Vertebral Artery Landmarks for the Far-Lateral Transcondylar Approach: An Anatomic Study

Uzak Lateral Transkondilar Girişimde Vertebral Arter İşaret Noktaları: Anatomik Çalışma

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Abstract: The far-lateral transcondylar approach is the method of choice for accessing lesions of the lower clivus, anterior foramen magnum, upper cervical spine and ventrolateral brainstem. This approach requires rapid identification and mobilization of the vertebral artery. In this article, we describe our use of cadaver dissections to identify landmarks that allow the surgeon to quickly locate the vertebral artery and its point of penetration through the dura. A thorough knowledge of the regional anatomy and skillful use of bony anatomic landmarks is required to obtain good results when performing the far-lateral transcondylar approach.

Key words: Anatomy, far-lateral transcondylar approach, landmarks, vertebral artery

Özet: Uzak lateral transkondilar girişim beyin sapının ön-yan bölümüne, üst servikal bölgeye, foramen magnum ve alt klivus lezyonlarına ulaşmak için seçilmis bir girişimdir. Bu cerrahi yaklaşımda vertebral arterin operasyonun erken safhasında bulunması ve mobilizasyonu esastır. Bu makale kadavra disseksiyonu yolu ile vertebral arterin önceden ayırtedilmesini ve duraya girdiği noktanın kemik işaret noktalarına göre bulunmasını açıklamaktadır. Uzak lateral transkondilar girişimde başarılı sonuçlar almak için bu bölgenin anatomik yapılarının iyi bilinmesi ve kemik işaret noktalarinin çok iyi kullanılması gerekmektedir.

Anahtar kelimeler: Anatomi, işaret noktası, uzak lateral transkondilar girişim, vertebral arter

INTRODUCTION

The far-lateral transcondylar approach, as previously described, is the best surgical method for resecting lesions located in the ventrolateral brainstem and anterior foramen magnum (2,3,6,8,11,12). However, lower clival and anterior foramen magnum lesions present special surgical challenges because of the significant morbidity and potential mortality associated with accessing this region (4,7,11). The disadvantages of the approach include the potential for vertebral artery injury during dissection of the muscular layer, drilling of the transverse foramen of C1, drilling of the posterior arch of C1, drilling of the occipital condyle, and mobilization of the vertebral artery. Our goals in this study were to define important bony landmarks of the craniocervical junction that will help the surgeon identify the vertebral artery and locate its point of penetration through the dura during the far-lateral transcondylar approach.

MATERIALS AND METHODS

This study was performed in the Harvey Ammerman Laboratories in the Department of Neurosurgery at the George Washington University School of Medicine. We dissected 10 adult cadaver specimens, the arteries and veins of which were injected with colored silicon. We performed the far-lateral transcondylar approach on each specimen and recorded specific measurements. A Carl Zeiss Universal S2 operating microscope was used during dissection of the vertebral artery and drilling of the transverse foramen of C1, posterior arch of C1 and the occipital condyle. Drilling was done using a Midas Rex high-speed air drill (Texas, USA). Marathon 8-inch/200 mm electronic digital calipers were used to make all measurements.

For each dissection, we approximated true intraoperative positioning by placing the cadaver in the three-quarter prone position with three-point fixation. A standard C-shaped skin incision was made, beginning at the level of the pinna. The upper edge of the incision curved around the ear near the body of the mastoid process, continued over the mastoid tip, curved over the sternocleidomastoid muscle, and ended near the level of C4. The most superficial muscle layer was composed of the sternocleidomastoid, trapezius, splenius capitus and semispinalis capitus muscles. We reflected the trapezius and splenius capitus medially, and identified the longissimus capitus muscle. Then we reflected the longissimus capitus inferiorly to expose the transverse process of C1, one of the most important bony landmarks for vertebral artery identification. Next, we identified the splenius cervicis muscle, which attaches to the transverse processes of C1-C3. Reflection of this muscle allowed visualization of the underlying vertebral artery (Figure 1). Muscle dissection proceeded with the goal of locating the suboccipital triangle composed of the superior and inferior oblique muscles, and the rectus capitus major muscle. Once it was found, we opened

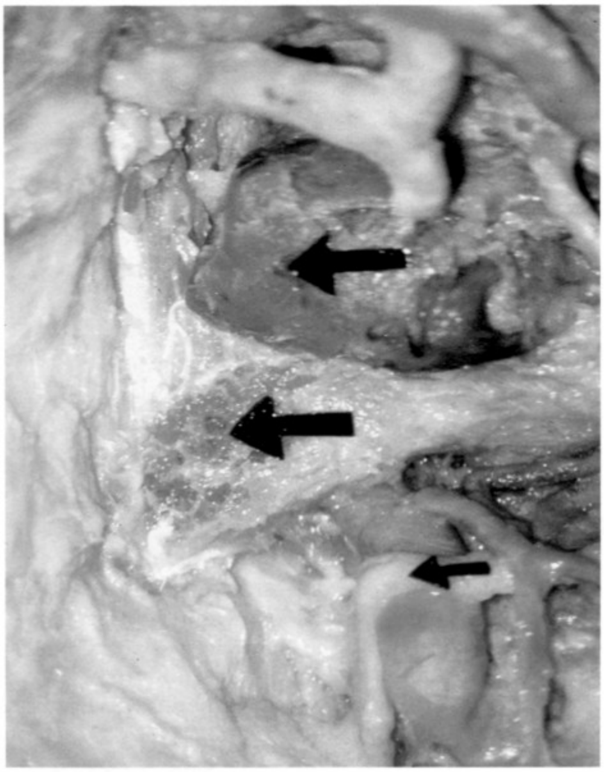

Figure 1: The arrows show the three classic landmarks for locating the vertebral artery; namely, the vertebral venous plexus, the transverse process of C1 and the C2 nerve root.

Figure 2: A left-sided suboccipital craniotomy, partial mastoidectomy, partial C1 laminectomy and partial facetectomy have been performed. The vertebral artery is mobilized posteromedially. SS: Sigmoid sinus, VA: Vertebral artery, cev: Condylar emissary vein, C1: C1 root, C2: C2 root

this triangle to reveal the vertebral artery between C1 and the occiput (13).

The next step was a suboccipital craniotomy of approximately 3-4 cm diameter that included the rim of the foramen magnum. We then did a partial mastoidectomy, removed the posterior arch of C1, and opened the transverse foramen of C1 to allow posteromedial mobilization of the vertebral artery (Figure 2). While protecting the extracranial vertebral artery, we then drilled the occipital condyle to the level of the hypoglossal canal (12). Once bone removal was complete, including extradural resection of the jugular tubercle, we opened the dura, leaving a small dural cuff around the vertebral artery (Figure 3). After the vertebral artery was mobilized, we could easily visualize the ipsilateral anterior spinal artery, jugular foramen and hypoglossal canal, and the contralateral vertebral artery (Figures 5 and 6).

For each dissection, we recorded the following measurements: 1) the distance from the transverse process of C1 to the point of vertebral artery penetration through the dura, 2) the distance from the point of dural entry of the artery to the midline, 3) vertebral artery diameter, and the mean distance from the transverse process of C1 to the point of vertebral artery penetration through the dura, 4) the

Figure 3: A left-sided partial condylectomy has been performed and the dural opening is outlined. OC: Occipital condyle, VA: Vertebral artery, mb: Muscular branch of the vertebral artery, C2g: C2 ganglion

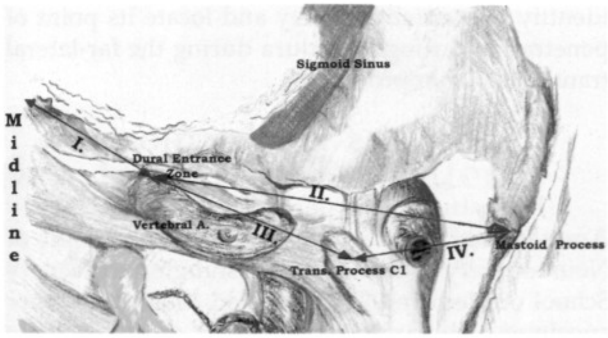

Figure 4: I) Distance from the site of dural entry to the midline.
II) Distance from the site of dural entry to the mastoid tip.
III) Distance from the site of dural entry to the transverse process of C1.
IV) Distance from the mastoid process to the transverse process of C1.

Figure 5: The right ventrolateral brainstem is exposed. The anterior spinal artery and both vertebral arteries can be seen without parenchymal retraction. RVA: Right vertebral artery, LVA: Left vertebral artery, asa: Anterior spinal artery

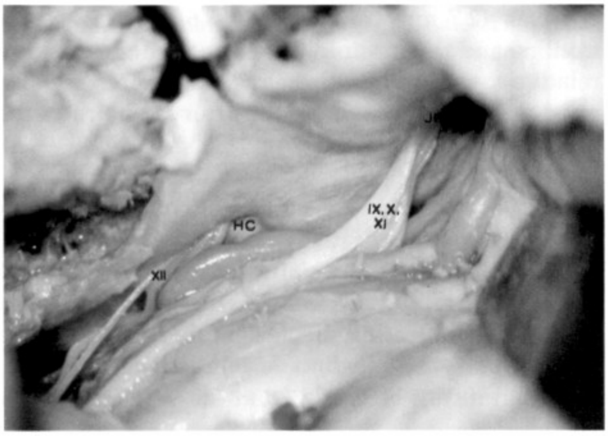

Figure 6: The left jugular foramen and hypoglossal canal are easily visualized. The lower cranial nerves can be seen exiting these foramina. HC: Hypoglossal canal, IX, X, XI: Glossopharyngeal, Vagus and Accessory nerve, respectively, XII: Hypoglossal nerve

distance from the mastoid tip to the site of dural entry, and 5) the distance from the mastoid tip to the transverse process of C1 (Figure 4).

RESULTS

We studied the anatomy of the vertebral artery from the transverse foramen of the atlas to its dural entry point. In all cases, the artery was located in the transverse foramen of C1 and traveled through the suboccipital triangle. In every cadaver, we noted a thick venous plexus around the vertebral artery, which was especially prominent at the point where the artery penetrated the dura. There was some variation among the specimens regarding vertebral artery length. The mean length from the distal end of the transverse foramen of C1 to the site of dural entry was 22.7 mm (range, 19.3-26.7 mm). The mean artery diameter was 4.9 mm (range, 4-6.4 mm). The average right vertebral artery diameter was 4.15 mm, whereas that for the left vertebral artery was 5.0 mm. In 50% of the specimens, the diameter of the left vertebral artery was larger than the diameter of the vessel on the right, in 30% the right vertebral artery diameter was larger, and in 20% the arteries were equal in diameter. None of the cadavers exhibited atretic or hypoplastic vertebral arteries. The artery was completely surrounded by bone at the posterior arch of C1 in 30% of cases.

In all cases, the radiculomuscular branches arose from the medial aspect of the vertebral artery. Also, the C2 nerve root crossed the vertebral artery inferior to the C1 transverse foramen and was tightly adhered to the artery in every case. The mean distance from the point of the dural penetration to the midline was 16.2 mm (range, 13.9-20.4 mm). The mean distance from the transverse process of C1 to the mastoid tip was 22.9 mm (range, 19.3-24.3 mm). In every cadaver, C1 was located posteromedial to the mastoid tip. The mean distance from the transverse process of C1 to the site of dural entry of the vertebral artery was 23.5 mm (range, 20.6-25.3 mm). The average distance between the mastoid tip and the dural entry point was 42.7 mm (39.2-45.6 mm).

DISCUSSION

It is difficult to surgically manage extradural lesions in the region of the lower clivus and anterior foramen magnum, and intradural ventrolateral brainstem lesions (2,3,6,8,11,12). Suboccipital craniotomy or craniectomy coupled with upper posterior cervical laminectomy has been the surgical approach of choice for addressing these lesions, but this method does not allow adequate visualization of the lesion and requires significant brainstem and upper cervical spine retraction; thus, complete excision of the lesion is virtually impossible.

In 1972, Hammon proposed a far-lateral suboccipital approach for managing vascular pathology of the vertebral artery and the vertebrobasilar junction (7). In 1978, Seeger first described a partial occipital condylectomy in an approach to the ventral surface of the brainstem (10). Later, in 1986, Heros pursued and described the use of far-lateral approaches for treating vascular lesions of the vertebral artery and the vertebrobasilar junction in more depth (8). Since then, the far-lateral transcondylar approach has been further developed, and six variations of this method have recently been defined. These include the retrocondylar approach, the partial transcondylar approach, the transtubercular approach, the transcondylar approach, the transjugular approach and the transfacetal approach. The choice of approach is determined by the location of the pathology (14).

The far-lateral transcondylar approach allows better visualization of the lesion and involves minimal parenchymal retraction, thus facilitating complete excision. However, the potential for vertebral artery injury is a significant disadvantage in this approach. Bone removal in the region is a very important aspect of the procedure. The jugular tubercle, the bone anterosuperior to the hypoglossal canal, must be resected as this is the key to maximizing intradural exposure (Figures 5 and 6). It is also important to recognize anatomic variations, such as extradural origin of the posterior inferior cerebellar artery, a variation that occurs in 5% of cases (9).

In order to avoid injury to the vertebral artery, the surgeon must know the anatomy of the region, the path of the vertebral artery, and the landmarks for locating the artery during the surgical approach. To avoid kinking the artery and possible subsequent brainstem infarction, it is important to consider the possibilities of calcification of the periosteal sheath and tunneling of the artery through the transverse groove. In general, the following three landmarks are used to rapidly identify the vertebral artery: 1) the transverse process of C1, 2) the C2 nerve root, which crosses the artery, and 3) the venous plexus around the artery (11).

We found it easiest and safest to locate the vertebral artery within the transverse foramen of C1. The C2 nerve root always crosses the artery inferior to this foramen; however, the root is always tightly adhered to the vessel. As a result, surgical dissection to isolate and identify this soft-tissue landmark risks injury to the vertebral artery. In contrast, the position of the artery within the foramen shields it from injury when this bony landmark is approached surgically for locating the vessel.

Reports in the literature state that the transverse process of C1 is located approximately 1.5-2.0 cm inferior and posteromedial to the mastoid tip (1,5). In our study, the mean for this distance was 22.9 mm. However, using this measure to locate the transverse process of C1 may be inaccurate because the distance varies according to the position of the patient's head relative to the upper cervical spine. The transverse process of C1 is best located by direct palpation after the superficial muscular layer has been dissected.

The site of dural penetration by the vertebral artery is most accurately located by following the vessel cephalad from the transverse foramen of C1. However, this site can also be located without visually tracing the atlanto-occipital section of the vertebral artery. We found that the mean distance from the vertebral artery dural entry site to the midline was 16.2 mm (range, 13.9-20.4 mm). The mean distance from the mastoid tip to the dural entry site was 42.7 mm (range, 39.2-45.6 mm). Since the midline and the mastoid tip do not change position relative to each other, these measurements are also good ways to locate where the artery penetrates the dura.

In our study, we consistently identified a venous plexus associated with the vertebral artery, and this plexus was especially dense in the occipital/C1 region. However, using this structure as a landmark for locating the vertebral artery or its site of dural entry may lead to vertebral artery damage, since significant bleeding from the veins can block visibility.

The far-lateral transcondylar approach is an excellent method for resecting lesions of the lower clivus, anterior foramen magnum, upper cervical region and ventrolateral brainstem. Inadvertent injury to the vertebral artery can lead to significant morbidity, and can even result in death. It is possible to damage the vessel during muscle dissection, when the transverse foramen of C1 is opened, when the posterior arch of C1 is removed, or during partial condylectomy. The best marker for rapidly identifying the vertebral artery is the transverse process of C1, a bony landmark that is easy to palpate. The safest way to perform the far-lateral transcondylar approach is to locate, visualize and mobilize this artery. With the significant potential for morbidity and mortality in performing this approach, it is important that the surgeon do multiple cadaver dissections to gain a thorough knowledge of the regional anatomy and the techniques used to expose and mobilize the vertebral artery.

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