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Morphometric Measurement of the Anatomical Landmark in Anterior Cervical Microforaminotomy

Jae-Chil Chang, M.D., Hyung-Ki Park, M.D., Hack-Gun Bae, M.D.,
Sung-Jin Cho, M.D., Soon-Kwan Choi, M.D., Park-Jang Byun, M.D.

Department of Neurosurgery, College of Medicine, Soonchunhyang University, Seoul, Korea

Objective : The lack of anatomical knowledge for the anterior cervical microforaminotomy is liable to injure the neurovascular structures. The surgical anatomy is examined with special attention to the ventral aspect exposed in anterior cervical microforaminotomy.

Methods : In 16 adult formalin fixed cadaveric cervical spine, the author measured the distances from the medical margin of the longus colli to the medical wall of the ipsilateral vertebral artery and the angle for the ipsilateral vertebral artery. The distances from the lateral margin of the posterior longitudinal ligament to the medial margin of the ipsilateral medial wall of the vertebral artery, to the ipsilateral dorsal root ganglion was measured too.

Results : The distance from the medial margin of the longus colli to the ipsilateral vertebral artery was 13.3~14.7mm and the angle for the ipsilateral vertebral artery was 41~42.5 degrees. The range of distance from the lateral margin of the posterior longitudinal ligament to the ipsilateral vertebral artery was 11.9~16.1mm, to the ipsilateral dorsal root ganglion was 11.6~12.9mm.

Conclusion : These data will aid in reducing neurovascular injury during anterior cervical approaches.

KEY WORDS : Anterior cervical microforaminotomy · Longus colli · Posterior longitudinal ligament · Vertebral artery.

Introduction

There are several ways to perform cervical disc surgery through anterior approach[2-5,8-12,15-17,19,20]. Regardless of which method is applied, widening the constricted intervertebral foramen region, either in the medial direction or lateral direction, is crucial. This region can be detected by examining the rear of the spine with the lateral margin of the posterior longitudinal ligament. However, in most cases, severe degenerative changes and adhesion between a ligament and the periosteum make it difficult to visualize the nerve root. Thus, it can be difficult to recognize which part of the intervertebral foramen is constricted.

Especially in cases of serious disc degeneration, in which the normal spinal structure is severely altered, it is difficult to recognize the anatomical structures relevant to the operation. In this case, a surgeon can predict the distance and angle at which to approach the region area with simple anatomical markers without a navigation aid. The longus colli muscle and posterior longitudinal ligament is very important anatomical markers.

The purpose of this research is to aid in the decompression of nerve root by anterior cervical microforaminotomy or other methods. Therefore, we measured the distances and angle from the logus colli muscle and posterior longitudinal ligament to important standard structure to estimate the location of dorsal root ganglion and vertebral artery.

Materials and Methods

16 adult (eight males and eight females) cadavers were used in this study. The cadavers were fixed in prone position in a mixture of formalin, phenol, alcohol and glycerin, and a saw was used to obtain the cranial-cervical area for dissection. All vertebrae from the second cervical vertebra to the first thoracic vertebra and the anterior of the cervical spine were completely exposed. Each cervical disc from the third to the seventh

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• Address for reprints : Hyung-Ki Park, M.D., Department of Neurosurgery, College of Medicine, Soonchunhyang University, 657 Hannam-dong, Yongsan-gu, Seoul 140-743, Korea Tel : +82-2-709-9268, Fax : +82-2-792-5976, E-mail : phk007@hosp.sch.ac.kr

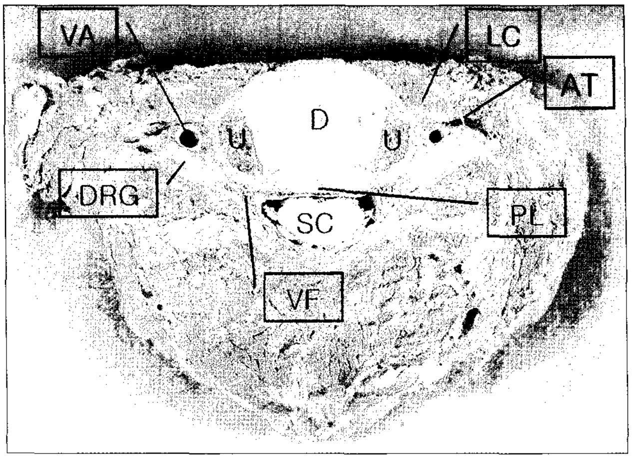

Fig. 1. Photography of the transverse section through the disc level of the cervical spine. The relationship of the cervical nerve root and dorsal root ganglion to the uncinate process and vertebral artery is well noted. D= disc; SC= spinal cord; U= uncinate process; VA= vertebral artery; LC= longus colli muscle; DRG= dorsal root ganglion; AT= anterior tubercle; VF= intervertebral foramen; PL= posterior longitudinal ligament.

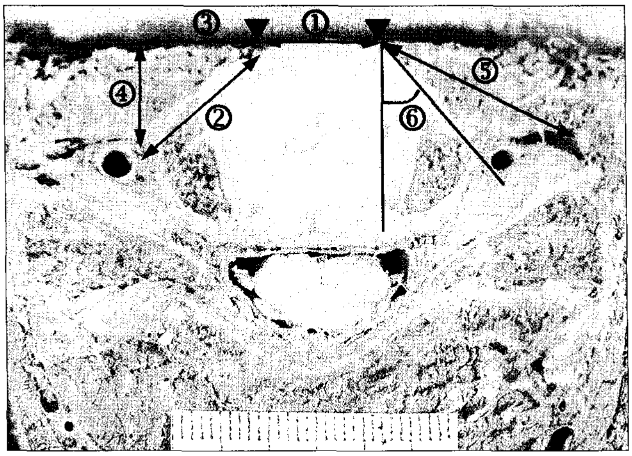

Fig. 2. Photography of the cadaver specimen showing measurement designs from the medial margin(arrow head) of the longus colli. ① width between both longus colli muscles, ② distance to the medial margin of the vertebral artery, ③ surface diameter to the medial margin of the vertebral artery(MMVA), ④ depth to the vertebral artery from the muscle surface, ⑤ distance to the anterior tubercle, ⑥ angle between the sagittal vertical line and the line to the MMVA.

cervical vertebra was transected by saw, exposing each cervical disc surface, the longus colli muscle, vertebral artery, anterior tubercle, dorsal root ganglion, posterior longitudinal ligament, spinal cord, and nerve roots. The relative distances of these structures were measured (Fig. 1). One surgeon carried out every measurement with a caliper and protractor to minimize errors.

Distances were measured from the medial margin of the longus colli muscle to the opposite medial margin of the longus colli muscle, the sagittal distance to the medial wall of the vertebral artery, the surface distance and depth to the medial wall of the vertebral artery, the distance to the anterior tubercle of the transverse process, and the angle between the sagittal line stemming from the longus colli muscle and the medial wall of the vertebral artery (Fig. 2).

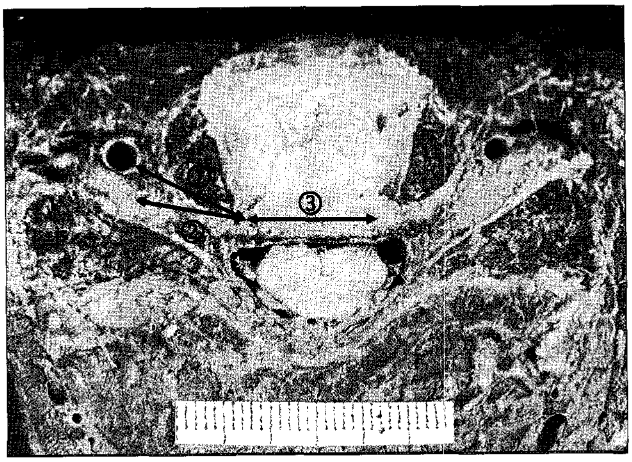

Fig. 3. Photography of the cadaver specimen showing the distance measurement designs from the lateral margin(arrow head) of the posterior longitudinal ligament(LMPLL). ① from the LMPLL to the MMVA, ② from the LMPLL to the medial margin of the dorsal root ganglion, ③ width of the PLL.

The distances were measured from the lateral margin of the posterior longitudinal ligament to the medial wall of the vertebral artery and the dorsal root ganglion (Fig. 3). The results were compared bilaterally in each patient and between both sexes.

Data were analyzed for statistical significance using a t-test by SPSS statistical program (version 11.0). The statistical significant range was $p<0.05$.

Results

The anatomical structure of the anterior cervical spine

The longus colli lies in two vertical arrangements along both anterolateral aspects of the cervical vertebrae and anterior cervical discs. The width between the medial margins of the left and right longus colli is greater at the lower cervical spine than at the upper cervical spine.

On transverse section, the width of the vertebral body is greater than its antero-posterial length. Within the lateral margins of the vertebrae, half-moon shaped uncinate processes are located from the antero-lateral margin to the postero-medial margin. The posterior longitudinal ligament is found between the postero-medial margins of the bilateral uncinate processes close to the posterior aspect of the cervical disc. Cervical roots exiting the spinal cord lie close to the posterior surface of the uncinate processes.

The posterior third to half of the uncinate process and vertebral artery are juxtaposed to the nerve root, and the nerve root becomes the dorsal root ganglion at the postero-lateral margin of the vertebral artery. The posterior longitudinal ligament is linked to the anterior aspect of the dura posteriorly and to the vertebrae or the posterior aspect of the cervical disc anteriorly (Fig. 1).

Morphometric measurement results from the medial margin of the longus colli

a) Width between the medial margins of the right and left longus colli.

This width at the third and fourth cervical disc (C3-4) was 10.2±2.3mm (average±standard deviation) but at the sixth and seventh cervical disc (C6-7) was 13.5±2.7mm. The average difference in width between C3-4 and C6-7 was 3 to 4mm (Table 1).

b) The straight distance from the medial margin of the longus colli to the medial wall of the vertebral artery.

The shortest distance between the medial margin of the longus colli to the medial wall of the vertebral artery was on average 13.3~13.6mm at C3-4, C4-5, and C5-6. However, the distance was longer at the C6-7 level (14.7mm) (Table 1).

c) The surface distance and depth from the medial margin of the longus colli to the medial wall of the vertebral artery.

The average surface distance in the coronal plane from the medial margin of the longus colli to the medial wall of the vertebral artery was longest at the C6-7 level (10.3mm). The distance was 8.6mm at C5-6 and 8.4mm at C4-5. The distance in the sagittal plane, or depth, from the medial margin of the longus colli to the medial wall of the vertebral artery was 13.4mm at the C3-4 level, 9.0mm at C4-5, 10.0mm at C5-6, and 8.4mm at C6-7. Thus, the vertebral artery was deepest at the C3-4 level and shallowest at the C6-7 level(Table 1).

d) The distance from the medial margin of the longus colli to the anterior tubercle of the cervical spine transverse process.

The distance from the medial margin of the longus colli to the anterior tubercle of the cervical spine transverse process at the C3-4 level was 17.9mm on average for both the right and left sides. This distance was 20.5mm at C6-7, since the width between the bilateral longus colli was narrower at the upper than lower cervical spine (Table 1).

e) The angle composed at the medial wall of the vertebral artery.

The angle between the sagittal line from the medial margin of the longus colli and the line to the medial wall of the ipsilateral vertebral artery was 41~42.5 degrees. This difference was not significantly different between each level of the cervical spine (Table 1).

Morphometric measurement results from the lateral margin of the posterior longitudinal ligament

a) The distance from the lateral margin of the posterior longitudinal ligament to the medial wall of the vertebral artery.

The average distance from the lateral margin of the posterior longitudinal ligament to the medial wall of the vertebral artery was 11.9mm at the C3-4 level, 12.7mm at C4-5, 13.7mm at C5-6, and 16.1mm at C6-7. This distance widened in the lower cervical regions (Table 2).

b) The distance between the lateral margin of the posterior longitudinal ligament to the dorsal root ganglion.

The average distance from the lateral margin of the posterior longitudinal ligament to the dorsal root ganglion was 9.7mm at the C3-4 level, 10.3mm at C4-5, 14.2mm at C6-7, and 15.3mm at C5-6 (Table 2).

c) The width of the posterior longitudinal ligament.

The width of the posterior longitudinal ligament was 11.6mm at the C3-4 level, 12.9mm at C4-5, 11.7mm at C6-7, and 12.6mm at C6-7. Thus, the width was greatest at the C4-5 level and smallest at C3-4(Table 2).

Table 1. The measurements to the various structures from the medial margin of the longus colli

	Distance in millimeters and degrees (mean±SD)			
	C3-4	C4-5	C5-6	C6-7
Width between the medial margin of the LC	10.2±2.3	11.6±2.11	13.3±2.4	13.5±2.7
Medial margin of the VA	13.6±2.2	13.3±1.6	13.6±2.4	14.7±1.8
The LC surface located upward directly from medial margin of the VA	8.9±2.0	8.4±1.8	8.6±1.7	10.3±2.2
The anterior tubercle	17.9±3.5	19.1±2.7	19.7±2.4	20.5±2.2
Height of the LC surface located upward directly from the VA	13.4±2.4	9.0±2.4	10.0±2.4	8.4±1.9
Angle composed medial margin directly downward and the VA	42.1±20.5	40.2±17.6	41.0±17.2	42.5±17.7

LC=Longus colli, VA=Vertebral artery, SD=Standard deviation

Table 2. The distances to the various structures from the lateral margin of the posterior longitudinal ligament

	Distance in millimeters (mean±SD)			
	C3-4	C4-5	C5-6	C6-7
Medial margin of the VA	9.7±2.0	10.3±2.0	15.3±2.3	14.2±2.6
The DRG	11.9±2.9	12.7±3.0	13.7±2.5	16.1±2.2
The PLL diameter	11.6±2.3	12.9±2.0	11.7±1.9	12.6±2.3

VA=Vertebral artery, DRG=Dorsal root ganglion, PLL=Posterior longitudinal ligament, SD=Standard deviation

Comparison between measurements on the male and female

The straight distance from the medial margin of the longus colli to the medial wall of the vertebral artery was 14.4±2.2 in males and 13.1±1.7 in females. This difference was statistically significant (p=0.02) (Table 3). The distance between the lateral margin of the posterior longitudinal ligament to the dorsal root ganglion was 14.7±2.5 in males and 12.1±3.1 in females. This difference was statistically significant (p<0.00) (Table 3).

Table 3. Gender difference of the biometric data

	Male(mean±SD)	Female	T-test
Distance between median margin of the LC	11.3±3.1	12.8±2.2	0.05
Medial margin of the LC from medial margin of the VA	14.4±2.2	13.1±1.7	0.02
Medial margin of the LC from the LC surface located upward directly from medial margin of the VA	9.5±1.9	8.4±2.0	0.09
Medial margin of the LC from the anterior tubercle	20.3±3.3	18.4±2.3	0.21
Height of the LC surface located upward directly from the VA	9.4±2.5	11.2±17.7	0.48
Angle composed medial margin of the LC directly downward and the VA	43.7±17.7	39.3±18.3	0.27
Lateral margin of the PLL from medial margin of the VA	12.1±2.6	12.3±1.6	0.91
The PLL lateral margin from the DRG	14.7±2.5	12.1±3.1	0.00
The PLL diameter	12.0±2.0	12.4±2.3	0.23

LC=Longus colli, VA=Vertebral artery, PLL=Posterior longitudinal ligament, DRG=Dorsal root ganglion, SD=Standard deviation

Table 4. Right and left difference of the biometric data

	Left(mean±SD)	Right	T-test
Distance between median margin of the LC	12.1±2.8	12.1±2.7	0.90
Medial margin of the LC from medial margin of the VA	13.3±1.8	14.2±2.2	0.04
Medial margin of the LC from the LC surface located upward directly from medial margin of the VA	8.7±2.0	9.3±2.0	0.13
Medial margin of the LC from the anterior tubercle	18.8±2.8	19.4±3.0	0.39
Height of the LC surface located upward directly from the VA	11.5±1.7	9.0±2.4	0.34
Angle composed medial margin of the LC directly downward and the VA	39.3±17.5	43.9±18.5	0.24
Lateral margin of the PLL from medial margin of the VA	11.1±2.7	13.4±1.7	0.32
The PLL lateral margin from the DRG	13.4±3.0	13.7±3.2	0.62
The PLL diameter	12.3±2.2	12.2±2.2	0.80

LC=Longus colli, VA=Vertebral artery, PLL=Posterior longitudinal ligament, DRG=Dorsal root ganglion, SD=Standard deviation

Comparison between measurements on the right and left sides

Although these differences between the right and left sides were observed, only the difference in the distance from the medial margin of the longus colli to the medial wall of the vertebral artery was statistically significant (p=0.04) (Table 4).

Discussion

The treatment of cervical disc disease by directly removing the herniated lesion via anterior cervical decompression and fusion, which was presented by Robinson, Smith[19], and Cloward[4] in the 1950s, is most popular method.

There are other modified methods using the anterior cervical decompression and fusion approach. Verbiest[20] described the removal of osteophyte via an anterolateral approach. Using a similar method, Hakuba[8] described removal of the uncinate process and cervical disc followed by bone fusion. Lesoin[17] also described favorable outcomes after foraminotomy and fusion. Jho[11] presented successful outcomes after anterior cervical microforaminotomy in which the uncinate process and cervical disc were directly removed without bone fusion. Because anterior cervical microforaminotomy directly removes the focal region, damage to the dynamic motor capacity of the cervical spine is minimized. Moreover, it maximizes the decompression effects in the accurate focal region. However, it is essential to acquire knowledge on the anatomical structure in this region to avoid damage to the vertebral artery[9,11,12]. Therefore, we studied the spatial relationships from the medial margin of the longus colli to the vertebral artery, nerve root, and anterior tubercle.

The logus colli is the first structure which exposed in the anterior cervical microforaminotomy. Therefore, we measured the medial margin of the longus colli as a primary standard point that can be estimated the surrounding structures anatomically because the surgeon may need to recognize the exact location of nerves and blood vessels visualizing toward the transverse process after incision of the longus colli.

Lu and Ebraheim[18] have previously described that the distance from the medial margin of the longus colli to the medial wall of the vertebral artery is narrower along the upper cervical region, being longest at the sixth cervical spine (11.5±1mm), and shortest at the third cervical spine (9.0±1.3mm). These measurements were narrower than ours, possibly due to subtle differences in measurement points. However, their observations that the distance between the medial margins of the bilateral longus colli is narrower along the upper cervical is consistent with our results.

We also observed that at the seventh cervical spine, the vertebral artery is located anteriorly to the transverse process instead of through the transverse foramen. Awareness of this aspect is required in performing surgeries involving this region. The distance between the medial margins of the bilateral transverse foramens at the mid-cervical region has reported to be 30mm. In classic anterior cervical discectomy and fusion, the middle 20mm of the disc and partial areas of surrounding vertebral bodies are removed, and the vertebral arteries are 5mm away from either side of the resected area[5]. Jho[11,12] has described that in anterior cervical microforaminotomy the vertebral artery can be easily damaged at the sixth and seventh cervical spine, at the external aspects of the uncinate processes and the transverse foramens; thus, much care and attention are needed when operating in this area. Moreover, Lee et al.[16] advised caution when drilling the posterior part of the vertebral body at the third and seventh cervical spine because the vertebral artery is in close proximity posterior to the vertebral body in these regions.

Knowing the relationships between anatomical structures is critical for surgery. For example, the vertebral artery is located in the posteromedial margin of the anterior tubercle in the cervical region (except at C7); thus, after skin incision, the location of the vertebral artery in the cervical region can be determined by palpating for the anterior tubercle of the transverse process. In this study, we determined that the distance from the medial margin of the longus colli to the anterior tubercle was 17.9~20.5mm. The distance from the medial margin of the longus colli to the vertebral artery was 13.3~14.7mm. This distance was longest at C6-7 and shortest at C3-4. The angle between the sagittal line of the medial margin of the longus colli and the medial wall of the vertebral artery from the medial margin of the longus colli was 41~42.5 degrees. Therefore, the surgeon must recognize that drilling the cervical vertebrae a distance of 13~15mm at a >40 degree angle from the medial margin of the longus colli will likely result in damage of the vertebral artery. The average horizontal distance and depth from the medial margin of longus colli to the medial wall of the vertebral artery were 8.4~10.3mm and 8~13.4mm, respectively. The horizontal distance was longest at the C6-7 level, and the depth was deepest at C3-4. This means that the surgeon can incise the most medial 5mm of the longus colli and drill directly posteriorly and still have a 3mm buffer from the vertebral artery. This method would avoid incising the longus colli unnecessarily. Moreover, it could reduce the damage to the sympathetic chain which traverses along the medial margin of the longus colli. This method also allows the surgeon to determine the location of the lateral margin of the posterior longitudinal ligament and the posterior margin of the uncinate process. According to Jang et al.[10] the operation can be performed by drilling a 7mm hole in diameter 1.5cm away from the center of the vertebrae. Based on the measurements of anatomical structure and size of 270 cervical uncinate processes, Lu and Ebraheim[18] have described that drilling a 5~6mm hole in diameter 5~6mm from the lateral margin of the uncinate process presented no damage to the vertebral artery. However, these reports rely on either the center of the vertebrae or the uncinate process as a standard point, which are both ambiguous points and quite variable between patients. In our study, we chose the medial margin of the longus colli as the measurement standard, which is relatively easy to expose and confirm. Thus, visualization of the medial margin of the longus colli would aid the surgeon in understanding the locations of the surrounding anatomical structures at the beginning of the operation.

According to Kotani et al., the uncinate process composing the Luschka joint contributes to the stabilization of the cervical spine, along with the disc and the posterior vetebral structure[13]. Jang et al.[10] have described that removing a posterior part of the uncinate process and osteophyte with the remaining lateral margin of the uncinate process presents no damage to the vertebral artery and no complications like instability or deformity of the cervical spine or decrease in disc height. Even though removing some part of the disc would be indispensable, removing only the pathologic part of the uncinate process and lesion of the cervical disc would give more biomechanical stability of the cervical spine than eliminating the whole uncinate process. In our study, we found that on transverse section of the cervical disc, the nerve root originating from the spinal cord lies in close proximity to the posterior part of the uncinate process which forms the anterior part of intervertebral foramen, and we confirmed that the nerve root is contiguous with the posteromedial third to half of the uncinate process. The anterior part of the uncinate process is usually not related to nerve root compression because it is not in direct contact with the nerve root; rather, it is separated from the nerve root by the vertebral artery and its surrounding connective tissue. In the case of radiculopathy caused by osteophyte, or hypertrophy of the uncinate process, it can be inferred that enough decompression can be achieved by only eliminating the 1/2~1/3 posterior part of the uncinate process rather than removing it in its entirety. Furthermore, simply removing the posterior part of the uncinate process to alleviate nerve root compression would help maintain biomechanical dynamic stability of the cervical spine.

Ebraheim et al.[6,7] have described in their anatomical studies on cadaver specimens that the distance between the lateral margin of the uncinate process and the medial margin of the transverse process is 3.3±1mm. This distance gets shorter at the upper cervical region (1.7±0.8mm at the C4). Thus, the classical approach to decompression in the upper cervical region would require the removal of the lateral part of the uncinate process and consequently poses a great risk of damage to the vertebral artery. Lu et al.[18] have described that the vertebral artery is more anterior in the upper cervical region than in the lower cervical region. In addition, the distance between the vertebral arteries is narrower in the upper cervical region, thus posing additional risk to damaging the vertebral artery in this area. Our study presumes that without removing the lateral part of the uncinate process and removing the posteromedial part of the uncinate process, the risk of damaging the vertebral artery is substantially lower. However, in cases of severe osteophyte, in which the entire intervertebral foramen is compressed toward the lateral uncinate process, we would use Jho's surgical approach to remove the entire uncinate process and osteophyte[11,12].

The location of the posterior longitudinal ligament can be identified after removing part of the longus colli and making a hole with a high speed drill in the cervical disc toward the uncinate process. In microscopic surgery, it is easy to distinguish the posterior longitudinal ligament because it has a longitudinal arrangement[1,5,14]. Rather, it is necessary to perform decompression on the lateral part of the posterior longitudinal ligament and proximal part of the nerves root. Thus, knowing the morphometric relationships between the posterior longitudinal ligament, vertebral artery, and nerve root are essential.

In our study, the width of the posterior longitudinal ligament was on average 5mm narrower than the width of the dura. The proximal 2mm of the nerve root lie outside of the lateral margin of the posterior longitudinal ligament. We found that the distance between the lateral margin of the posterior longitudinal ligament and the vertebral artery was wider in the lower cervical region than in the upper cervical region (9.7~10.3mm at C3-4 and C4-5 and 14.2~15.3mm at C5-6 and C6-7). Lu et al.'s finding that the vertebral artery is positioned most anterolaterally at C6 and that its position changes to the posteromedial side of the vertebra in the upper cervical region agreed with our results[18].

The distance from the lateral margin of the posterior longitudinal ligament to the dorsal root ganglion also got wider in the lower cervical region (11.9~12.7mm at C4-5, 13.7mm at C5-6, and 16.1mm at C6-7). The vertebral artery was located between the dorsal root ganglion and the lateral margin of the uncinate process. Therefore, nerve compression is rare from the lateral margin of the uncinate process. During surgical removal of this region, excessive removal on the uncinate process is avoided to prevent damage to the vertebral artery and maintain the biomechanical function of the cervical spine.

The nerve root originates from the spinal cord and travels along the posterior uncinate process through the anterior intervertebral foramen to the dorsal root ganglion[4]. In our studies, the width of the intervertebral foramen was 4.8~5.9mm. While incising along the lateral margin of the uncinate process, careful monitoring of the nerve root by microscopy can help prevent damage to the nerve root.

Conclusion

The medial margin of the longus colli is easy to expose and serves as an anatomical landmark by which to locate peripheral structures in the cervical spine at the beginning of surgery. The medial margin of the vertebral artery is 13.3~14.7mm away from the longus colli at 41~42.5 degrees from the sagittal line of the medial margin of the longus colli. The horizontal distance and depth from the longus colli to the medial margin of the vertebral artery are 8.4~10.3mm and 8.0~13.4mm, respectively. The range of distance from the lateral margin of the posterior longitudinal ligament to the medial margin of the ipsilateral medial wall of the vertebral artery was 11.9~16.1mm, to the ipsilateral dorsal root ganglion was 11.6~12.9mm.

These data provide new information leading to the vertebral artery and neural foramen from the ventral surface of the cervical spine and will aid in reducing neurovascular injury during anterior cervical approaches.

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Commentary

Any surgeon who tries to conduct anterior approach in patients with cervical spine disease, always expose himself to danger of vertebral artery injury, Especially, in anterior uncovertebral approach and anterior cervical microforaminotomy, a surgeon may be at more risk of vertebral artery injury than the other conventional anterior cervical approaches, even if these minimal invasive approaches have some advantages compared to the conventional anterior approaches such as no need of interbody fusion. The results of the morphometric study with cadaver may set forth guidelines for spinal surgeons to conduct these kinds of anterior cervical approaches, as well as to make an attempt to remove far posterolateral part of hypertrophied uncinate process even in conventional anterior cervical approaches. There have been similar morphometric cadaver studies for anterior cervical approaches. The strongest point of the authors' study is to present anatomical data for practical use. When the anterior part of the cervical spine is exposed during surgery, one the first structures a surgeons faces is the longus colli, and the deepest structure observable without difficulty following discectomy is the posterior longitudinal ligament. The authors give spinal surgeons an idea how far the most risky structure, the vertebral artery is from these easily recognized landmarks.

Chun-Kun Park, M.D., Ph.D.
Department of Neurosurgery,
The Catholic University of Korea