colli muscle (Fig. 1). We found that all specimens possessed anterior branches at the C-3 level; however, the incidence of anterior vessel presence at the lower cervical levels was smaller (70% at C-4, 35% at C-5, and 25% at C-6 level).

**Posterior Branches of the V2 Segment**

Posterior V2 segment branches were identified as those that supplied the dorsal surface of the vertebra’s lamina and the posterior paravertebral muscles. The level at which the posterior branch most often appeared was C-4 (45%), whereas it was 27.5% at C-3, 37.5% at C-5, and 10% at C-6.

**Medial Branches of the V2 Segment**

The medial group of V2 segment branches was the most anatomically complex. We identified these vessels in four branch subcategories according to their origins and/or courses: 1) arteries supplying the anterior spinal canal; 2) arteries supplying the posterior spinal canal; 3) the anterior and posterior RAs; and 4) arteries supplying the dura mater.

**The ASA.** Branches of the V2 segments of the left and right VAs that lead to the anterior spinal canal form an arcuate system of arteries on the posterior surfaces of the cervical VBs. These arches sweep around each pedicle, forming a continuous series of linked arcades (Fig. 2). This architecture is created by transverse anastomoses connecting arching vessels that originate from the left and right sides. The resultant arches form at the midline of each VB dorsal to the posterior longitudinal ligament. We found that this arterial plexus was present in all specimens at C-3, whereas it was observed at C-4, C-5, and C-6 at rates of 55, 45, and 40%, respectively.

**The PSA.** The second set of branches forms an arcuate pattern in the posterior part of the interior of the spinal canal, mirroring the pattern in its floor. These vessels lie on the interior peristeum of the lamina and on the ligamentum flavum. Vessels of this arcuate system penetrate the lamina, contributing to its blood supply and to that of the spinous processes, pedicles, and zygapophysial joints. We found that these branches were most frequent at C-3 (60%), whereas they were demonstrated at C-4, C-5, and C-6 at rates of 10, 35, and 35%, respectively. This arterial network is depicted in Fig. 3.

**The RAs.** The major sets of vessels that enter the intervertebral foramina are the neural branches of the VAs, which give rise, segmentally, to anterior and posterior RAs. These vessels course alongside the nerve roots and penetrate the dural root sheaths. They pass through these sheaths to the anterior or posterior surface of the cervical spinal cord in a subpial position, where they join the anterior or posterolateral longitudinal arterial channel of the spinal cord, respectively (Fig. 4). The incidence of the anterior RA at C-5 was 50%, whereas it was 35% at C-4 and C-6. In one specimen we noted that the anterior RA was absent at all cervical levels. The incidence of the posterior RA at C-6 was 40%.

**Dural and Meningeal Branches.** The incidences of dural and meningeal branches at C-3, C-4, C-5, and C-6 were 50, 40, 40, and 15%, respectively (Fig. 5).

**Lateral Branches of the V2 Segment**

We subcategorized the lateral branches of the V2 segment as a muscular branch, an osteoarticular branch, and a branch supplying the dorsal root ganglion. The incidences of these lateral branches varied widely among the specimens. The highest incidence (80%) of muscular branches was observed at C-3 (Fig. 6). Lateral branches supplying the dorsal root ganglia were also most frequently demon-
The V₂ segment and its branches

The anatomy of the VA and its contributions to the vascularization of the cervical spine and the spinal cord were first described as early as the 18th century.¹,¹²,²⁷ It has long been accepted that the blood to the upper spine (C₁–₃) is supplied by the VAs, that the C₄–₆ region is supplied by the VAs and the ascending cervical artery, and that the C₇–T₁ segment is supplied by the costocervical trunk.⁹,¹¹,²³ In this study we have provided a detailed description of the anatomy of the perforating branches that arise from the V₂ segment of the VA and described the vascular patterns of V₂ at each cervical level. We found that the VA makes its largest vascular contributions in the upper cervical segments.

**Discussion**

The anatomy of the VA and its contributions to the vascularization of the cervical spine and the spinal cord were first described as early as the 18th century.¹,¹²,²⁷ It has long been accepted that the blood to the upper spine (C₁–₃) is supplied by the VAs, that the C₄–₆ region is supplied by the VAs and the ascending cervical artery, and that the C₇–T₁ segment is supplied by the costocervical trunk.⁹,¹¹,²³ In this study we have provided a detailed description of the anatomy of the perforating branches that arise from the V₂ segment of the VA and described the vascular patterns of V₂ at each cervical level. We found that the VA makes its largest vascular contributions in the upper cervical segments.

Anatomy of the VA can be considered in sagittal and axial contexts. With respect to the former, the left and right VAs arise from the left and right subclavian arteries, respectively, and research indicates that they enter the C₆ transverse foramina (the start of the V₂ segment) in 89.8% of cases. This is considered normal anatomy; thus, in our study, we included only VAs that followed this

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**TABLE 2**

*Origin/cause of each branch of the V₂ segment stratified by cervical level in the 20 VA specimens*

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* Values represent the numbers of specimens exhibiting each respective origin or course.

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**FIG. 1.** Photographs. The anterior branches of the V₂ segment supply the anterior surface of the VB and form the arterial network that lies beneath the longus colli muscle, superficial to the costal processes (CP). The high incidence of anterior branches of the V₂ segment at C-3 is due to the presence of the anterior ascending artery (aaa) in this region. Bv = branch of the VB; IVD = intervertebral disc; Mus = muscular branch.

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course. With regard to axial organization of the VA, the anatomical arrangements are complex. The left and right VAs are asymmetrical, and different numbers of branches of the V2 segment may be present at any given spinal level. The authors of previous work have demonstrated that the left VA is larger in caliber than the right and that the incidence of its branching tends to be higher on the left side. We observed both these features in our study. Additionally, one branch often subdivides into multiple branches that supply the VB, spinal cord, and/or paravertebral muscles. To better understand this vascular anatomy, we devised a system in which the branches of the V2 segment are classified based on origin, course, and target tissues. Accordingly, we identified four main branch categories (anterior, posterior, medial, and lateral) and then calculated the rate of occurrence for each branch category (subcategories for the medial and lateral branches) at each cervical level.

Descriptions and nomenclature involving vessels that supply the vertebrae and spinal tissues have varied considerably. Many authors have contended that the vasculature of the cervical spine is atypical. Typically, it has been assumed that knowledge of thoracolumbar vasculature is applicable to the cervical region. Abiding by these assumptions, each segmental artery or its regional equivalent is thought to supply each vertebral region with several sets of nutritional vessels—namely anterior central, posterior central, prelaminar, and postlaminar branches. In attempt to recognize differences in the vascularization of the cervical vertebrae, Crock and Yoshizawa introduced new terminology in 1971. These authors used the term “anterior spinal canal artery” instead of posterior central artery, and used “posterior spinal canal artery” instead of prelaminar artery; however, this classification scheme did not provide a detailed understanding of the anatomy. To understand better the vessels that originate from the V2 segment, we classified the perforator structure in a new system into anterior, posterior, medial, and lateral categories.

**Anterior Branches of the V2 Segment**

As previously defined, the anterior vessels are those that supply the ventral surface of the cervical VB and the longus colli musculature. The traditional label for this branch of V2 is the anterior central artery. According to Parke and Sherk, this vessel directly penetrates the cortical bone of the VB and forms an anterior spinal plexus beneath the longus colli muscle. We found that the anterior branch was most consistently present at the C-3 and C-4 levels and that rates were much lower in the lower cervical spine. The high frequency of anterior V2 branches at C-3 is due to the presence of the anterior ascending artery in this region. This vessel arises from the anterior aspect of the V2 segment and passes beneath the longus colli muscles to reach the ventral surface of the C-2 VB. Along its course, it forms an arch around the apex of the C-2 odontoid process and sends fine medial branches into the substance of the VB.

**Posterior Branches of the V2 Segment**

In our classification system, the posterior branches of the V2 segment supply the posterior paravertebral muscles...
and the musculature overlying the lamina. This branch has typically been termed the postlaminar artery. These vessels send small nutrient branches that enter into the bone through multiple nutrient foramina located just posteros medial to the articular capsule and the posterior part of the lamina. The incidences of posterior branches occurring at the different cervical levels varied considerably in our specimens. As reported, the rates were 27.5% at C-3, 45% at C-4, 37.5% at C-5, and 10% at C-6. These findings indicate that the main blood supply to the posterior cervical muscles below C-4 is not the VA, but, rather, the deep cervical artery, which originates from the costocervical trunk. The paravertebral muscles above C-4 are also supplied by an arterial network that originates from the ascending and deep cervical arteries as well as by descending branches of the occipital arteries.

Medial Branches of the V₂ Segment

The ASA. Harris and Jones first described the ASA in 1956. This vessel is also known as the anterior central artery. It may enter the vertebral foramen as a single vessel, or it may arise from the posterior segment branch of the VA as an independent ramus. This vessel passes over the posterolateral surface of the intervertebral disc and divides into caudal and cranial branches that supply the two adjacent VBs. The ASA was present at C-3 in all our specimens. At this level, the vessel forms the posterior ascending branch of the C-2 odontoid process (Fig. 2). Our findings verified that the posterior ascending branch of the odontoid process originates from the ASA.

The PSA. This artery is also known as the prelaminar artery. It courses in the posterior aspect of the spinal canal and follows the inner surface of the vertebral arches. It supplies the ligamentum flavum, the anterior part of the lamina, and the epidural tissue. In our study, this branch was most frequently detected at C-3 (60% of cases), whereas at C-5 and C-6 it was 35%. In only 10% of the specimens was this vessel observed at C-4, and we cannot explain the particularly low incidence at this level.

The RAs. Anterior and posterior radicular branches may be present in the cervical region, and the authors of several studies have focused on a variety of these vessels and the cervical levels at which they are found. Before the 1700s, it was generally believed that an RA accompanied each nerve root and that all RAs contributed to the vascularization of the spinal cord. Von Haller was the first to note the considerable variation in the sizes and segmental entrance sites of the RAs. In 1889, Kadyi reported that four to eight RAs supply the cervical spinal cord. More than 70 years later, Turnbull, et al., showed that this region of the cord receives zero to six anterior RAs and zero to eight posterior RAs. At approximately the same time, Corbin named three types of RA: the RA, the pia-RA, and the radiculomedullary artery. In two separate studies of the vascularization of the spinal cord, Lazorthes and colleagues found that most radicular branches of the VA are small, and that only a few extend to the surface of the spinal cord.

Our results indicate that anterior RAs may be present at any cervical level (C3–6). In most of our 20 specimens, two or three RAs were observed along the V₂ segment, and C-5 was found to be the level most frequently associated with RAs in our series. These features are in line with findings reported by Gillilan in 1958 and Chakravorty in 1971; however, in neither study was the exact origin of the
RAs demonstrated. Based on our dissections we found that the RAs in the cervical region branch directly off the VA. Interestingly, one of the specimens in our series had no RA at any cervical level, and in another no RAs below C-4 were observed. Gillilan claimed that any of the arteries in the cervical region could give rise to RAs. Analysis of our findings indicates that the presence and numbers of these arteries, which ultimately become permanent feeding channels, vary widely in individuals. We also observed a higher incidence of left-sided RAs, which may be explained by dominant circulation on this side.

**Dural and Meningeal Branches.** There are two types of arteries in this subcategory. The dural branches of V2 segment target the dura of spinal cord, whereas the meningeal branches of this segment usually do not penetrate the dura. The latter ascend and descend in the spinal canal along the surface of the dura. We assessed these two types together because both usually originate from a single branch off the V2 segment.

**Lateral Branches of the V2 Segment**

As we define it, this category is subdivided into a muscular branch, an osteoarticular branch supplying the facet joint, and a branch supplying the dorsal root ganglion. Alleyne, et al., detected the ganglionic artery in greater frequency at C-4 (65% of 20 specimens), C-5 (60% of 20 specimens), and C-6 (39% of 18 specimens) than at higher cervical levels. The rates of ganglionic branches in our study were 50% at C-3, 35% at C-4, 20% at C-5, and 10% at C-6. Correspondingly the rates of muscular branches were 80, 55, 25, and 20%, respectively, at these levels.

**Conclusions**

Detailed knowledge of the normal anatomy and anatomical variations of the perforating vessels of the V2 segment will help surgeons and radiologists in the clinical setting. We have offered detailed anatomical information about the origins, courses, anastomoses, and target tissues of the branches that arise from the V2 segment of the VA. In our system, these vessels are classified as anterior, posterior, medial, or lateral types. This new classification system allows for better understanding of the vasculature in the C3–6 region.

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References


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