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ANATOMY OF THE GREAT VESSELS BY MAGNETIC RESONANCE IN ANTERIOR LUMBAR INTERBODY FUSION

ANATOMIA DOS GRANDES VASOS POR RESSONÂNCIA MAGNÉTICA NA FUSÃO INTERSOMÁTICA LOMBAR ANTERIOR

ANATOMÍA DE LOS GRANDES VASOS POR RESONANCIA MAGNÉTICA EN FUSIÓN INTERSOMÁTICA LUMBAR ANTERIOR

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ABSTRACT

Objective: To perform an analysis of the anatomy of the great vessels relevant to the access for anterior lumbar interbody fusion (ALIF), determining the level of their bifurcation, the distance between the iliac vessels at L5-S1, the morphological configuration of the left iliac vein and the presence of fatty tissue between the vessel and the disc. Methods: Two hundred magnetic resonance imaging (MRI) scans of the lumbar spine of patients (18-80 years old) were evaluated using axial, coronal, and sagittal cuts at levels L1-S1 in T2 weighting. The interiliac distance was defined as the measurement between the left iliac vein and the right iliac artery. The presence of fatty tissue was defined as the identification of space between the vessel and the disc. Vessel morphology was divided into oval and flat. Results: The population's average age was 49.6 years, with 52% being female. The average interiliac distance at L5-S1 was 27.48mm. The bifurcation of the aorta artery was identified at the level of L4 in 56.3%, as well as the confluence of the iliac veins (37.2%). The left iliac vein was identified as oval in 69% of patients and flat in 31% of patients. Fat tissue was evidenced in 60.5% of the exams. Conclusion: As a routine preoperative examination and surgical planning, lumbar MRI is fundamental in investigating the anatomy regarding anterior approach surgeries, allowing an effective assessment of the relationships between the great vessels and the lumbar spine. ***Level of Evidence IV; Retrospective Investigation.***

Keywords: Spine; Magnetic Resonance; Arthrodesis; Iliac Vein.

RESUMO

Objetivo: Realizar uma análise da anatomia dos grandes vasos relevantes ao acesso para fusão intersomática lombar anterior (ALIF), determinando o nível de sua bifurcação, a distância entre os vasos ilíacos em L5-S1, a configuração morfológica da veia ilíaca esquerda e a presença de tecido gorduroso entre o vaso e o disco. Métodos: duzentos exames de ressonância magnética (RM) da coluna lombar de pacientes (18-80 anos) foram avaliados, utilizando cortes axiais, coronais e sagitais nos níveis L1-S1, na ponderação T2. A distância interilíaca foi definida como a medida entre a veia ilíaca esquerda e artéria ilíaca direita. A presença de tecido gorduroso foi definida como identificação de espaço entre o vaso e o disco. A morfologia do vaso foi dividida em oval e plana. Resultados: A idade média da população foi de 49,6 anos, sendo 52% mulheres. A distância média interilíacas em L5-S1 foi 27,48 mm. A bifurcação da artéria aorta foi identificada ao nível de L4 em 56,3%. A confluência das veias ilíacas também foi mais frequente ao nível de L4, representando 37,2%. A veia ilíaca esquerda foi identificada com o formato oval em 69% e plana em 31% dos pacientes. Tecido gorduroso foi evidenciado em 60,5% dos exames. Conclusão: Como rotina no exame pré-operatório e no planejamento cirúrgico, a RM lombar tem fundamental importância na investigação da anatomia visando cirurgias de abordagem anterior, pois permite uma avaliação eficaz das relações entre os grandes vasos e a coluna lombar. ***Nível de Evidência IV; Investigação Retrospectiva.***

Descritores: *Coluna Vertebral; Ressonância Magnética; Artrodese; Veia Ilíaca.*

RESUMEN

Objetivo: Realizar un análisis de la anatomía de los grandes vasos relevantes para el acceso en artrodesis intersomática lumbar anterior (ALIF), determinando el nivel de su bifurcación, la distancia entre los vasos ilíacos en L5-S1, la configuración morfológica de la vena ilíaca izquierda y la presencia de tejido graso entre el vaso y el disco. Métodos: Se evaluaron 200 imágenes de resonancia magnética (RM) de la columna lumbar de pacientes (18-80 años) mediante cortes axiales, coronales y sagitales en los niveles L1-S1, en ponderación T2. La distancia interilíaca se definió como la medida entre la vena ilíaca izquierda y la arteria ilíaca derecha. La presencia de tejido graso se definió como la identificación de espacio entre el vaso y el disco. La morfología de los vasos se dividió en ovalados y planos. Resultados: La edad media de la población fue de 49,6 años, de los cuales 52% eran mujeres. La distancia interilíaca media en L5-S1 fue de 27,48 mm.

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La bifurcación de la arteria aorta se identificó a nivel de L4 en 56,3%, así como la confluencia de las venas ilíacas (37,2%). La vena ilíaca izquierda se identificó como ovalada en 69% y plana en 31%. Se evidenció tejido graso en 60,5% de los exámenes. Conclusión: Como rutina en examen preoperatorio, la RM lumbar es fundamental en la investigación de anatomía de cirugías de abordaje anterior, permitiendo una evaluación eficaz de las relaciones entre los grandes vasos y la columna lumbar. ***Nivel de Evidencia IV; Investigación Retrospectiva.***

Descriptores: *Columna Vertebral; Resonancia Magnética; Artrodesis; Vena Ilíaca.*

INTRODUCTION

The previous approach to treating lumbar spine diseases was first described by Burns,[1] in 1933, using a transperitoneal approach for a case of L5-S1 spondylolisthesis. Lane and Moore[2] reported the first anterior lumbar intersomatic fusion (ALIF) procedures performed for degenerative changes in 1948. Southwick and Robinson[3] were the first to describe the retro-peritoneal approach to the lumbar spine in 1957. To meet the criteria for minimally invasive surgery, Onimus et al.[4] reported the video-assisted extra-peritoneal approach and, later, Mayer et al.[5] the concept of mini open for ALIF. Given the most recent progress of anterior fusion and lumbar disc replacements, previous exposure has become more popular for treating lumbar degenerative diseases.[5]

ALIF offers advantages compared to posterior fusion techniques, including preserving paravertebral muscles, posterior ligaments, and facet joints. The decompression of the neural structures is performed indirectly, reducing the risk of neurological injury. In addition, it allows the removal of most of the disc, making it possible to insert a centrally placed hyperlordotic cage, with an improvement in height and segmental angle and a greater gain in lumbar lordosis. Anterior intersomatic fusion has the benefits of minimally invasive surgery: shorter surgical time, lower blood loss, and shorter recovery time. The disadvantages of ALIF are mainly related to the risk associated with surgery performed in the vicinity of the vital intra- and retroperitoneal structures. In particular, venous injuries, arterial thrombosis, and retrograde ejaculation.[6-8]

Serious vascular injuries do not occur very frequently during lumbar spine surgery (0.017% to 0.14%), but they can be considered devastating complications with a high mortality rate.[9] On the other hand, complications related to large vessels are regularly reported in the literature, with an estimated incidence of 2% to 12%. These complications include minor vein or artery injuries, venous thrombosis, and arterial occlusion.[9]

Prior surgery at the L4-L5 level is associated with higher rates of vascular injury, ranging from 2.9% to 15.6%. Venous lesions are more frequent at this level and occur due to the position of the iliocaval junction.[8-10] The main vessels include the abdominal aorta, the inferior vena cava, and the common iliac arteries and veins located just before the lumbar spine. These structures, especially the veins positioned in front and juxtaposed to the lumbar spine, are vulnerable to lacerations during surgery involving the intervertebral disc.[9,11] For access to this level, attention must also be paid to the iliolumbar vein since it can act as a limiting factor for mobilization and subsequent surgical exposure.[12]

A clear understanding of the vascular anatomical features of previous surgical access to the lumbar spine may be an effective measure to avoid these intraoperative complications. This study aims to analyze the anatomy of the great vessels of the lumbar vertebrae using magnetic resonance imaging and, consequently, to assess the safety of performing the anterior access of the lumbar spine in a Brazilian population.

METHODS

Two hundred and forty lumbar spine magnetic resonance (MRI) exams were evaluated. The tests were randomly chosen among patients aged 18 to 80 who sought medical care with complaints of low back pain/sciatica between January 2018 and June 2020 at a tertiary center in Brazil.

Forty patients outside the age group or who had previously undergone posterior lumbar spine instrumentation, retroperitoneal surgery, or who had abdominal vascular diseases, malformations, or intra-abdominal tumors were excluded, resulting in a final number of two hundred patients included in the study.

The study was submitted and approved by the institution's ethics committee (CAAE: 35586520.7.0000.5135), which granted us exemption from "free and informed consent" (TCLE) to carry out this project, considering that the study used only data obtained by routine magnetic resonance imaging. The study respected patients' privacy and confidentiality, as well as the confidential information involved in the research, and guaranteed that the data would not be released.

All exams were initially reviewed, and evaluated by the service's chief radiologist. The necessary measurements and evaluations were performed by a spinal surgery fellow under the supervision of the senior surgeon (CMM) and the senior radiologist (LMA) using the institution's digital radiology repository (Carestream Health®). The images were evaluated with a T2 weighting starting from the lumbar levels of L1 to S1 in the axial, coronal, and sagittal sections.

The levels at which the abdominal aorta artery (AA) bifurcates and the iliac vessels merge into the inferior vena cava (ICV) have been established. Five levels were stipulated about the lumbar vertebrae: vertebral body of L3, disc L3-L4, vertebral body of L4, disc L4-L5, and vertebral body of L5. The interiliac distance was defined as the shortest distance, in millimeters, between the most medial aspect of the left common iliac vein and the most medial region of the right common iliac artery at the level of the L5-S1 disc. (Figure 1)

Statistical analysis was performed using absolute and relative frequency measurements, and then applied statistical tests.[13,14] This study used The chi-square likelihood ratio test for independent samples. A significance level of p-value < 0.05 was adopted to perform the test. Thus, the collected data were tabulated, interpreted, processed, and analyzed using descriptive and inferential statistics. For the data analysis, computing resources were used through processing in the Microsoft Excel system, Statistic Package for Social Sciences (SPSS) version 24.0, all in a Windows 7 environment.

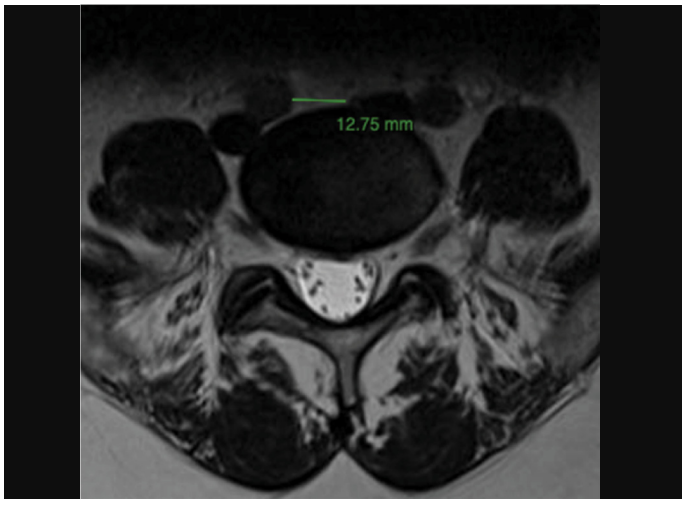


Figure 1. Interiliac distances.

RESULTS

The average age of the studied population was 49.6 years, with 26.6% (n = 53) of the cases aged between 38 and 47 years, 104 women and 96 men. (Table 1)

The mean interiliac distance was 27.48 mm, with a standard deviation of 10 mm (σ = 10.37). The minimum interiliac measurement was 0.00mm, and the maximum was 49.37mm. (Table 2)

Females had the highest average interiliac measurement (29.77 mm) compared to men (25.03 mm). The standard deviation of the interiliac measurement (σ = 10.68 mm) among men shows that the average measurement varied more in males (95% CI = 22.99; 27.08) (p = 0.001). (Table 3)

The interiliac distance measurement was divided into five intervals, to group the values more clearly. The most frequent interval, in 35.2% of the cases, was 20 to 30 mm. The aortic artery bifurcation and the confluence of the iliac veins were also divided into five previously stipulated levels (vertebral body of L3; disc L3-L4; vertebral body of L4; disc L4-L5 and vertebral body of L5). Aortic bifurcation was more frequent at the level of the L4 vertebra (n=112; 56.3%), as was the confluence of the iliac veins (n=74; 37.2%). (Figures 2, 3 and 4)

There is no significant relationship (p>0.05) of dependence between the location of the aortic bifurcation and the gender of the patients, so the frequency of the bifurcation level follows a pattern in both men and women. (Figure 5)

P-value (0.955) by sex - Pearson's chi-square test (Wilks' G^2) for independence (p-value < 0.05).

Total p-value (0.0124) - Spearman's Rô test (weak association).

There was a significant relationship (p<0.05) of dependence between the location of the confluence of the iliac veins and the gender of the patients so that the confluence in females occurs at the level of the vertebral body for the most part. The confluence at the level of the L4-L5 disc was higher in men (n=31; 51.7%). (Figure 6)

Regarding the shape, 31% had a flat shape, while the most prevalent in the sample was the oval with 69%, with no significant relationship (p=0.590) with the patient's gender. Between the left iliac vein and the disc, 60.5% of the patients had fatty tissue, with statistical significance (p<0.05) about the observed format (Figure 7) and distribution by sex. (Figure 8)

Table 1. Sociodemographic characterization of the patients evaluated according to age group and gender.

Characterization	n	%
Age Range		
18 to 27 years old	14	7.0%
28 to 37 years old	27	13.6%
38 to 47 years old	53	26.6%
48 to 57 years old	44	22.1%
58 to 67 years old	34	17.1%
68 years or older	27	13.6%
Gender		
Female	104	52.3%
Male	95	47.7%

Source: Research Protocol (2021).

Table 2. Average interiliac distance in L5-S1.

Variable	N	Minimum	Maximum	Average	Standard Deviation
L5-S1 interiliac (mm)	200	0.00	49.37	27.48	10.37

Source: Research Protocol (2021).

Table 3. Averages of interlaces measurements, by gender.

Gender	N	Average	SD	95% CI
Female	104	29.77	9.58	(27.81; 31.73)
Male	96	25.03	10.68	(22.99; 27.08)

p=0.001. Combined SD= 10.1224. Source: Research Protocol (2021).

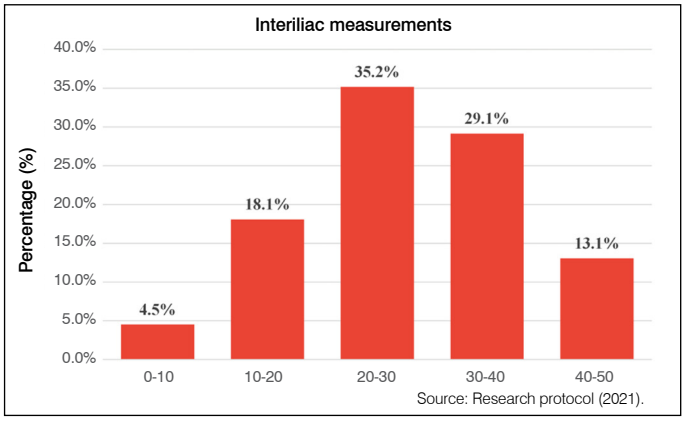


Figure 2. Distribution of interiliac measurements L5-S1.

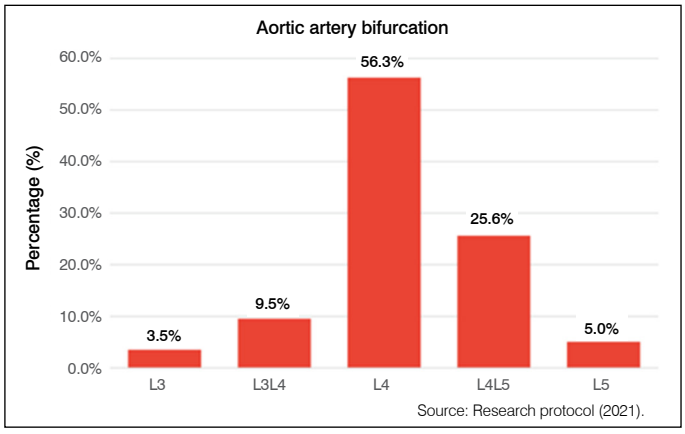


Figure 3. Distribution of the aortic artery bifurcation.

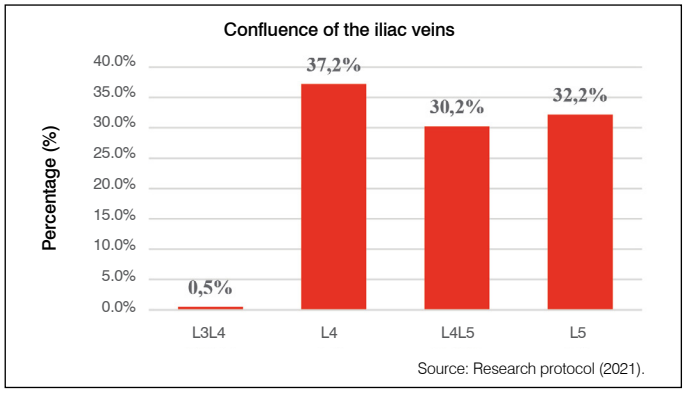


Figure 4. Distribution of the confluence of the iliac veins into the inferior vena cava.

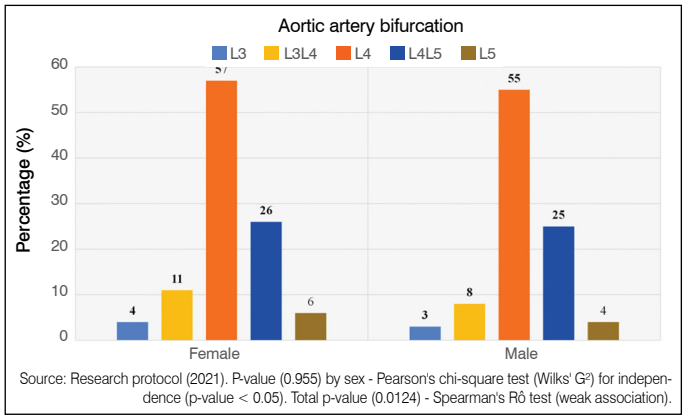
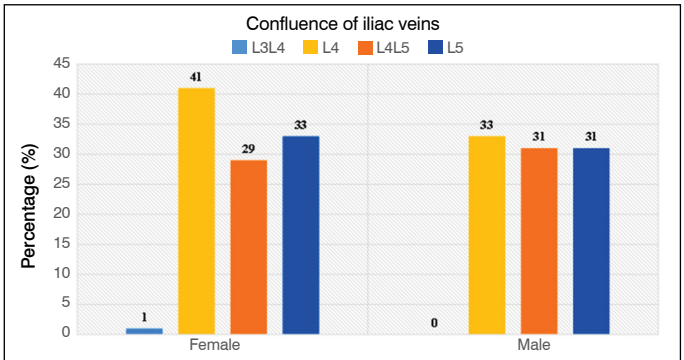
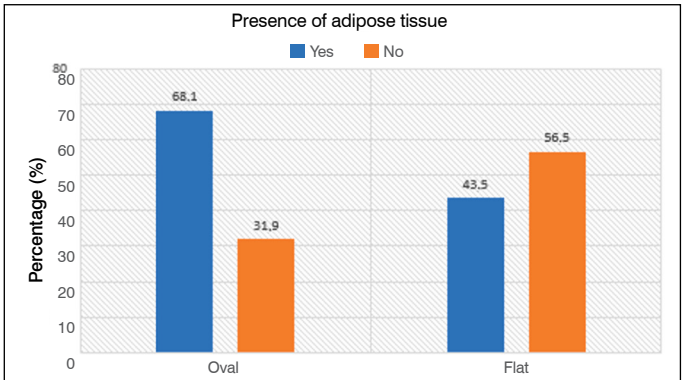


Figure 5. Distribution of aortic artery bifurcation by gender.



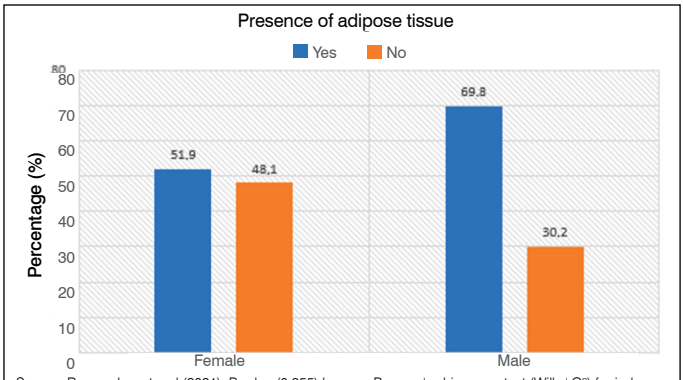
Source: Research protocol (2021). P-value (0.955) by sex - Pearson's chi-square test (Wilks' G^2) for independence (p-value < 0.05). Total p-value (0.0124) - Spearman's Rô test (weak association).

Figure 6. Distribution of the confluence of the iliac veins by gender.



Source: Research protocol (2021). P-value (0.955) by sex - Pearson's chi-square test (Wilks' G^2) for independence (p-value < 0.05). Total p-value (0.0124) - Spearman's Rô test (weak association).

Figure 7. Distribution of the presence of fatty tissue by shape.



Source: Research protocol (2021). P-value (0.955) by sex - Pearson's chi-square test (Wilks' G^2) for independence (p-value < 0.05). Total p-value (0.0124) - Spearman's Rô test (weak association).

Figure 8. Distribution of the presence of fatty tissue by gender.

DISCUSSION

Since its initial description, lumbar intersomatic fusion has become a surgical treatment for various pathologies of the spine: degenerative, traumatic, infectious, and tumor. Advances in surgical techniques and instruments in spinal surgery have allowed the development of less invasive approaches, standing out as a safe alternative and resource to traditional open-back surgery for many specialists. A clear understanding of the anatomical features of the vertebral column allowed the development of anterior access to the lumbar spine.[15,16]

Anterior lumbar intersomatic fusion brings the benefits of highly reliable fusion, the significant corrective potential for sagittal alignment, and minimally invasive nature. Due to vascular anatomy, the ALIF approach is suitable for L4-L5 and L5-S1 levels, especially L5-S1.[15-18] ALIF performed at higher levels requires more aggressive mobilization of large vessels, significantly increasing the chance of vascular injuries.[19]

Several studies have shown a risk of vascular lesions in this technique.[20-23] Even though they are not the most common complications, they are injuries that can cause serious complications, according to the study by Garg et. Al,[20] 212 patients submitted to the previous lumbar spine approach, 13 (6.1%) had vascular complications. On the other hand, Manunga et. Al,[21] in a more robust study, with 1,178 patients submitted to ALIF at 2,352 levels, reported 17 cases (1.4%) of vascular lesions, 13 of which were venous and four arterial. Of the venous lesions, 11 occurred at access levels L4-L5 and two at L5-S1. Two of the four patients with arterial lesions developed acute limb ischemia requiring an embolectomy. Twenty patients (1.7%) developed venous thromboembolism, two of whom suffered damage to the left iliac vein during the exposure.[21]

Quraishi et. al[22] evaluated the complications related to the previous access for lumbar fusion in 304 patients. The authors divided them into major complications (6.2%) - venous injury requiring repair with suture (n = 14; 4.6%) and arterial injury (n = 5; 1.6% [3 repaired, 2 thrombolyzed]) and minor complications (13.8%) - venous injury treated without repair (n = 5; 1.6%). In another study published by Mobbs et. al,[23] 227 cases of ALIF were performed, with 15 (6.6%) patients presenting with intraoperative vascular injury requiring primary repair with sutures.

Due to the risk of possible vascular complications, prior knowledge of the anatomy of the large abdominal vessels is essential to perform the ALIF. Several studies have been published to study the anatomy of the anterior access to the lumbar spine and reduce the occurrence of injuries in these structures.[24-33]

Tribus and Belanger[33] conducted a study with 35 corpses, in which the average distance found was 33.5 mm between the left and right iliac vessels obtained at the lower limit of the vertebral body of L5. In contrast, another cadaveric study conducted by Ebraheim N. et. Al[31] evaluated the anatomical characteristics of the iliac vessels based on the previous approach to the lumbosacral junction. After analyzing 40 specimens, they measured 55.9 mm for men and 55.3 mm for women.

By analyzing images obtained using nanotomography, Liu L. et al.[25] investigated the anatomy of the large lumbosacral vessels in 62 Chinese patients. The distances between the left and right iliac vessels at the lower limit of L5 and the upper limit of S1 were analyzed. The distances were 31.1 mm ± 13.5 mm and 43.4 mm ± 11.0 mm, respectively. Barrey C. et. al[26] submitted 146 ALIF candidate patients to the vascular window study using a similar imaging resource. The results obtained were 34.5 mm ± 12 mm in L5-S1 and 23 mm ± 0.8 mm in L4-L5. For the L5S1 level, the vascular window was < 25 mm in approximately 25% of the patients.

Using the L5-S1 intervertebral disc as a parameter, when evaluating the measurements between the left iliac vein and the right iliac artery, the present study found an average distance equal to 28 mm (μ = 27.51), varying with a standard deviation of 10 mm (σ = 10.37). In 35.2% of the cases, the interiliac distance was between 20 and 30 mm, with a minimum of <1 mm and a maximum of 49.37 mm (p = 0.000). Lower results compared to the studies mentioned.

In contrast to the study by Ebraheim N. et. Al,[31] females had a higher mean interiliac measurement than males, 29.77 mm and 25.03 mm, respectively (p = 0.001). However, it is necessary to consider the method used for the measurements. Comparative studies used cadaver analysis and angiotomography as a methodology. In the present study, magnetic resonance imaging was used.

Regarding the abdominal aortic bifurcation (AA) level, Inamasu, Kim and Logan[24] evaluated 100 patients using angiotomography. As a result, in 55% of the patients, the bifurcation was found at L4, 23% at L4-L5, and 18% at L5. Combined with the observation of the confluence level of the iliac/cava veins (IVC), 68% in L5, 17% L4, and 14% in L4L5, it was concluded that the bifurcation of the abdominal aorta is generally located 1-2 segments above the confluence of the IVC.

Also using nanotomography, Moussallem C, et al[30] studied 181 patients and showed that aortic bifurcation was found more frequently in the L4-L5 disc space (34.8%). At the same time, CVI was observed in the upper portion of L5 (29.3%). In contrast, Barrey C. et al.[26] evaluated 146 patients and found that the most frequently observed level of aortic bifurcation was L4 (64%), while CVI occurred more frequently in L5 (44%).

In a study with 65 cadavers, Lakchayapakorn and Siriprakarn[27] observed that the bifurcation of the AA was between L3 and L5, most commonly at the level of L4 (63%) and the ICV at the level of the vertebral body of L5 (69%). Pirró N. et. al[28] also used cadavers (n=35) and demonstrated that the ICV was between L4 and S1, mostly at the level of L5 (n = 20). The confluence covered the entire L5-S1 disc in 14% of the cases.

With a similar number of cadavers studied (n=66), Panagouli et al.[32] obtained the lower third of the vertebral body L4 (27.6%) as the average level of aortic bifurcation. The level of aortic bifurcation varied between the lower third of the vertebral body L3 and the lower third of the body L5. The authors also conducted a systematic literature review with 3,537 specimens in 31 studies that met the inclusion criteria. According to the results, the most common mean level of aortic bifurcation was the body of the L4 vertebra (42.2%), while the aortic bifurcation band was described from the upper third of the L3 vertebrae to the upper third of the S1 vertebrae (52.8%).[32]

In a magnetic resonance imaging (MRI) study, Chithriki, Jaibaji, and Steele,[29] evaluated 44 patients and found the bifurcation of AA at the L4 level in 67% of the cases. Data that corroborate the work of Marchi et al[9] in which 108 cases were analyzed based on T2-weighted MRI exams in a supine position. The aortic bifurcation was generally ahead of L4 (52%) and less frequently in L3-L4 (28%) and L4-L5 (18%). The ICV, in general, at the level of L4-L5 (38%) and L5 (37%), and less frequently at L4 (26%).[9]

Following the literature, the present study shows that the bifurcation of AA was most viewed at the L4 level (56.3%), followed by the L4-L5 level (25.6%), differing from the second highest prevalence mentioned in the studies that also used MRI, which demonstrated the level of L3-L4 as second in frequency. In relation to CVI, firstly, the highest frequency was observed at the level of the L4 vertebra (37.2%), in contrast to the findings of Marchi et al,[9] mentioned earlier. Second, L5 (32.2%), and then L4L5 (30.2%), with all of these measurements having a significant p (p = 0.000).

Evaluating the level of confluence by sex, there is a significant relationship ($p<0.05$) of dependence between the location of the confluence of the iliac veins and the gender of the patients. The confluence at the vertebral body level, L4 or L5, mostly occurs in females, while the confluence at the level of the L4-L5 disc was higher in males (31; 51.7%). No statistically significant correlation was found between the two sexes in the other studies presented.

The presence of fatty tissue between the vessel and the disc is related to easier vascular mobilization for access to the desired level. Chung, NS. et al.[34] evaluated 65 patients submitted to ALIF and classified them into three categories according to the difficulty of mobilizing the vessel: type I (without the need for mobilization; left common iliac vein (LCIV) runs laterally for more than two-thirds of the length of the left side of the L5-S1 disc), type II (easy mobilization; LCIV obstructs the space of the L5-S1 disc, but perivascular adipose tissue is present) and type III (potentially difficult mobilization; without perivascular adipose tissue). Type III (n=15; 23.1%) presents potential difficulty in mobilization without the presence of fatty tissue between the iliac vein and disc and is related to a greater chance of vascular injury (33.3%).[34]

Although the oval shape was the most prevalent among the sexes in the analyzed sample, there was no statistical difference between them (p=0.590). On the other hand, the presence of fatty tissue was more prevalent in males (69.8%) than in females (51.9%), with a significant relationship ($p<0.05$). A higher frequency of adipose tissue was also observed when the vein was oval (68.1%), which may be related to a lower probability of vascular injury.

CONCLUSION

Knowledge of the anterior lumbar region's vascular anatomy is essential to perform the ALIF procedure safely. The present study observed that the use of magnetic resonance imaging, an examination requested in the preoperative routine as a planning tool and as a method for evaluating the morphology and relationships between the large prevertebral abdominal vessels, vertebrae, and the lumbar intervertebral discs, is useful to minimize potential complications in previous intersomatic fusion surgery of the lumbar spine in a Brazilian population.

All authors declare no potential conflict of interest related to this article.

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