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A Morphometric Study of Cadavers for the Anterior Approach to the Lower Lumbar Spine

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ABSTRACT

AIM: To explore the relationship between the retroperitoneal vasculature and anterior surface of the lower spine, and to establish values for aiding in prediction of the pertinence of anterior approach at the L4-L5 and L5-S1 intervertebral discs.

MATERIAL and METHODS: The study included 13 fresh human cadavers. After exploration of the abdominal cavity and removal of the visceral organs, the vasculature, and anterior spinal surface were revealed beneath the lower extension of the perirenal fascia. Morphometric measurements of the great vessels and the intervertebral discs were obtained. All measurements were analyzed and presented as mean and standard deviation. Differences in the values between sexes were assessed.

RESULTS: The anterior height of the L4-L5 and L5-S1 intervertebral disc was 6.8 ± 0.81 mm and 6.7 ± 0.99 mm, respectively. The widths of the aorta, inferior vena cava, right and left common iliac arteries, and right, and left common iliac veins were 16.4 ± 3.58, 20.6 ± 3.36, 11.5 ± 2.32, 11.5 ± 2.43, 14.7 ± 3.13, and 15.5 ± 3.27 mm, respectively. The mean aortic bifurcation angle was 45.5°. The aortic bifurcation was located above the lower endplate of the L4 vertebrae in 53.8% of the cadavers. The area of the interarterial and interiliac trigones was 14.6 ± 5.33 cm^2 and 7.1 ± 4.35 cm^2, respectively. No statistically significant differences were noted between the sexes.

CONCLUSION: An elaborate radiological examination of the vasculature should be performed prior to surgery to avoid unwanted vascular complications during the anterior approach. Knowing the area of the interarterial and interiliac triangles and the aortic bifurcation location could be aid in assessing the safe working zone.

KEYWORDS: Safe zone, Anterior approach, Lumbar spine, Fresh cadaver, Anatomy

ABBREVIATIONS: ALIF: Anterior lumbar interbody fusion

INTRODUCTION

Spinal fusion is indicated for several prevalent spinal disorders such as degenerative disc disease, spondylolisthesis, deformities, and fractures. At the lumbar spine, fusion can be obtained via posterior pedicle screw and interbody systems. Anterior lumbar interbody fusion (ALIF) was first introduced in the 1930s. Carpener first performed ALIF for the treatment of spondylolisthesis and Ito et al. performed it to treat Pott's disease (4,17). Despite the opposition from

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Stauffer and Coventry to the anterior approach in the 1970s, there have been many substantial papers published by authors during that time (8,9,12,21,27).

Compared to the other approaches, anterior approach provides a more direct view of the disc without encountering the neural structures; thus, it reduces the risk of injury to the dura and neural structures. Furthermore, paraspinal muscle dissection can be avoided with this approach (25, 28). However, ALIF has distinctive complications that should be considered. The main complications observed following anterior approach originate from the vascular structures. The risk of encountering vascular injury is reportedly 1.9%–26% (1-3,6,14). Vascular lacerations commonly occur in the left common iliac vein; arterial injury is less frequently affected due to the thicker wall of the main arteries (15). Deep vein thrombosis is another vascular complication encountered with the anterior spinal approach (1,3).

The main arterial and venous structures pass anterior to the surface of the spine. At the L5-S1 level, the space between both the common iliac arteries and veins forms a window that allows disc interventions to be performed anteriorly. Furthermore, the abdominal aorta and unilateral common iliac vein and artery traverse medial to the working site at the level of the L4-5 disc. Knowledge of the vascular anatomy and its variations is essential for neurosurgeons to anticipate or avoid unwanted complications. Thus, in this study, we aimed to determine the relationship between retroperitoneal vascular structures and anterior spinal surface using measurements obtained from fresh cadavers. This is fundamental to ensure a safe anterior approach to the spine.

MATERIAL and METHODS

This study was approved by the Turkish Republic Ministry of Justice, Forensic Medicine Institution (Date: 21/04/2015; No: 21589509/387). A total of 13 fresh human cadavers, including 7 males, and 6 females, were studied. The mean age at the time of death was 41.2 years (range, 27–58 years). The cadavers did not exhibit any signs of previously having undergone spinal surgery. None of the cadavers exhibited notable signs of congenital or acquired anomalies. The study was designed to evaluate the major retroperitoneal vascular structures and their relation to the anterior surface of the spine.

Cadavers were placed in the neutral supine position. After exploration of the abdominal cavity, soft tissues and visceral organs were removed via the lower extension of the perirenal fascia covering the lower abdominal vascular structures. The lower abdominal aorta and inferior vena cava, bifurcation of aorta, confluence of the common iliac veins, bilateral common iliac arteries, bilateral common iliac veins, median sacral artery and vein and anterior surface of the spine were identified by meticulously dissecting and retracting the perirenal preaortic fascia to preserve the anatomical relationships. Every study area was photographed along with a marker for scaling and evaluated using a digital image analysis software (ImageJ; Rasband W.S., U.S. National Institutes of Health, Maryland).

The following were principally measured: 1) width of the aorta adjacent to its bifurcation, 2) width of the inferior vena cava adjacent to its confluence, 3) width of bilateral common iliac arteries, 4) width of bilateral common iliac veins, 5) aortic bifurcation angle, 6) height of the L4-L5 and L5-S1 intervertebral discs, and 7) distance between the aortic bifurcation and lower end plate of the L5 vertebrae (Figure 1). The position of the aortic bifurcation was classified based on its relation to the L4-L5 intervertebral disc. Bifurcation above the level of the L4-L5 intervertebral disc was classified as *supradiscal bifurcation*; bifurcation at the level of the L4-L5 intervertebral disc was classified as *prediscal bifurcation*; and bifurcation below the level of the L4-L5 intervertebral disc was classified as *infradiscal bifurcation*.

Two different trigones were described to achieve a different viewpoint and more detailed calculation of the probable working areas in the anterior spinal approach (Figure 2). The area located between the common iliac arteries and the lower endplate of the L5 vertebrae was considered the interarterial trigon, and the area between the right common iliac artery,

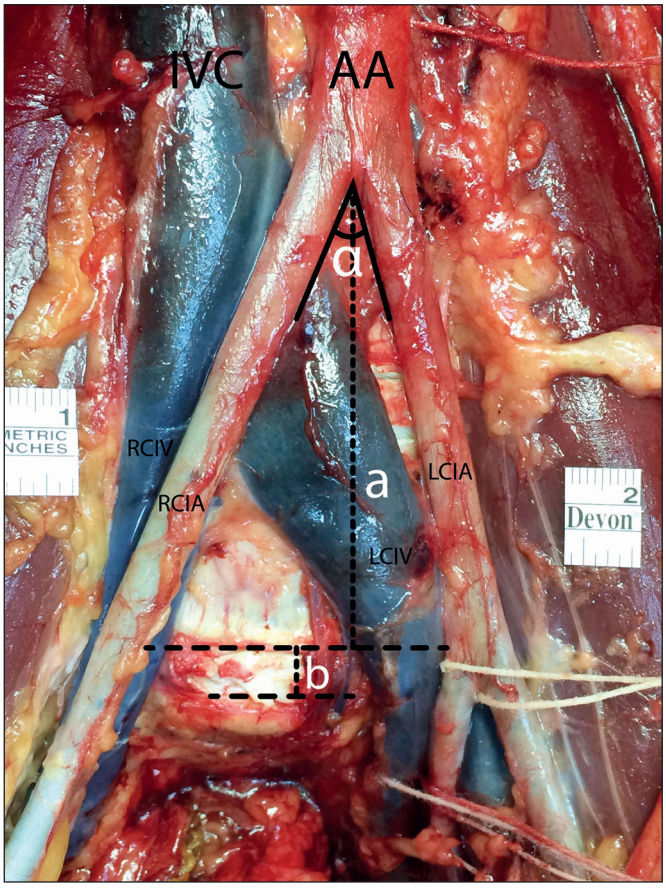

Figure 1: a: Distance between the aortic bifurcation and lower endplate of the L5 vertebrae. **b:** Anterior disc height of the L5-S1 intervertebral disc. Anterior disc height at the L4-5 level was measurable after removal of the great vessels. **AA:** Aorta artery. **IVC:** Inferior vena cava. **RCIA:** Right common iliac artery. **RCIV:** Right common iliac vein. **LCIA:** Left common iliac artery. **LCIV:** Left common iliac vein. **α:** Aortic bifurcation angle.

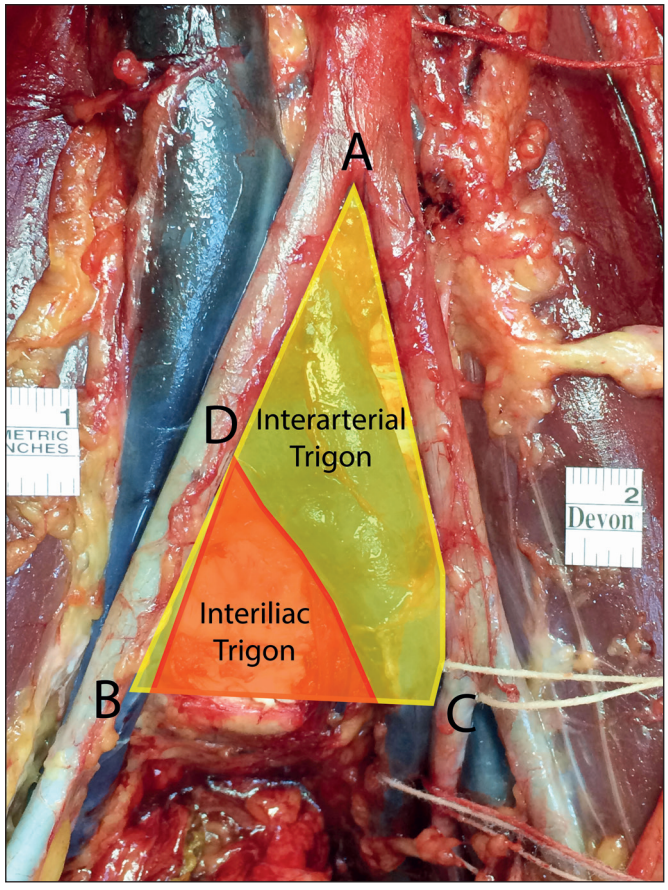

Figure 2: Interarterial and interiliac trigons. **A:** Aortic bifurcation angle, **BC:** Upper endplate of the S1 vertebral, **D:** Intersection of the confluence and the right common iliac artery.

left common iliac vein, and lower endplate of the L5 vertebrae was considered the interiliac trigon. The field measurements were made and noted as square centimeters.

Statistical Analysis

Statistical analysis was performed by using IBM SPSS (version 20; SPSS Inc., Chicago). Descriptive data were presented as $\chi \pm S$. The *Mann–Whitney U* test was used to examine the difference between sexes. A p-value of <0.05 was considered a statistically significant difference.

RESULTS

The dimensions of the intervertebral and vascular structures and the difference in the measurements, observations, and statistical parameters between sexes are demonstrated in Tables I and II.

Both intervertebral anterior disc heights were approximately the same: 6.8 ± 0.81 mm at the L4-L5 level and 6.7 ± 0.99 mm at the L5-S1 level.

The mean aortic width was 16.4 ± 3.58 mm (range, 10.5–23.2 mm), and the mean inferior vena cava width was 20.6 ± 3.36 mm (range, 15.7–25.1 mm). The inferior vena cava was significantly wider than the aorta in all the cadavers, except for in two. The mean width of the right common iliac artery and vein was 11.5 ± 2.32 mm and 14.7 ± 3.13 mm, respectively. In all cadavers, the right common iliac artery lay above the right iliac common vein, and the right common iliac vein mostly lay anterolateral to the anterior longitudinal ligament. In contrast, the left common iliac vein lay medial to the left common iliac artery. Furthermore, the left common iliac vein lay anterior to the L4-L5 intervertebral disc, if the confluence was located

Table I: Measurements of Vasculature, Anterior Disc Heights and Areas and p Value Between Sexes

	Mean ± SD	Minimum	Maximum	p-value
Widths				
Aorta	16.4 ± 3.58 mm	10.5 mm	23.2 mm	0.116
Vena Cava Inferior	20.6 ± 3.36 mm	15.7 mm	25.1 mm	0.224
Right Common Iliac Artery	11.5 ± 2.31 mm	7.2 mm	14.4 mm	0.475
Left Common Iliac Artery	11.5 ± 2.43 mm	6.3 mm	14.5 mm	0.252
Right Common Iliac Vein	14.7 ± 3.13 mm	10.3 mm	21.4 mm	0.520
Left Common Iliac Vein	15.5 ± 3.27 mm	11.2 mm	23.9 mm	0.253
Aortic Bifurcation Angle	45.5°	28.8°	82.3°	0.252
Distance to L5 End-Plate	56.3 ± 11.4 mm	41 mm	78.5 mm	0.391
L4-5 Anterior Disc Height	6.8 ± 0.81 mm	5.4 mm	8.1 mm	0.520
L5-S1 Anterior Disc Height	6.7 ± 0.99 mm	4.9 mm	7.9 mm	0.282
Interarterial Trigon	14.6 ± 5.33 cm^2	7.9 cm^2	23.1 cm^2	0.391
Interiliac Trigon	7.1 ± 4.35 cm^2	1.8 cm^2	15.1 cm^2	0.721

Table II: Distribution of Aortic Bifurcation Level

Aortic Bifurcation Level (Relative to L4-L5 intervertebral disc level)	n	%
Supradiscal	7	53.8
Prediscal	2	15.4
Infradiscal	4	30.8
Total	**13**	**100**

anterior to the L4 vertebrae, and paramedial to the L5-S1 intervertebral disc. The mean width of the left common iliac artery and vein was 11.5 ± 2.43 mm and 15.5 ± 3.27 mm, respectively.

The mean angle of the abdominal aorta bifurcation was 45.5° (range, 28.8–82.3°). The abdominal aorta bifurcation was mostly supradiscal (53.8%). The bifurcation was prediscal in two cadavers (15.4%) and infradiscal in four cadavers (30.8%). Moreover, the distance between the L5 lower endplate and aortic bifurcation was 56.3 ± 11.43 mm. The shortest distance between the bifurcation and the L5 lower endplate was 41 mm.

The individual measurements of the interarterial and interiliac trigons varies. The mean surface area of the interarterial and interiliac trigons was 14.6 ± 5.33 cm^2 (range, 7.9–23.1 cm^2) and 7.1 ± 4.35 cm^2 (range, 1.8–15.1 cm^2), respectively (Figure 3). The smallest surface areas of the interiliac trigon were 1.8 cm^2 and 2.7 cm^2 respectively, which limit the comfort of the anterior approach (Figure 4).

No statistically significant differences in the morphometric measurements between male and female cadavers were noted.

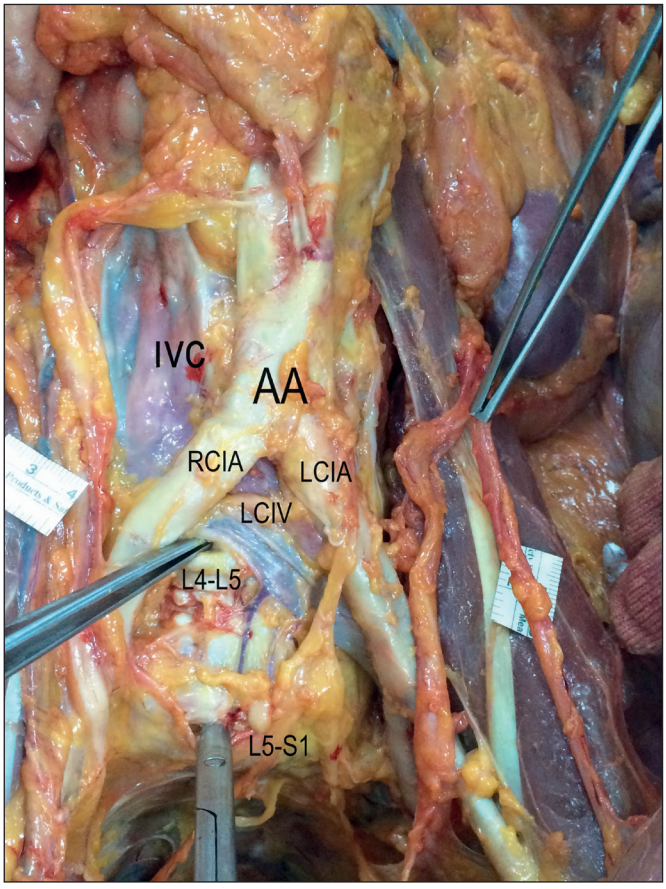

Figure 3: Supradiscal aortic bifurcation. Intervertebral disc of L4-L5 and L5-S1 levels are demonstrable despite the aortic bifurcation being at a higher level and being partially covered by the confluence and left common iliac vein. **AA:** Aorta artery. **IVC:** Inferior vena cava. **RCIA:** Right common iliac artery. **LCIA:** Left common iliac artery. **LCIV:** Left common iliac vein.

DISCUSSION

Anterior interbody fusion has gained popularity following improvements in the surgical techniques and successful results after the 1980s. Currently, the use of solo or posteriorly supplemented ALIF as an optimal treatment option for degenerative spinal disorders remains controversial (22). However, advances in the instrumentation methods for ALIF promises better stabilization and restoration of the disc height. Furthermore, increased experience in the anterior approach may allow neurosurgeons to perform the procedure more often than in the previous era.

Even though working away from the neural structures in the anterior approach allows neurosurgeons to avoid injuring the dura or roots, significant complications may occur due to the anatomical structures passing in the surgical pathway. Vascular structures, sympathetic nerve branches, ureters, and visceral organs are at risk of injury, especially while gaining access to the intervertebral disc. The prominent complications associated with anterior approach originate in the vascular or autonomic nervous system. Autonomic nervous system injury may cause retrograde ejaculation in men (incidence, 0.5%–24%) due to injury to the superior hypogastric plexus injury and warmer limb (incidence, 1.4%–43%) due to the loss of autonomic function on the innervated vessels because of sympathetic chain injury (5,11,24,29).

Vascular injury is the most important complication which requires a perioperative multidisciplinary intervention or reexploration of the retroperitoneal space to prevent the consequences of hemorrhage (10). Bleeding may result from venous traction, avulsion, or laceration (6,10,12,24,26,29). Occasionally, vessels may be injured during exposure, and the left common iliac vein is the most commonly injured vessel perioperatively (15). Thus, the precise location of the vasculature and the natural openings through which the lumbar region can be accessed are crucial in planning a spinal surgery using the anterior approach. The preoperative preparation should be elaborate to determine the level of aortic bifurcation and iliac confluence. The arterial and venous branches must be studied radiologically, and the natural openings should be evaluated for proper working space. The planned route must consider predisposing vascular factors or existing

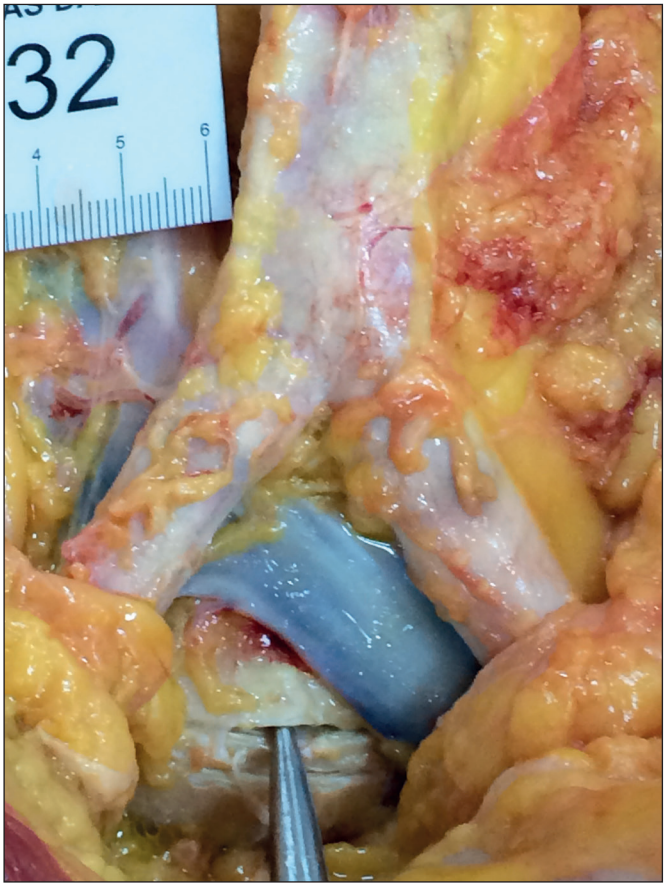

Figure 4: Infradiscal aortic bifurcation with a narrow interiliac trigon providing a limited surgical window for the anterior approach.

abnormalities. Several studies have evaluated the relationship between vascular structures and spine to better understand the surgical site. Radiological devices or embalmed cadavers are usually used to study the vasculature. However, fresh cadavers provide us a direct and most accurate perspective of the anterior surface of the spine.

The disc heights in our study were almost equal (6.8 mm and 6.7 mm); these results were considerably different from those of previous studies. The mean anterior disc height, which was measured at the midline of the L5-S1 intervertebral disc, was 18.8 mm in the study by Cho et al. (7). Tribus and Belanger reported that the height of the L5-S1 intervertebral disc was 13.5 mm (30). In a radiological study, the mean anterior height of the L4-L5 intervertebral disc was 9.6 mm (13).

Pirro et al. determined that that the width of the aorta, inferior vena cava, and right, and left common iliac veins were 22.1 mm, 42 mm, 15 mm, and 16 mm, respectively (23). Ebraheim et al. determined that the mean width of the right common iliac arteries was 10.5 mm in both sexes, and the mean width of the left common iliac arteries was 9.5 mm in males and 8.9 mm in females (10). The width of the aorta and inferior vena cava in our study was lesser than that in previous studies. However, the width of the bilateral common iliac arteries and veins in our study were comparable to the previous studies. Such unpredictable variations can be encountered. Inamasu et al. reported a case with a tortuous abdominal aorta and inferior vena cava covering the anterior surface of the lumbar spine (16).

The level at which the aorta bifurcates is a determinant of the comfort level during surgery at both L4-L5 and L5-S1 levels. At the L4-L5 level, following the interval between the lateral vascular structures and sympathetic chain is preferred for an anterior approach with the aortic bifurcation at a higher level. In this case, the common iliac artery and vein could be a complicating factor, which creates the need for extra vasculature traction to reach the intervertebral disc. However, a wider distance between the bilateral common iliac vessels and an aortic bifurcation at a higher level could ease the approach to the L5-S1 intervertebral disc. If the distance between the iliac vessels is inadequate, an approach lateral to the unilateral iliac vessels may be preferred for the L5-S1 level.

In a study that included embalmed cadavers, aortic bifurcation was noted 62.5 mm and 59.5 mm from the upper endplate of the S1 vertebra in males and females, respectively (10). In our study the aortic bifurcation was noted 56.3 mm from the lower endplate of the L5 vertebra. Considering the mean anterior intervertebral disc height at the L5-S1 level is 6.7 mm, our results were similar to those of the previous studies. Additionally, we determined that 53.8% of the cadavers had supradiscal bifurcation and 15.4% had prediscal bifurcation. Khamanarong et al. performed a study using embalmed cadavers and determined that aortic bifurcation occurred above the level of the L4-L5 intervertebral disc in 70.1% of cadavers and in front of the disc in 12.3% of the cadavers (18). Pirro et al. determined that the aorta bifurcated above the lower endplate of the L4 vertebra in 52% of the cadavers and in front of the disc in 7% of the cadavers (23). Inamasu et al. determined that the aortic bifurcated above the lower endplate of the L4 vertebra in 55% using tomographic angiography (16).

In a cadaveric study by Lakchayapakorn and Siriprakan, the mean aortic bifurcation angle was 54° (19). In another study, the mean aortic bifurcation angle was estimated to be 45.4 ± 9.25° using tomographic angiography (20). The aortic bifurcation angles in our study were similar to those report by Liu et al. (20). However, the range was wider (28.8–82.3°) in our study than in the previous studies. In general, the venous structures tended to exhibit a wider variation. However, the findings suggested that the variations in aortic bifurcation angle occurred regardless of the bifurcation level. Thus, we propose that the level of aortic bifurcation and the width of the surgical surface area determine the angle of aortic bifurcation.

The interiliac and interarterial trigone areas in this study were 7.1 cm^2 and 14.6 cm^2, respectively. Considering that ≥60% of aortic bifurcation occurs at or above the level of the L4-L5 intervertebral disc and that the area between the iliac vessels is most likely sufficient, interiliac triangle may be regarded as safe zone for approaching the L5-S1 intervertebral disc, as indicated by Ebraheim et al. (10). Similarly, Cho et al. stated that access to the L5-S1 intervertebral disc was comfortably obtained in 60% of their cadavers (7). In our study, we encountered two cadavers where the trigone area was

beyond the limits to allow surgical interventions for the L5-S1 intervertebral disc without significant vessel mobilization perioperatively. In such cases, the disc can be approached from lateral to the common iliac vessels. Conversely, a lower aortic bifurcation and narrower interarterial triangle area may be considered as indirect indications of an easier access to the L4-L5 intervertebral disc. Because vascular route variations are difficult to classify and several studies show consistent vascular measurements, except for the uncommon, and extreme variations, measuring the safe area between the vessels and locating the aortic bifurcation may help determine the convenience in performing an anterior approach to the lower lumbar levels. However, additional measurements and further research are required to externally validate our test results.

CONCLUSION

Several major vessels are encountered when approaching the anterior surface of the lower lumbar spine. Thus, thorough evaluation is required prior to surgery. Several studies suggest some parameters to better understand the convenience of the approach. However, a universally accepted method has not been established. Because of the difficulty in classifying the vessel routes, due to their unpredictable variations, calculating the access areas and knowing the aortic bifurcation location could help determine the convenience with which the disc space can be approached. Additionally, we have presented our findings regarding vascular and disc morphometry, and its comparisons in the literature. With this knowledge, the pertinence of anterior approach to the lower lumbar spine can be assessed and paraspinal muscle dissection, root and dural injury, and lumbar, or lumbosacral plexus injury can be avoided.

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AUTHORSHIP CONTRIBUTION

Study conception and design: HC, EC, HD, CK
Data collection: HC, HD, CK
Analysis and interpretation of results: OO, OB
Draft manuscript preparation: HC, OO, HD
Critical revision of the article: EC, OB, AA, AS
Other (study supervision, fundings, materials, etc...): AA, AS
All authors (HC, OO, EC, HD, OB, CK, AA, AS) reviewed the results and approved the final version of the manuscript.

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