ABOUT THE SUBOCCIPITAL PART OF THE VERTEBRAL ARTERY AND THE NEIGHBORING BONE-JOINT AND NERVE RELATIONSHIPS

Abstract—Length measurements, nerve-vessel relationships, and vessel relationships to articulations and the dura mater were examined in 65 head and neck halves. The paramedian distance of the vertebral artery (midpoint) is a mean of 15.8 mm on the right, and a mean of 17.3 mm on the left. In the area of the intervertebral symphysis C2-C3 at the transverse foramen of the axis the artery has a paramedian mean distance of 17 mm. After the exit of the artery from the axis four types of loop formations of the axoatlantal part and their occurrences are described. Also, the atlantal part of the artery was studied: the overlapping of the posterior arch of the atlas was 5.14 (0 to 13) mm. The length of the axoatlantal part of the vertebral artery was a mean of 39 mm, and the length of the atlantal part was a mean of 44 mm. Besides the measurements of the outer diameter of the artery, the branches and anastomoses of the V₃ segment, nerve-vessel and nerve-joint relationships of the artery, and some veins of the craniocervical junction are described. All findings are discussed in relation to their clinical significance.

The part of the vertebral artery that runs between discus intervertebralis C2-C3 and passes through the dura mater was described as the V₂ segment by Fisher¹ and that part inside the subarachnoid cavity was called the V₄ segment. The V₃ segment of the artery is of great biologic importance: (1) During head rotation, the head and atlas can turn by 35° from zero position to the opposite side. Therefore the course of the artery between atlas and axis has to be especially elastic or to contain reserve loops; (2) the axoatlantic course runs in the immediate neighborhood of the lateral atlantoaxial articulation. There occur alterations of the joint surface of the atlas with regard to that of the axis: impairment of the artery during rotation of the head? (3) the ramus ventralis C2 runs behind this artery and courses to the front: it has to have either an extra length to facilitate a low-lengthening effect during rotation or have special ability to stretch at this sector.

Recently, surgical approach is practicable to this segment of the vertebral artery in the following situations:

1. In the case of arteriovenous fistulas of the atlanto-occipital transition.
2. In the case of caroticovertebral or occipitovertebral anastomoses.^{2,3} According to Laurian and George,⁴ surgical approach to the V₃ segment presents no essential technical difficulties.⁵
3. Redtenbacher et al⁶ described an easier approach to the axoatlantal part of the vertebral artery. They only dissect the posterior edge of the sternocleidomastoid and the splenius capitis muscles, divide the ventral ramus of C2 and anastomose the distal segment of the vertebral artery using a venous bypass to the common carotid or external carotid arteries.

This investigation shall draw attention to biologic problems and surgical dangers during approach to the vertebral artery in this region. This part of the vertebral artery was investigated earlier.⁷⁻¹²

MATERIAL AND METHOD

The course of the vertebral artery between intervertebral disc C2-C3 and entrance of the artery to the dura mater was examined in 65 head and neck halves. For preparation, magnifying glasses (Zeiss, $\times 2.5$) and stereomicroscopes (Zeiss, $\times 6$ to $\times 40$) were used. Measurements of the arterial width were taken using comparison tubes of polyethylene, a pair of dividers, and actually marking the outer diameter of the vessels on paper. Differences between the sexes and right-left differences are included in accordance with presently accepted bi-mathematical methods.

RESULTS

Course

At the area of the intervertebral symphysis C2-C3, the paramedian distance of the vertebral artery (midpoint) is 15.76 mm (11 to 22) on the right and 17.34 mm (12 to 23) on the left.

The transverse foramen of the axis is situated more lateral than that of the third cervical vertebra. Therefore the artery runs from the upper rim of the transverse foramen C3 upward and laterally to the transverse foramen of the axis. On its course through the transverse foramen of

the axis, the midpoint of the vertebral artery is 27.78 mm (21 to 36) paramedian (Fig. 1). The course of the artery inside the transverse foramen of the axis runs upward, laterally, and mostly somewhat dorsally. Below the spinal ganglion C2 as well as the dorsal and ventral rami C2, the paramedian distance of the vertebral artery was measured (see Fig. 1).

In our specimens the greatest lateral extension of the axoatlantal part was 28.25 mm (22 to 27) in the lower sector and below the ramus ventralis C2. The midpoint of the vertebral artery is situated 27.78 mm (21 to 36) paramedian at the entrance to the lower rim of the transverse foramen of the atlas.

The medial borders of the upper rims of the two transverse foramina of the atlas have a distance of 52 mm (44 to 59) in our osteologic material; their lateral rim is 64 mm (56 to 70) in these specimens. After emerging from the transverse foramen of the atlas, the vertebral artery courses, as a rule, backward and medially and afterward to the front. The pars atlantica of the vertebral artery consists of these segments. For a long time the groove for the vertebral artery was described as lying at the first cervical vertebra. It is now known that not the artery but its accompanying vein lies flat against this groove.⁷

Pars Axoatlantis, Loop Formations

At the upper rim of the transverse foramen of the axis the vertebral artery curves sideward, as a rule, and then courses upward to the transverse foramen of the atlas (Fig. 2). Referring to the intervertebral disc C2-C3, the first

Figure 1. Length values of the vertebral artery between the disc C2-C3 and the lower border of the atlas and length between the lower border of the atlas and the penetration of the vertebral artery through the dura mater. Given are also the outer diameters of the vertebral artery and the height of the posterior arch of the atlas. On the right are seen the results of our measurements of paramedian distances of the vertebral artery. All measurements are in millimeters (extremes).

Figure 2. Axoatlantal part of the vertebral artery, loop formations (viewed dorsally). Given are the percentage of the formations seen in our material.

bend occurs 8.64 mm (0 to 14) above it. This segment is situated 17 mm (9 to 25) paramedian. Then the vertebral artery curves on average 11 mm sideward and turns upward. This second site of bending is 28.25 mm (22 to 37) paramedian.

TYPE I. As type I we categorized the textbooklike course of the artery. This type occurred in 64.6% in the specimens studied. In this connection the first bend of the artery is located at the transverse foramen of the axis. On average, at 11.2 mm paramedian, the second bend occurs upward toward the transverse foramen of the atlas. On the right, this course was ascertained in 64.6%, on the left in 62.5%. The site of bending can be situated on the level with its passage through the transverse foramen of the axis or 6 mm above it.

TYPE II. According to our division, vertebral arteries are among the type II, which form a loop sideward more or less caudally and somewhat dorsally after their outflow from the transverse foramen of the axis. This course was found in nearly 14%: on the left, in 18.8%, on the right, in 9.1%.

TYPE III. Those specimens belong to type III whose vertebral arteries showed clear loops in the dorsal direction and then coursed upward to the transverse for-

men of the axis. This situation was found in 10.8%, more often on the left (12.5%) than on the right (9.1%). The second bend of the vertebral artery can be developed on the same level or up to 8 mm above and 4 mm below.

TYPE IV. With type IV, the vertebral artery courses slantingly from the transverse foramen of the axis sideward and upward. In that case more or less clear curves of the vessel exist in the ventral direction, before it runs toward the transverse foramen of the atlas. This course type occurred in 10.8%: In 15.2% the slanting course was to the right, and in 6.3%, to the left.

Comparison of both sides was made in only 32 specimens (12 males, 4 females), revealing the same configuration on each side in 56.3%. In the remainder there were different types on the right and on the left.

Transverse Foramen of the Atlas

The transverse foramen of the atlas is a short and mostly slantingly canal from below medially to above and laterally as well as dorsally. Figures in Lang^{7,10} show unclosed transverse foramina of the atlas and some measurements are explained. As a rule, the artery bends in the atlas in the dorsal direction as it is marked by its transverse foramen. Previously its course was described as *pars atlantis* or, according to *Nomina Anatomica*,¹³ as *pars atlantica*. In one of our specimens the artery showed a clear loop in the lateral direction after its outflow from the transverse foramen of the atlas. As a rule, however, a dorsal course occurs toward the posterior arch of the atlas. Then the artery runs approximately in the transverse plane to medial. On the studied specimens, it turned out that the arterial wall projects into the posterior arch of the atlas by 5.14 mm (0 to 13) in the 65 examined preparations. The standard deviation (SD) is 3.11 mm for this measurement, and the mean of the standard deviation ($\bar{X}$ SD) is 0.39 mm. Differences between the sexes and right to left were not significant. In 37% the outer diameter of the artery was located 2.02 mm (0 to 4) dorsal to the back arch of the atlas, in 53.8%, 6.21 mm (4.5 to 8) dorsal to the back arch, and in 9.2%, 11.33 mm (9 to 13) dorsal to this landmark (Fig. 3).

Afterward, the artery courses first medially and then to the front to its passage through the dura. The paramedian distance of the arterial center at its penetration through dura was 11.82 mm (6 to 20) on the 65 specimens (SD 2.70 mm, and $\bar{X}$ SD 0.33 mm). Difference between the sexes was not significant. Peculiarly, the mean on the right was 11.06 mm, on the left, 12.61 mm.

Measurements of Length

At the outset, it should be stressed that the transverse part of the vertebral artery at its entrance into the 6th cervical vertebra to the level of the intervertebral symphysis between C2 and C3 measured 70.3 mm (52 to 89) on our material.

Figure 3. Posterior wall of the atlantal part of the vertebral artery dorsal to the posterior arch of the atlas. Given are also measurements from Rickenbacher¹⁸ about the distance between the transverse process of the atlas to this dorsal point of the vertebral artery and the paramedian distance of the dura penetration. All measurements are in millimeters (extremes) and some right-left differences are given.

In somewhat more than 89% the artery runs nearly straight in this area, in 7.7% it meanders slightly, and in 3.1% clear loops occur.

The length of the axoatlantal part (between symphysis intervertebralis C2/C3 and along the artery to the lower rim of the transverse foramen of the atlas) was 38.91 mm (29 to 56) (SD, 5.53, $\bar{X}$ SD, 0.69 mm). Right-left and sex differences were not significant (see Fig. 1). The height of the back rim of the foramen transversarium atlantis was between 2 and 5.5 mm. As already mentioned, this lamella can be missing. The length of the vertebral artery from its entrance into the transverse foramen of the atlas to its passage through dura mater was 44.3 mm (27 to 60) (SD 6.27 mm, $\bar{X}$ SD 0.78 mm). Differences between sexes and right-left were not significant.

Vertebral Artery, Width

The outer diameter of the right vertebral artery at the level of the intervertebral symphysis between C2 and C3 was 3.88 mm (2.5 to 5); for the left vertebral artery, it was 4.3 mm (3 to 5) (Fig. 1). That is, in this investigation (as well as in previous studies of our material) the left vertebral artery is wider than the right. A comparison of both sides in pairs revealed this situation in 56.3%, reversed proportions in 25%, and right-left correspondence in 18.8%.

At 5 mm below the transverse foramen of the atlas,

the width of the right vertebral artery was 3.85 mm (2.5 to 5.0); of the left vertebral artery, 4.34 mm (3 to 5.5). A significant difference between the sexes could not be detected, but a right-left difference was at the 99% level (SD 0.60 mm, $\bar{X}$ SD 0.11 mm).

In the middle region of the atlantal part, the outer diameter of the vertebral artery was 4.20 mm (2.5 to 6.0). It seems peculiar that no right-left difference was revealed at this point, but there was a clear difference between the sexes. On 50 arteries of male cadavers, the width was 4.31 mm (2.5 to 6.0); on the 15 females, the outer diameter was 3.8 mm (3 to 5).

At the passage through the dura, the outer diameter of the vertebral artery was 4.23 mm (2 to 6) (SD 0.81 mm, $\bar{X}$ SD 0.19 mm). Clear right-left differences could not be found. In male individuals the outer diameter of the arteries was 4.36 mm (2 to 6); in females, 3.83 mm (2.5 to 5).

Secondary Results

V₃ Segment of the Vertebral Artery, Branches, and Anastomoses

As a rule, from the first and second bends of the V₃ segment branches go the spinal ganglion C2 and spinal rami which run along the root sleeves into the spinal canal. Outside the vertebral canal anastomoses occur with the occipital artery, the ascending cervical artery, and the deep cervical artery (nomenclature after Lang⁹) (Fig. 4).

Figure 4. Axoatlantal and atlantal parts of the vertebral artery with its branches and nerve-vessel relationships and relationships to the joints, viewed from dorsally. It should be noted that the intracranial opening of the middle part of the hypoglossal canal is situated 26 mm (20 to 33) anterior to the opisthion, its middle part 30 mm (22 to 38) anterior, and its exit zone 34 mm (24 to 43).

From the mostly vertical second segment of the axoatlantal part of the vertebral artery, up to 0.8 mm thick rami musculares were observed in the present and the previous specimens. These rami develop anastomoses with neighboring arteries. Further rami musculares with similar anastomoses were found at the region of the vertebral artery immediately above the transverse foramen of the atlas as well as in its following pars atlantica.

In approximately 4% of our preparations extradural origins of the inferior posterior cerebellar artery could be detected. As a rule, immediately proximal to its dura passage a ramus meningeus posterior to the dura and to the occipital squama branches off the vertebral artery.

Nerve-Vessel and Nerve-Joint Relationships

The ramus ventralis C2 embraces the vertical sector of the axoatlantal part of the vertebral artery dorsally. In some specimens the nerve runs inside a ventral bend of this arterial segment ventrally. The spinal ganglion C2 and especially the frontal motor part of the second cervical nerve have relationships to the lateral atlantoaxial articulation. On all preparations, however, a venous plexus was found between joint capsule and nerve course. Mostly

above the atlas, fibers leave the ganglion cervicale superius and run to the nervous network around the vertebral artery.

In all specimens the suboccipital nerve runs below the vertebral artery and through or above the venous plexus around the artery. The branching of the ramus ventralis C1 occurs below the artery as well. Occasionally, a small ganglion spinale C1 is found below the atlantal part of the vertebral artery.

A few times our specimens showed small branches of the artery which pass through the dura and as arteriae spinales posteriores through the cerebellomedullary cistern toward the medulla oblongata.

Veins

In the present material and also from previous examinations in approximately 30% transcisternal veins were found running from the medulla oblongata through the cerebellomedullary cistern to the dura mater between occiput and atlas. These veins can flow in a marginal sinus of the great foramen or pass the dura. In the meantime inside

the dura of the craniocervical junction sinuslike blood spaces have repeatedly been found in our material.

The venous network around the vertebral artery (atlanto-occipital plexus) accompanied the pars atlantica and also the pars axoatlantis downward. Particularly, veins to the pars atlantica, but also to the pars axoatlantis, were detected coming from the underside of the jugular foramen as well as from the hypoglossal canal and the condylar emissary vein and streaming into vertebral veins. Further venous inflows in this network occur from muscles, nerves, and bony parts as well as via radicular veins.

DISCUSSION

Course

Relatively few anatomic findings are available concerning the course of the axoatlantal part of the vertebral artery. About the paramedian distance of the artery at the transverse foramen of the axis, we could not get any information from the literature. Previously (see Lang¹⁰), the paramedian distance of the medial rim of the transverse foramen of the axis was measured and found to be 13.2 mm (8.5 to 16). After having measured 65 preparations, the distance is 17.02 mm (9 to 25) in the middle of the foramen transversarium C2. This value is of medical importance for operations of the spinal column and the spinal canal from the front (transoral, transnasal, transcervical approaches) and from behind. Probably the loop formation of the axoatlantal part was first thoroughly investigated by Kräyenbühl and Yasargil¹⁴ in 250 angiograms. These authors as well as Schwerdt¹⁵ defined different subdivisions or organizations: slight bendings, small curves, nearly no loop formation or waves and moderate loopings, loop formation, and so on. Francke et al⁵ subdivided first loops (concave downward and laterally and inside the transverse foramen of the axis). They point out that this bending increases during aging. Also, illustrations in the anatomic atlas of Toldt and Hochstetter¹⁶ and in an article by Lasjaunias¹⁷ show this bend, which we classified as textbook course (about 65%). According to our examinations, the vessel runs laterally in the above-mentioned percentage then turns upward toward the transverse foramen of the atlas. This second bend (on average 28 mm paramedian) is described as a second contour by Francke et al. Measurements of the paramedian distances of the foramen transversarium atlantis were made on our material in 1986 (osteologically and without differentiating between the sexes). Accordingly, the medial rims of the transverse foramina of the atlas at the underside of the first cervical vertebra are situated 47 mm from one another; the lateral borders have a distance of 60.6 mm from each other. At the upper side of the atlas, the distance between the medial rims was calculated at 52 mm, the lateral at 64 mm, on average. According to the results we

now have at hand, the midpoint of the vertebral artery at its entrance to the transverse foramen of the atlas is situated 27.78 mm (21 to 36) paramedian. This value corresponds well with the previously mentioned measurements taken from osteologic material, especially if the course of the vertebral veins inside the transverse foramen of the atlas is in one's calculations. Course types and measurements of the axoatlantal part, as carried out by us on anatomic preparations, have not become known to us from the literature.

After leaving the transverse foramen of the atlas, the artery turns backward, as a rule. In one of our specimens, we could observe a loop sideward which became visible during preparation directly below the occipital artery and lateral to the rectus capitis major muscle as well as below the obliquus capitis superior muscle. About the following atlantal part of the vertebral artery, anatomic investigations were carried out by Rickenbacher.¹⁸ This research scientist determined the distance between the greatest projection of the transverse process of the atlas and the backmost bending point of the atlantal part of the vertebral artery to be 6 to 7 mm up to 20 to 21 mm. Most of the values were between 12 and 13 mm. It is known that the transverse process of the atlas is extraordinarily variable. Wackenheim¹⁹ described aplasias of the lateral mass of the atlas, asymmetries, and so on. For example, we showed transverse foramina that were unclosed to the front (see Lang⁷). It should be stressed that especially large transverse processes have been confused with tumors of the parotid gland.²⁰ In 7% there are bilateral ponticuli over the vertebral artery, in 14% unilateral ponticuli developed. These can be developed more or less completely (see Lang⁷). The projecting of the vertebral artery over the posterior arch of the atlas (on the material studied on average by 5.14 mm) is significant, especially by using a surgical approach to this vessel segment. At present, punctures for angiographies are scarcely carried out in this area. Afterward the atlantal part courses in a roughly transverse direction medially.¹⁸ Afterward the artery runs to the front around the posterior atlanto-occipital membrane to pass through the dura medial to the atlanto-occipital articulation. Penetrating through the dura, it is situated 11.8 mm (6 to 20) paramedian in the material examined. According to Francke et al,⁵ the paramedian distance is 10 to 15 mm, and according to George and Laurian,²¹ it is 12 to 15 mm.

Our extremes are spread farther apart. The right-left difference of this value is peculiar in our material. The medium distance was 11.06 mm on the right and 12.31 mm on the left (to the midpoint of the vertebral artery at its passing through the dura).

Measurements of Length

In the literature we did not find any length measurements of the vertebral artery between symphysis interver-

tebralis C2-C3 and lower rim of the transverse foramen of the atlas. The posterior rim of the transverse foramen of the atlas is 2 to 5 mm and can be missing.

The longitudinal distance between the lateral zone of the symphysis intervertebralis C2-C3 to the transverse foramen of the axis is between 7 and 10 mm. The axoatlantal part therefore is on average 30.4 mm in length. This arterial segment is straightened and possibly stretched during head and atlas rotations.

Lang²²⁻²⁴ reported on the wall changes of the vertebral artery during its course in the prevertebral part, its extradural part, and its intradural part. Accordingly, a relatively large portion of elastic fibers proved to be in the axoatlantal part inside the middle coat of the artery. Also, inside the adventitia of the artery there are more elastic fibers than in other vessel segments. Weber,²⁵ Kunert,^{26,27} and Stevens²⁸ dealt with the stretching of the axoatlantal segment during head and atlas rotations. In nearly all figures of these researchers but also those of the excellent clinical anatomist Hollinshead,²⁹ the course of the artery is certainly described incorrectly.

During head rotations, the artery of the opposite side is slightly narrowed but not throttled down. About the branches of the vertebral artery in the axoatlantal and atlantal sectors, we reported in detail.^{7,8,10,24} These vessels are undoubtedly significant when using a surgical approach to the vertebral artery. Extradural origins of the inferior posterior cerebellar artery were first described by Lang.²⁴ The distance from the lower rim of the transverse foramen of the atlas to the dura is subject to still greater variations. This vessel length was 44.3 mm (27 to 60). We attributed the great variability of the vessel length to the different loop formations of the artery and different breadth of the atlas.

Vertebral Artery, Width

Numerous examinations are available of the width of the vertebral artery. We ascertained, as previous researchers did,³⁰ that the left vertebral artery is in most cases somewhat wider than the right. Extreme malformations as described numerous times (*arteriae hypoglossicae primitivae*, *arteria suboccipitalis proatlantica*) did not occur in the material studied.

Formerly, it was stressed especially that occlusion of this artery can cause Wallenberg's syndrome. The penetration of a vessel with that origin through the dura occurs, as a rule, behind the uppermost origin indentation of the denticulate ligament (see Lang^{24,31}). This is rare in cases with narrow vertebral arteries.

The lateral approach to the atlantal part of the vertebral artery was carried out (during the World War I) by Küttner³² as well as by Drüner.³³ Issing and Lang¹² described the distances between the tip of the mastoid process and the atlantal part of the vertebral artery and the distance between the most lateral point of the transverse

process of the atlas and the vessel; also given are the measurements of some suboccipital muscles. Jefferson et al³⁴ chose this approach to aneurysms of the vertebral artery (for further details see Lang³¹). It was emphasized that the vertebral artery can also form a loop laterally immediately above the lateral mass of the atlas (site for danger). Spetzler³⁵ reported on a posterolateral approach to the clivus and pointed to this fact, as we did.²⁴

A vertebral artery that runs below the atlas medially and penetrates the dura at a place described in textbooks could not be found in the material examined. Rickenbacher¹⁸ and Takahashi³⁶ described this course. The anterior and posterior axis arteries branch off, as a rule, at the disc level between C2 and C3. They were not taken into consideration during this investigation. Articular rami to the atlantoaxial articulation and to the atlanto-occipital articulation are found commonly as well as branches from the atlantal part to the atlas. Particularly, those running to the posterior atlantal arch can come from the occipital artery.

V₃ Segment of the Vertebral Artery, Branches, and Anastomoses

Arteriae radicales ventrales C1 could be detected in 28 to 40% of our material,³⁷ those of C2 in 8 to 40%. *Arteriae radicales dorsales* C1 were found more frequently in our material on the left, in 60%, and *arteriae radicales dorsales* C2 in approximately 20% on both sides. These arteries arise, as a rule, from the vertebral artery. Numerous anastomoses occur with neighboring vessels at the spinal cord.

Nerve-Vessel and Nerve-Joint Relationships

The ganglion spinale C3 lies flat at the back of the vertebral artery on the level of the symphysis intervertebralis C2-C3. This segment of the vertebral artery is accompanied by a thin nerve network coming from the vertebral nerve. In addition, the vertebral artery is surrounded by a venous network inside the transverse foramen of the axis.

The ganglion spinale C2 is mostly situated medial to the second bend of the axoatlantal part of the vertebral artery. The ramus ventralis C2 embraces this segment of the artery dorsally. As a rule, it branches off the truncus nervus spinalis somewhat medial to the vertebral artery. Separated by a venous cushion, the ganglion spinale C2 is located directly at the back of the lateral atlantoaxial articulation (see Lang³¹).

Lang¹⁰ reports a ramus ventralis C2 becoming deposited in a loop of the axoatlantal part of the vertebral artery ventrally. This loop was called "winding of pars atlantoaxialis" by the translator. Tomita et al.³⁸ described two patients whose ramus ventralis C2 caused a constriction of the vertebral artery (the patients had cervical instability after car accidents). Tomita et al.³⁸ used the approach to the vertebral artery described by Henry³⁹ and cut the ramus ventralis C2.

In 1983 we described the nerves to the articulation of the craniocervical junction in detail, also with regard to their medical importance.⁹ Mainly, Loeweneck⁴⁰ dealt with the innervation of these articulations, after that so did Bogduk.⁴¹ In this connection anastomosal formations between dorsal rami and ventral rami of the two upper cervical nerves should also be stressed. Branches of the ganglion cervicale superius of the sympathetic trunk properly anastomose with the ventral nerve loop C1-C2. From it fibers run to the vertebral artery whose atlantal part is also reached by direct fibers of the superior cervical ganglion or one of its branches. These fibers can be discerned under the operation microscope, especially at the intracranial segment of the vertebral artery, without staining with osmium tetroxide. Using magnifying glasses for preparation and with the aid of the operation microscope, we could not definitely prove the fine nerve plexus to the ampulloglomerular organ at the penetration zone of the vertebral artery through the dura mater. Also in our histologic sections (see Lang²⁴) we were not successful in detecting this structure. DeJong et al⁴² and others pointed to nystagmus and other coordination disturbances in anesthesia of the sympathetic nerve fibers of this sector.

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REVIEWER'S COMMENTS

This is another excellent anatomic work from Professor Lang's laboratory. This portion of the vertebral artery is very important for the surgeon to be familiar with during the management of foramen magnum and upper cervical tumors. We have recently reported on an extreme lateral approach to this area, which involves mobilizing the vertebral artery through its entire extradural and intradural course, including its point of entry into the dura (Sen CN, Sekhar LN: An extreme lateral approach to intradural lesions of the cervical spine and foramen magnum. *Neurosurgery* 27: no. 2, 1990). Once the artery is fully dissected, the occipital condyle can be partially or completely drilled off to allow better access to the foramen magnum area. This type of mobilization greatly facilitates dissection of the vessel from both intra and extradural neoplasms. Also, the blood supply to some of these tumors can arise from the vertebral artery V₃ segment, which if sacrificed early in the operation, can be a great help to the surgeon. We have also used vein graft reconstruction of this vessel in a patient in whom the artery was completely encased by tumor. Although exposing the artery from the C2 area up to its dural entry is somewhat tedious and painstaking, it makes tumor removal safer and more complete. The variations of the anatomy described in detail by Dr. Lang are worth remembering, and this is yet another fine example of the application of detailed anatomic study to microsurgery at the cranial base.

Chandra N. Sen, M.D., and Laligam N. Sekhar, M.D.