Research article

Anatomical Study of the Positional Relationships Between Lumbar Arteries and Adjacent Structures in Adult Vietnamese Cadavers

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Abstract

Background/Objectives: The lumbar arteries play a crucial role in the vascularization of the posterior abdominal wall, lumbar spine, and surrounding musculature. Understanding their anatomical relationships with adjacent structures is essential for various surgical procedures, including spinal, vascular, and reconstructive interventions. However, previous studies have primarily focused on non-Vietnamese populations, leaving a gap in region-specific anatomical data. This study aims to investigate the positional relationships of lumbar arteries with the diaphragmatic crura, psoas major muscle, lumbar sympathetic trunk, vertebral borders, and major vascular landmarks in adult Vietnamese cadavers.

Materials and Methods: A descriptive cross-sectional study was conducted on 23 Vietnamese embalmed cadavers, resulting in a total of 46 dissected specimens. Standardized anatomical dissection techniques were used to expose and document the lumbar arteries' origin, course, segmental distribution, and spatial relationships with adjacent anatomical structures. Measurements were taken using digital calipers and micrometers, and data were statistically analyzed using STATA 18.0.

Results: The study revealed distinct anatomical patterns in the relationship between lumbar arteries and surrounding structures. Most L1 and L2 arteries were positioned posterior to the diaphragmatic crura, while L3 and L4 showed minimal association. All lumbar arteries passed posterior to the psoas major muscle and lumbar sympathetic trunk. The segmental distribution analysis indicated that L3 and L4 arteries predominantly originated in the upper third of the vertebrae. The spatial mapping of lumbar arteries in relation to major vascular landmarks demonstrated progressive changes in distance from the superior mesenteric artery, renal arteries, inferior mesenteric artery, aortic bifurcation, and sacral promontory across different lumbar levels. Lateral variations were noted but not statistically significant.

Conclusions: This study provides a detailed anatomical mapping of the lumbar arteries in adult Vietnamese cadavers, offering critical reference data for surgical applications. The findings contribute to reducing vascular injury risks in spinal and vascular surgeries and aid in the design of stent grafts for abdominal aortic aneurysm repair, potentially preventing spinal cord ischemia and post-intervention complications.

Keywords: Lumbar arteries, anatomical variations, vascular landmarks, Vietnamese cadavers, surgical anatomy.

1. INTRODUCTION

The lumbar arteries play a crucial role in the vascularization of the posterior abdominal wall, lumbar spine, and surrounding musculature. Understanding their anatomical relationships with adjacent structures is essential for various surgical procedures, including anterior spinal approaches, vascular surgeries, and reconstructive interventions. Despite the recognized importance of lumbar arteries, there remains a lack of comprehensive anatomical studies detailing their spatial relationships with key structures such as the diaphragmatic crura, lumbar sympathetic trunk, psoas major muscle, and major vascular landmarks in adult Vietnamese cadavers.

Previous studies have primarily focused on the morphology and surgical implications of lumbar arteries in Western and other non-Vietnamese populations. For example, Arslan et al. (2011) conducted a cadaveric study highlighting the morphological variations of lumbar arteries and their potential impact on spinal surgeries[1]. Similarly, Bissell et al. (2015) explored the clinical applications of lumbar artery perforators, emphasizing their utility in reconstructive procedure [2]. However, these studies did not comprehensively analyze the anatomical consistency, segmental distribution, and laterality-based variations of lumbar arteries.

Given the anatomical and clinical significance of lumbar arteries, this study seeks to address the gaps in the existing literature by providing a detailed morphometric analysis of the positional relationships between lumbar arteries and adjacent anatomical structures in Vietnamese cadavers.

This study aims to:

1. Describe the positional relationships of lumbar arteries with the diaphragmatic crura, psoas major muscle, and lumbar sympathetic trunk.

2. Assess the anatomical variation in the segmental distribution of lumbar arteries across vertebral levels.

3. Quantify the distances between lumbar artery origins and major vascular landmarks, highlighting laterality-based differences.

2. STUDY SUBJECTS AND METHODS
2.1. Study Subjects

This study was conducted on 23 adult Vietnamese cadavers, with each cadaver dissected bilaterally, resulting in a total of 46 specimens. The cadavers consisted of 28 male samples (60.9%) and 18 female samples (39.1%), with an age range of 25 to 88 years and a mean age of approximately 67.8 years. The cadavers were preserved for 2 to 9 years, with the majority having a preservation period of 7 to 9 years, ensuring clear visualization of vascular structures for anatomical study.

The cadavers were required to meet specific inclusion criteria, properly embalmed to preservation standards, and having intact lumbar regions. Cadavers were excluded if they exhibited lumbar spine deformities, injuries to the lumbar region, damage to adjacent anatomical landmarks such as the diaphragmatic crura, psoas major muscle, and lumbar sympathetic trunk, desiccation or decomposition of skin, muscle, or vascular structures in the lumbar region, or if the abdominal aorta was damaged, adhered to lumbar vertebrae due to malignancy or intra-abdominal infections, or previously dissected.

The study was conducted at the Department of Anatomy, Faculty of Medicine, University of Medicine and

Pharmacy at Ho Chi Minh City, and the Department of Anatomy, Faculty of Basic Sciences, Pham Ngoc Thach University of Medicine, from April to December 2024.

2.2. Research Methods

This study was designed as a descriptive cross-sectional study conducted on embalmed cadavers of Vietnamese adults. Anatomical variations in the lumbar arterial structures were noted and documented, including the absence of L1 in 2 specimens, L2 in 1 specimen, L3 in 1 specimen, and L4 in 3 specimens.

A detailed dissection was performed using a standardized protocol to expose the lumbar arteries and their branches. Measurements, including the origin, course, and dimensions of the arteries, were recorded using precision instruments such as digital calipers and micrometers. The anatomical relationships of each artery with adjacent structures, such as the psoas major muscle, lumbar sympathetic trunk, and vertebral borders, were meticulously documented.

In the analysis of positional relationships, numerical values were assigned to indicate the relative locations of the lumbar arteries concerning defined anatomical reference points. Negative values represent positions inferior to the reference landmark, whereas positive values indicate positions superior to the reference landmark.

2.3. Data Processing

All collected data were encoded and entered into Microsoft Excel for initial management and verification. Statistical analysis was conducted using STATA 18.0 to ensure precise measurements. Descriptive statistics were applied to summarize qualitative variables, including frequency and percentage distributions. Quantitative variables following a normal distribution were expressed as mean and standard deviation.

2.4. Ethical Considerations

This study was conducted following ethical principles and was approved by the Ethics Committee for Biomedical Research of Can Tho University of Medicine and Pharmacy under the approval number 23.031. NCS/PCT-HĐĐĐ, dated December 25, 2023 . Cadaveric specimens used in this study were obtained with the consent of the Department of Anatomy, Faculty of Medicine, University of Medicine and Pharmacy at Ho Chi Minh City, and the Department of Anatomy, Faculty of Basic Sciences, Pham Ngoc Thach University of Medicine.

3. RESULT

3.1. Positional Association of Lumbar Arteries (L1-L4) Relative to the Diaphragmatic Crura

Table 1: Positional Relationship of Lumbar Arteries (L1-L4) to the Diaphragmatic Crura

Position Relative to the Diaphragmatic Crura	Lumbar Arteries L1		Lumbar Arteries L2		Lumbar Arteries L3		Lumbar Arteries L4	
	Right	Left	Right	Left	Right	Left	Right	Left
No relation	0	0	1	6	20	20	23	20
Completely posterior	21	19	20	15	1	0	0	0
Posterior to the posterior half	2	2	0	1	0	0	0	0
Posterior to the anterior half	0	0	2	0	1	0	0	0
Completely anterior	0	0	0	0	1	2	0	0
Total	23	21	23	22	23	22	23	20

The relationship between the lumbar arteries (L1-L4) and the diaphragmatic crura shows distinct patterns on both the right and left sides. For L1, the majority of arteries pass completely behind the crura (91.30% on the right and 90.48% on the left), while a small proportion (8.70% on the right and 9.52% on the left) pass behind the posterior half. Similarly, most L2 arteries also pass completely behind the crura (86.96% on the right and 68.18% on the left), though a small percentage are unrelated (4.35% on the right and 27.27% on the left). In contrast, L3 and L4 arteries show a different pattern, with most having no relationship with the crura (86.96% for L3 and 100% for L4). Only a small number of L3 arteries pass in front or behind the anterior half.

3.2. Anatomical Consistency in the Course of Lumbar Arteries Relative to the Lumbar Sympathetic Trunk and Psoas Major Muscle

Table 2: Anatomical Relationship of Lumbar Arteries with the Lumbar Sympathetic Trunk and Psoas Major Muscle

Lumbar Arteries	Lumbar sympathetic trunk		Psoas major muscle	
	Before	Behind	Before	Behind
L1 (n=44)	0%	100%	0%	100%
L2 (n=45)	0%	100%	0%	100%
L3 (n=45)	0%	100%	0%	100%
L4 (n=43)	0%	100%	0%	100%

The data indicate a consistent anatomical relationship between the lumbar arteries, the lumbar sympathetic trunk, and the psoas major muscle. All lumbar arteries (L1-L4) pass behind both the lumbar sympathetic trunk and the psoas major muscle, with 100% of cases showing a posterior course.

3.3. Anatomical Variation in the Distance of Lumbar Arteries from Vertebral Borders

Table 3: Distance of Lumbar Arteries from the Superior and Inferior Borders of Vertebrae

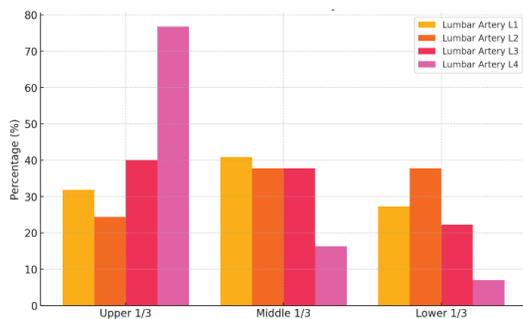| Lumbar Arteries	Distance to the Superior Border of the Vertebra		Distance to the Inferior Border of the Vertebra	
	Mean	Standard Deviation	Mean	Standard Deviation
L1 (n=44)	-11.98	7.98	8.01	9.01
L2 (n=45)	-14.93	9.89	10.62	10.99
L3 (n=45)	-12.06	8.22	14.84	8.60
L4 (n=43)	-3.33	7.73	20.22	9.33

The data show variations in the distance of the lumbar arteries (L1-L4) from the upper and lower borders of the corresponding vertebrae. On average, all lumbar arteries originate below the upper border of their respective vertebrae, with L2 having the greatest negative mean distance (-14.93 mm) and L4 the smallest (-3.33 mm). The distance to the lower border increases progressively from L1 to L4, with L4 having the highest mean distance (20.22 mm). Standard deviations indicate notable variability, particularly for L2 and L3.

Table 4: Laterality-Based Distance of Lumbar Arteries from the Superior and Inferior Borders of Vertebrae

Lumbar Arteries		Distance to the Superior Border of the Vertebra		Distance to the Inferior Border of the Vertebra	
		Mean	Standard Deviation	Mean	Standard Deviation
L1 (n=44)	Right	-13.27	7.81	6.94	8.65
	Left	-10.55	8.12	9.18	9.46
L2 (n=45)	Right	-15.35	9.74	9.94	11.48
	Left	-14.49	10.26	11.35	10.68
L3 (n=45)	Right	-12.75	7.88	13.57	8.21
	Left	-11.35	8.69	15.17	8.97
L4 (n=43)	Right	-3.63	8.70	21.54	10.27
	Left	-2.99	6.66	21.70	8.11

Notably, there are minor differences between the right and left arteries at each level, with the left-side arteries generally originating slightly higher and extending slightly further toward the lower vertebral border than their right-side counterparts. The standard deviations indicate substantial variability in these measurements, particularly at L2 and L3.
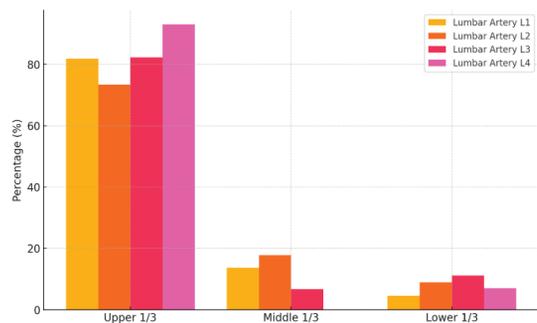
3.4. Segmental Distribution of Lumbar Artery Origins Across Vertebral Thirds

and an equal distribution between the middle and lower thirds for L2 (37.78%). In contrast, L3 shows a higher concentration of origins in the upper third (40.00%), with fewer origins in the middle (37.78%) and lower thirds (22.22%). L4 demonstrates a distinct pattern, with the vast majority of origins (76.74%) located in the upper third, while the middle (16.28%) and lower thirds (6.98%) are significantly less frequent.

Figure 1: Distribution of Lumbar Artery Origins Across Vertebral Thirds

Figure 2: Distribution of Lumbar Artery to the Parasagittal Plane of the Vertebra

The bar chart illustrates the distribution of lumbar arteries (L1-L4) based on their origin positions relative to the vertebrae, categorized into upper, middle, and lower thirds. L1 and L2 show a more even distribution, with the middle third being the most common origin for L1 (40.91%)

The bar chart illustrates the distribution of lumbar arteries (L1-L4) in relation to the parasagittal plane of the vertebra, categorized into upper, middle, and lower thirds. The majority of lumbar arteries across all levels originate in the upper third. L4 shows the highest proportion to the parasagittal plane

of the vertebra in the upper third (93.02%), followed by L3 (82.22%), L1 (81.82%), and L2 (73.33%). The middle third accounts for a smaller percentage of arterial, with L2 having the highest proportion in this region (17.78%), followed by L1 (13.64%) and L3 (6.67%). Interestingly, L4 has no arteries originating in the middle third. The lower third demonstrates the least contribution to arterial, with percentages ranging from 4.55% for L1 to 11.11% for L3 and 6.98% for L4.

3.5. Spatial Relationships Between Lumbar Arteries and Major Vascular Landmarks

Table 5: Mean Distance from Major Arterial Landmarks to Lumbar Artery Origins (L1-L4) with Right and Left Variability

Distance to origin of		Lumbar Arteries L1 (n=44)		Lumbar Arteries L2 (n=45)		Lumbar Arteries L3 (n=45)		Lumbar Arteries L4 (n=43)	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
Superior mesenteric artery	Right	-12.27	14.59	-37.80	13.01	-65.27	14.20	-90.72	16.45
	Left	-10.33	11.35	-37.24	13.44	-64.96	12.80	-95.13	13.33
Renal artery	Right	0.93	13.52	-28.64	12.42	-54.05	12.91	-79.77	13.25
	Left	4.07	11.28	-28.00	13.96	-51.44	8.71	-79.09	11.82
Inferior mesenteric artery	Right	57.94	16.80	28.37	13.81	1.11	10.10	-25.28	9.93
	Left	57.77	13.51	29.24	15.08	1.50	11.03	-26.77	10.01
Aortic bifurcation	Right	98.83	18.14	67.44	16.23	41.07	10.87	15.57	11.84
	Left	97.63	17.05	67.86	18.36	42.01	12.30	17.81	11.58
Sacral promontory	Right	141.33	18.04	109.28	17.51	84.67	12.08	59.56	9.77
	Left	141.27	18.95	111.86	19.42	86.62	14.93	64.39	13.09

The data illustrate the distances to the superior mesenteric artery (SMA) and renal arteries decrease progressively from L1 to L4 on both sides. L1 is closest to the SMA, with a slightly greater distance on the right side (-12.27 mm) compared to the left (-10.33 mm), while L4 is farthest, with -90.72 mm (right) and -95.13 mm (left). Similar trends are observed with the renal arteries, where L1 is slightly above the artery on both sides (0.93 mm on the right, 4.07 mm on the left), while L4 is far below (-79.77 mm on the right and -79.09 mm on the left). For the inferior mesenteric artery (IMA) and the aortic bifurcation, the distances decrease consistently from L1 to L4. L1 is farthest from the IMA (57.94 mm right, 57.77 mm left) and the aortic bifurcation (98.83 mm right, 97.63 mm left), while L4 is closest to both landmarks, with aortic bifurcation distances of 15.57 mm (right) and 17.81 mm (left). The distances to the sacral promontory also follow this trend, with L1 farthest (141.33 mm right, 141.27 mm left) and L4 closest (59.56 mm right, 64.39 mm left).

4. DISCUSSION

4.1. Positional Association of Lumbar Arteries (L1-L4) Relative to the Diaphragmatic Crura

The present study demonstrates distinct anatomical relationships between the lumbar

arteries (L1–L4) and the diaphragmatic crura, revealing significant variation across different lumbar levels. The findings indicate that the upper lumbar arteries (L1 and L2) predominantly pass completely posterior to the crura, while the lower lumbar arteries (L3 and L4) exhibit a higher frequency of no relationship with the crura.

In summary, our findings provide a detailed anatomical mapping of the lumbar arteries in relation to the diaphragmatic crura, filling an existing knowledge gap. The results hold potential clinical significance, particularly for surgical approaches involving the lumbar arteries, such as anterior spinal procedures and vascular reconstructions. Future studies employing imaging modalities such as computed tomographic angiography, as used by Sommeling et al. (2017), could enhance the understanding of this anatomical relationship [3].

4.2. Anatomical Consistency in the Course of Lumbar Arteries Relative to the Lumbar Sympathetic Trunk and Psoas Major Muscle

The present study demonstrates a remarkable anatomical consistency in the course of the lumbar arteries (L1–L4) as they uniformly pass posterior to both the lumbar sympathetic trunk and the psoas major muscle. This finding suggests a fundamental structural organization of the lumbar vascular and nervous systems, potentially influencing surgical interventions in this region.

Previous anatomical studies have documented variations in the course of the lumbar arteries, though with less emphasis on their relationship to the lumbar sympathetic trunk. Arslan et al. (2011) reported that the lumbar arteries consistently arise posterior to the psoas major muscle, aligning with the

current findings [1]. Similarly, the current results align partially with the work of Kiil et al. (2009), who observed that the lumbar arteries follow a posterior-lateral trajectory relative to the psoas major and quadratus lumborum muscles [4].

This consistency has critical implications for surgical procedures involving anterior lumbar spine approaches, where injury to the sympathetic trunk or psoas major muscle may be minimized by accounting for the predictable posterior course of the lumbar arteries.

4.3. Anatomical Variation in the Distance of Lumbar Arteries from Vertebral Borders

The present study reveals a consistent trend in the anatomical positioning of lumbar arteries relative to vertebral borders, demonstrating that all lumbar arteries originate below the superior border of their respective vertebrae, with increasing distance from the inferior border from L1 to L4. This variation aligns with previous studies investigating lumbar artery morphology but provides new insights into their positional trends across vertebral levels.

Yu et al. (2015) reported that variations in lumbar pedicle dimensions influence the anatomical relationship between vascular structures and vertebral landmarks . Specifically, their findings highlight that larger pedicle widths at lower lumbar levels may create a more defined anatomical corridor for arteries, possibly contributing to the increased inferior border distance observed in L3 and L4 arteries in the present study [5].

A comparison with Pinho et al. (2022) , who examined the vascular anatomy of the lower lumbar arteries, reveals a similar trend where the fourth lumbar artery (L4)

is positioned closer to the superior border of the vertebra than the third lumbar artery (L3). This aligns with our findings that show a decreasing distance to the superior border from L1 to L4 [6].

Similarly, Hung and Son study (2024) reveals both similarities and key differences. Their study reported that the distance from the lumbar artery to the superior border was greater than the distance to the inferior border at L1 and L2, whereas the opposite trend was observed at L3 and L4. This aligns with our findings that L3 and L4 arteries are positioned relatively higher on the vertebral body, while L1, L2 arteries are positioned closer to the inferior border [7].

The minor differences in right- and left-sided arteries, with left-sided arteries originating slightly higher and extending further, are consistent with prior research on vascular asymmetry. Morphometric studies such as those by Pan et al. (2021) have demonstrated that even small variations in vertebral morphology can affect the relative positioning of vascular structures [8].

4.4. Segmental Distribution of Lumbar Artery: Variability Across Vertebral Thirds

The present study provides a detailed analysis of the segmental distribution of lumbar artery origins, demonstrating significant variability across different vertebral levels. The findings reveal that while L1 and L2 arteries exhibit a relatively balanced distribution, L3 and L4 arteries favor the upper third of the vertebral body. These variations may have implications for surgical approaches involving the lumbar spine, particularly in procedures such as lateral interbody fusion or anterior lumbar interventions.

Our findings align partially with previous studies such as Zhou et al. (2000), Willburger et al. (2005), which documented vertebral morphology and its impact on vascular structures. The observed concentration of L3 and L4 arteries in the upper third suggests a potential anatomical adaptation that allows for stable blood supply distribution [9] [10].

Similarly, Liu et al. (2019) investigated lumbar artery distribution in relation to the extrapedicular approach, reporting that the majority of L3 and L4 lumbar arteries originate from the upper or middle third, with fewer arteries emerging from the lower third. This trend is consistent with our study, where L3 and L4 exhibit a preference for the upper third [11].

A comparison with Amuti et al. (2021) , who conducted a cadaveric and CT-based study, reveals a similar tendency for lumbar arteries to originate from the upper third of the vertebral body, particularly for L1–L3. However, their study reported that the fourth lumbar artery (L4) predominantly originates at the lower third, in contrast to our findings where L4 is primarily located in the upper third (76.74%). This discrepancy may stem from population-based anatomical variations, as their study focused on a Kenyan sample, whereas ours is based on Vietnamese cadavers [12].

Regarding the relationship with the parasagittal plane, our study found that most lumbar arteries originate in the upper third, with L4 exhibiting the highest proportion (93.02%). This trend aligns with Amuti et al. (2021), who also observed that L1–L3 arteries are mostly positioned in the upper third. However, their study noted that L4 arteries were evenly distributed across the vertebral body, a variation likely attributable to differences in sample demographics and methodologies [12].

4.5. Spatial Relationships Between Lumbar Arteries and Major Vascular Landmarks: Mean Distances and Laterality Variations

The present study provides detailed measurements of the distances between lumbar artery origins (L1–L4) and key vascular landmarks, revealing a consistent trend in arterial positioning along the lumbar vertebral column. The data indicate that as the lumbar artery levels descend, their distances from the superior mesenteric artery (SMA) and renal arteries progressively increase, while their proximity to the inferior mesenteric artery (IMA), aortic bifurcation, and sacral promontory decreases. This systematic shift highlights the predictable nature of lumbar artery positioning, which has significant implications for vascular and spinal surgeries.

These findings align with those of Seker et al. (2005), who reported a similar descending pattern of lumbar arteries in fetal specimens, though variations in developmental anatomy may account for slight discrepancies [13].

Prakash et al. (2011) observed that the SMA originates at L1 in approximately 76% of cases, and the IMA at L3 in 68% of cases. The current study reinforces these findings, demonstrating that the lumbar arteries progressively shift away from the SMA and closer to the IMA as they descend the vertebral column. This trend is crucial in surgical procedures involving the aorta and its branches, where precise anatomical knowledge is required to minimize vascular injury [14].

Furthermore, Khamanarong et al. (2009) conducted a cadaveric study on the aortic bifurcation, finding that in 70.1% of cases, it occurs at the level of L4. The present study corroborates this, demonstrating that L4 arteries are closest to the aortic bifurcation (16.61 mm on average), supporting the idea that L4 is a key transitional level for major vascular structures. This is especially relevant for anterior lumbar spine approaches, where aortic bifurcation proximity must be carefully managed to avoid vascular complications [15].

Additionally, the study highlights lateral variability in artery positioning. Although minor, differences between right and left lumbar arteries in relation to the SMA, renal arteries, and aortic bifurcation are evident. Zhou et al. (2000) previously reported slight asymmetries in lumbar vascular positioning, which they attributed to vertebral and soft tissue variations. These variations may influence procedural planning for lateral lumbar interbody fusion and other retroperitoneal approaches [9].

5. CONCLUSION

The study confirms that the lumbar arteries exhibit consistent posterior positioning relative to the lumbar sympathetic trunk and psoas major muscle, which is crucial for minimizing vascular complications in retroperitoneal and spinal surgeries. The segmental distribution analysis reveals that L3 and L4 arteries predominantly originate from the upper third of the vertebrae, a pattern that should be considered in surgical planning. Furthermore, the study quantifies the distances between lumbar artery origins and key vascular landmarks, emphasizing the importance of laterality-based variations in clinical applications.

The findings of this study have significant clinical implications, as precise knowledge of lumbar artery positioning can help minimize vascular injuries during spinal surgeries and retroperitoneal procedures. Additionally, this study provides valuable reference data for the design of stent grafts

in abdominal aortic aneurysm repair, aiding in the prevention of spinal cord ischemia and post-intervention complications. Future research incorporating high-resolution imaging and larger sample sizes will further refine our understanding of lumbar artery variations and their clinical relevance.

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