

Neurovascular structures adjacent to the lumbar intervertebral discs: an anatomical study of their morphometry and relationships

Laboratory investigation

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Object. Although infrequent, injury to adjacent neurovascular structures during posterior approaches to lumbar intervertebral discs can occur. A detailed anatomical knowledge of relationships may decrease surgical complications.

Methods. Ten formalin-fixed male cadavers were used for this study. Posterior exposure of the lumbar thecal sac, nerve roots, pedicles, and intervertebral discs was performed. To identify retroperitoneal structures at risk during posterior lumbar discectomy, a transabdominal retroperitoneal approach was performed, and observations were made. The distances between the posterior and anterior edges of the lumbar intervertebral discs were measured, and the relationships between the disc space, pedicle, and nerve root were evaluated.

Results. For right and left sides, the mean distance from the inferior pedicle to the disc gradually increased from L1–2 to L4–5 (range 2.7–3.8 mm and 2.9–4.5 mm for right and left side, respectively) and slightly decreased at L5–S1. For right and left sides, the mean distance from the superior pedicle to the disc was more or less the same for all disc spaces (range 9.3–11.6 mm and 8.2–10.5 mm for right and left, respectively). The right and left mean disc-to-root distance for the L3–4 to L5–S1 levels ranged from 8.3 to 22.1 mm and 7.2 to 20.6 mm, respectively. The root origin gradually increased from L–1 to L–5. The right and left nerve root-to-disc angle gradually decreased from L–3 to S–1 (range 105°–110.6° and 99°–108°). Disc heights gradually increased from L1–2 to L5–S1 (range 11.3–17.4 mm). The mean distance between the anterior and posterior borders of the intervertebral discs ranged from 39 to 46 mm for all levels.

Conclusions. To avoid neighboring neurovascular structures, instrumentation should not be inserted into the lumbar disc spaces more than 3 cm from their posterior edge. Accurate anatomical knowledge of the relationships of intervertebral discs to nerve roots is needed for spine surgeons. (DOI: 10.3171/2010.11.SPINE09149)

KEY WORDS • lumbar discectomy • complications • vascular perforation • intervertebral disc • anatomy

LAMINECTOMY for decompression of lumbar disc herniation is one of the most common neurosurgical procedures performed. Injury to nerve roots and perforation into the anterior annulus fibrosis and anterior longitudinal ligament with major vascular injury are rare. However, complications may occur due to the proximity of the intervertebral disc to adjacent neurovascular structures. These major vessels include the abdominal aorta, the inferior vena cava, and the common iliac arteries and veins, situated directly anterior to the lumbar spine.^{2,3,9,13,20,26} These vessels, especially the

veins, are vulnerable to injury during lumbar discectomy.^{1,6,7,10–12,18,19,23,24}

The incidence of life-threatening vascular injury with such procedures ranges from 0.01% to 0.05%.⁶ Considerable variation has been found with anatomical and radiological studies of the abdominal aorta, inferior vena cava, and their branches.^{4,5,8,25,27} In this study, we examine the neurovascular structures most likely to be injured in lumbar discectomies at different levels and angles and also their relationships to the lumbar discs. The aim of the present cadaveric study was to elucidate the 3D orientation and adjacent neurovascular relationships of the lumbar intervertebral discs.

Abbreviations used in this paper: DH = disc height; DIPD = disc–inferior pedicle distance; DRA = disc–nerve root angle; DROD = disc–nerve root origin distance; DSPD = disc–superior pedicle distance; RP = reference point.

This article contains some figures that are displayed in color online but in black and white in the print edition.

Methods

Ten male formalin-fixed cadavers (21–72 years of age at death) were used for the study. Specimens with gross deformities, such as scoliosis, kyphosis, or collapsed or herniated intervertebral discs were excluded from the study. With the cadavers in the prone position, soft tissues were removed from the underlying laminae of the lumbar vertebrae. Laminae were then removed using bone rongeurs, exposing the thecal sac, nerve roots, pedicles, and intervertebral discs. Cadavers were then placed in the supine position, and a transabdominal approach to the spine was performed. Relationships between regional neurovascular structures (including the aorta, inferior vena cava, left common iliac vein and artery, lumbar arteries, median sacral artery, superior hypogastric plexus, and sympathetic chain) were observed. Each intervertebral disc was separated from the vertebrae by transecting the disc from the edge of the adjacent vertebrae. Disc sizes were measured from a reference point from the anterior margin of the disc in various directions. Relationships between the intervertebral discs and the adjacent pedicles and corresponding nerve roots were evaluated. All measurements were performed bilaterally and made with a digital caliper (0.01 mm of precision) and a goniometer (1° of precision). Statistical analysis was performed using Wilcoxon signed rank tests, with significance set at $p < 0.05$.

Specifically, the following measurements were made: 1) the distance between the inferior edge of the intervertebral disc and the superior border of the inferior pedicle (DIPD); 2) the distance between the superior edge of the intervertebral disc and the inferior border of the superior pedicle (DSPD); 3) the distance between the inferior edge of the intervertebral disc and the superior border of the origin of the corresponding spinal nerve root (DROD); 4) the angle between the intervertebral disc and the lateral edge of the corresponding nerve root (DRA); 5) the disc height in the anterior midline (DH); and 6) the distances between a reference point (RP) and points A, B, C, and D (Figs. 1 and 2). The RP was defined as the intersection between the posterior edge of the intervertebral disc and a line from the medial border of the facet through which instrumentation is placed into the disc space at the posterior edge of the intervertebral disc for disc decompression. Point A is the line of an instrument inserted into the disc space at an angle of 0° to the sagittal plane, as would be used to remove the intervertebral disc; Point B, at an angle of 20°; Point C, at an angle of 40°; and Point D, at an angle of 60°.

Results

The findings of all measurements are shown in Tables 1–5.

Disc–Inferior Pedicle Distance and Disc–Superior Pedicle Distance

The DIPD gradually increased from L1–2 to L4–5, while there was some decrease at the L5–S1 intervertebral discs. The nearest discs level to corresponding infe-

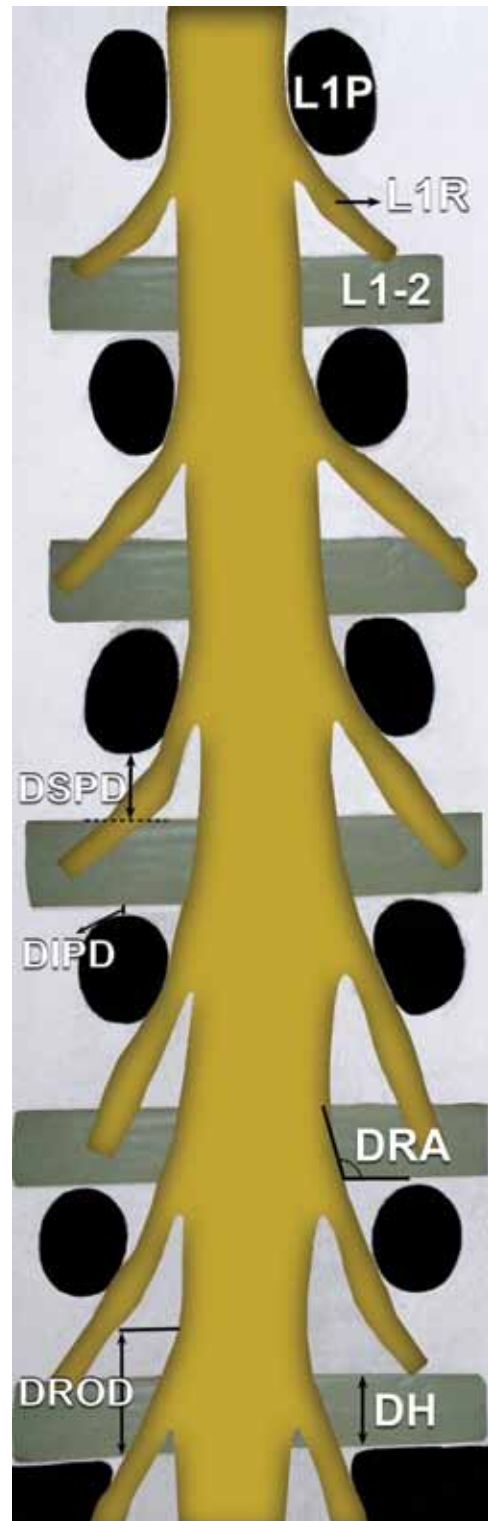


FIG. 1. Drawing showing the thecal sac, lumbar nerve roots, pedicle, and intervertebral disc and diagrams indicating the measurements made in the present study. L1P = L-1 pedicle; L1R = L-1 nerve root; L1-2 = L1–2 disc level.

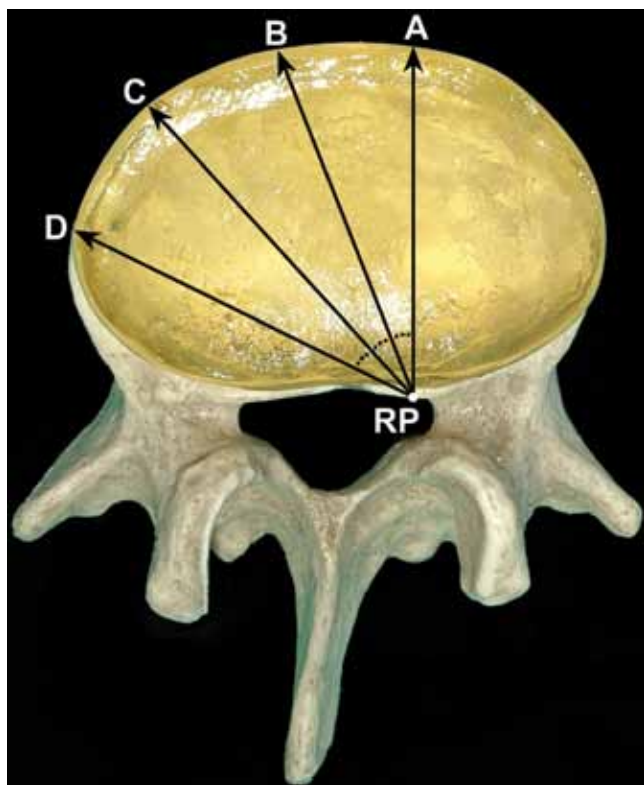


Fig. 2. Illustration of measurements between the anterior and posterior borders of the intervertebral disc. A = 0° angle to the sagittal plane; B = 20°; C = 40°; D = 60°.

rior pedicles was L5–S1 (mean 2.6 mm), and the farthest disc was L4–5 (mean 4.5 mm). The DSPD on both sides was approximately the same for all disc spaces (Table 1). There were no significant differences for DIPD and DSPD between right and left sides of the vertebrae ($p >$

0.05), except for DIPD at L2–3 and L4–5, and for DSPD at L4–5 ($p < 0.05$; Table 4).

Disc–Root Origin Distance

In all specimens, the L-1 and L-2 roots originated below the T12–L1 and L1–2 disc levels, respectively; the L-3 nerve root originated just below L2–3. Therefore, the L-1, L-2, and L-3 roots corresponded to any disc level. The L-4 nerve root corresponded to the L3–4 disc, L-5 to the L4–5 disc, and S-1 to the L5–S1 disc. The L-4 root usually originated at the level of the L3–4 disc; and the L-5 and S-1 roots always originated above the inferior edges of the L4–5 and L5–S1 disc levels, respectively (Figs. 1 and 3–5). The right and left mean distances between the L-4 root and L3–4 disc level were 8.3 and 7.2 mm; for the L-5 root and L4–5 disc level, 17.0 and 15.6 mm; and for the S-1 root and L5–S1 disc, 22.1 and 20.6 mm, respectively. The closest disc level to the corresponding nerve root was L3–4 (mean distance 8.3 mm for the right side and 7.2 mm for the left) and the farthest disc was L5–S1 (mean distance 22.1 mm for the right side and 20.6 mm for the left) (Table 1). There were significant differences in the DROD between right and left sides ($p < 0.05$; Table 4).

Disc–Nerve Root Angle

For the L1–2 and L2–3 levels, the DRA did not exist, because the L-1, L-2, and L-3 nerve roots originated below the corresponding disc level. The mean right and left angles between the L-4 root and L3–4 level were 110.6° and 108.8°; between the L-5 root and L4–5 disc, 106.8° and 100°; and between the S-1 root and L5–S1 disc, 105° and 99.8°, respectively. It gradually decreased from the L3–4 to the L5–S1 level. The greatest mean value was the angle between the L3–4 level and the L-4 root (110°), and the lowest was the angle between L5–S1 and S-1 (99°)

TABLE 1: Measurements between lumbar disc space and surrounding structures (in mm)*

Level & Side	Mean DIPD (range)	Mean DSPD (range)	Mean DROD (range)†
L1–2			
right	2.7 ± 0.6 (1.92–3.2)	11.6 ± 0.9 (10.8–13.0)	
left	2.9 ± 0.8 (1.7–3.8)	10.5 ± 1.2 (8.6–11.9)	
L2–3			
right	3.0 ± 0.4 (1.9–3.29)	10.7 ± 1.2 (8.9–11.8)	
left	4.1 ± 1.0 (2.8–5.3)	9.3 ± 0.9 (7.9–10.4)	
L3–4			
right	3.0 ± 0.6 (2.2–3.4)	10.5 ± 1.0 (9.0–11.7)	8.3 ± 0.4 (7.5–8.7)
left	3.6 ± 0.7 (2.8–4.5)	10.2 ± 0.7 (9.5–11.3)	7.2 ± 0.4 (6.6–7.9)
L4–5			
right	3.8 ± 1.0 (2.3–4.9)	11.1 ± 0.2 (11.0–11.5)	17.0 ± 1.0 (15.5–18.4)
left	4.5 ± 0.8 (3.4–5.3)	9.3 ± 1.0 (8.2–10.7)	15.6 ± 1.4 (13.7–17.3)
L5–S1			
right	2.9 ± 1.1 (2.3–4.6)	9.3 ± 2.5 (6.7–12.6)	22.1 ± 0.9 (21.06–23.5)
left	2.6 ± 1.1 (2.3–4.6)	8.2 ± 1.1 (7.0–9.7)	20.6 ± 0.4 (20.3–21.4)

* Mean values are presented ± SDs.

† For DROD measurements at the L3–4, L4–5, and L5–S1 levels, respectively, the L-4, L-5, and S-1 nerve roots were used.

TABLE 2: Lumbar disc heights and angles between discs and corresponding spinal nerve roots

Disc & Side	Mean DH in mm (range)	Mean DRA in ° (range)*
L1–2	11.3 ± 0.8 (10.2–12.5)	
L2–3	11.7 ± 0.7 (10.7–12.7)	
L3–4	14.5 ± 1.1 (12.6–15.2)	
right		110.6 ± 1.7 (108.5–112.5)
left		108.8 ± 2.1 (108.5–112.5)
L4–5	14.7 ± 1.0 (13.1–16.0)	
right		106.8 ± 2.3 (103–109)
left		100 ± 1.8 (97.5–102)
L5–S1	17.4 ± 0.9 (16.4–18.9)	
right		105 ± 2.3 (102.5–108)
left		99.8 ± 2.5 (97–103)

* No disc–nerve root angles are given for the L1–2 and L2–3 levels because the L-1, L-2, and L-3 roots originated below corresponding disc levels.

(Figs. 1, 3, 4; Table 2). There was a statistically significant difference between the mean values of the right and left sides ($p < 0.05$).

Disc Sizes

The DH gradually increased from the L1–2 to the L5–S1 level (Table 2). The mean values for RP–A, RP–B, RP–C, and RP–D were smallest (36.4, 40.3, 44.1, and 39.2 mm, respectively) at the L1–2 level and greatest (41.3, 45.6, 49.4, and 44.9 mm) at the L4–5 level. The mean values gradually increased from L1–2 to L4–5 depending on the diameter of the vertebral bodies, but some decreased at L5–S1. In brief, for the L1–2 level, the mean values for RP–A, RP–B, RP–C, and RP–D were 36, 40, 43, and 39 mm; for the L2–3 level, 36, 40, 43, and 38 mm; for the L3–4 level, 38, 42, 45, and 40 mm; for the L4–5 level, 41, 45, 49, and 44 mm; and for the L5–S1 level, 38, 43, 47, and 42 mm. The RP–C distance was the greatest for each level; the RP–A distance was the least (Fig. 2;

Table 3). The distance between the RP and points A–D from L1–2 to L5–S1 did not differ significantly between the right and left sides ($p > 0.05$; Table 4).

Anatomical Relationships

The vascular anatomy of the anterior aspect of the lumbar vertebral bodies was variable from one cadaver to another. In general, the aorta was located in the midline, and the inferior vena cava was situated to the right of the aorta. The aortic bifurcation was usually positioned immediately anterior to the body of the L-4 vertebra and less frequently at the L3–4 and L4–5 disc spaces. The origin of the common iliac vein was usually found anterior to the L-5 vertebral body and less commonly at the L4–5 disc space or at the L5–S1 level. The left common iliac vein usually coursed lateral to the L5–S1 level but in a small number of specimens coursed directly over the disc space. At L1–2 and L2–3, the aorta and the inferior vena cava lay adjacent with no overlap. This was the predominant location found in all specimens. At the L3–4 level, 2 cadavers had a high aortic bifurcation, with the left common iliac artery positioned anterior to the disc space and the right common iliac artery partly overlapping the inferior vena cava. At the L4–5 level, the ilioaval junction lay next to the superior border of the L4–5 disc in 2 cadavers (high ilioaval junction). In these specimens, the ilioaval junction, the right common iliac vein, the left common iliac vein, and the left common iliac artery were located anterior to the L4–5 disc. The left common iliac vein crossed the midline at the L4–5 disc. In the remaining cadavers (8 cadavers), the major vessels had normal configuration. The inferior vena cava was positioned to the right of midline, and the left common iliac artery was located to the left of the midline. The right common iliac artery partly overlapped the inferior vena cava. At the L5–S1 level, in 8 of 10 cadavers, the right common iliac vein crossed the L5–S1 disc to the right of midline and the right common iliac artery overlapped the right common iliac vein; the left common iliac vein and artery traveled adjacent with no overlap to the left of midline. In 2 cadavers, the left common iliac vein coursed medial to the left common

TABLE 3: Distances between the RP and different points on the anterior edge of the intervertebral disc (in mm)

Distance & Side	Mean (range)				
	L1–2	L2–3	L3–4	L4–5	L5–S1
RP–A (0°)					
right	36.6 ± 2.0 (34.3–38.3)	37.3 ± 1.7 (34.4–38.7)	39.8 ± 2.6 (36.1–43.0)	41.4 ± 2.7 (38.6–45.5)	40.5 ± 3.3 (38.0–46.3)
left	36.3 ± 1.2 (35.0–38.2)	36.1 ± 2.5 (32.5–38.3)	38.9 ± 2.9 (36.5–43.8)	41.2 ± 1.6 (39.0–42.7)	39.0 ± 2.5 (37.4–43.5)
RP–B (20°)					
right	40.6 ± 0.7 (39.7–41.6)	40.4 ± 1.3 (38.4–41.8)	42.9 ± 3.0 (39.4–45.8)	46.3 ± 2.3 (43.7–48.7)	43.8 ± 3.9 (41.3–50.7)
left	40.0 ± 0.7 (39.4–41.0)	40.0 ± 1.4 (38.1–41.7)	42.1 ± 3.1 (39.4–46.3)	45.0 ± 2.3 (42.5–48.6)	43.0 ± 2.7 (40.9–47.8)
RP–C (40°)					
right	44.5 ± 1.8 (42.2–47.1)	43.5 ± 1.1 (42.3–44.8)	46.3 ± 3.4 (41.4–49.9)	50.0 ± 1.3 (48.2–51.3)	47.0 ± 3.8 (44.6–46.4)
left	43.7 ± 0.5 (43.1–44.4)	43.9 ± 1.1 (42.0–45.2)	45.4 ± 4.4 (41.9–51.3)	48.9 ± 3.2 (46.1–54.5)	47.1 ± 3.1 (43.9–52.2)
RP–D (60°)					
right	39.4 ± 1.4 (37.4–40.6)	38.9 ± 0.8 (38.0–40.1)	40.6 ± 4.2 (36.6–45.6)	45.6 ± 1.5 (43.6–47.6)	42.4 ± 4.0 (39.8–49.4)
left	39.0 ± 0.7 (38.3–39.8)	39.3 ± 0.9 (37.7–40.2)	40.8 ± 4.6 (37.1–47.0)	44.3 ± 3.4 (41.3–50.1)	42.5 ± 3.3 (39.0–47.9)

TABLE 4: Comparison of mean values from right and left sides

Measurement	Mean (mm)		p Value
	Right	Left	
RP-A disc distance (lateral)	39.8860 ± 2.66273	38.9840 ± 2.99429	0.345
RP-B disc distance (midline)	42.9860 ± 3.01634	42.1900 ± 3.13539	0.225
RP-C disc distance (lateral)	46.3080 ± 3.43956	45.4260 ± 4.41406	0.686
RP-D disc distance (far lateral)	40.6620 ± 4.28964	40.8160 ± 4.65027	0.686
DROD, L3-4	8.3440 ± 0.48926	7.2760 ± 0.45457	0.043*
DROD, L4-5	17.0860 ± 1.03973	15.6920 ± 1.47128	0.043*
DROD, L5-S1	22.1280 ± 0.96131	20.6680 ± 0.49058	0.043*
DIPD, L1-2	2.7350 ± 0.63364	2.9250 ± 0.85317	0.465
DIPD, L2-3	3.0160 ± 0.40129	4.1400 ± 1.09633	0.043*
DIPD, L3-4	3.0560 ± 0.65775	3.6080 ± 0.72572	0.345
DIPD, L4-5	3.8460 ± 1.04323	4.5460 ± 0.89941	0.043*
DIPD, L5-S1	2.9725 ± 1.15205	2.6650 ± 1.19333	0.465
DRA, L3-4	110.6000 ± 1.78185	100.8000 ± 2.13892	0.042*
DRA, L4-5	106.8000 ± 2.36114	100.0000 ± 1.83712	0.043*
DRA, L5-S1	105.0000 ± 2.31840	99.8000 ± 2.58844	0.042*
DSPD, L1-2	11.6225 ± 0.98141	10.5200 ± 1.38927	0.273
DSPD, L2-3	10.7440 ± 1.22320	9.3900 ± 0.98242	0.08
DSPD, L3-4	10.5280 ± 1.01677	10.2920 ± 0.71643	0.500
DSPD, L4-5	11.1780 ± 0.21649	9.3580 ± 1.01714	0.043*
DSPD, L5-S1	9.3250 ± 2.53079	8.2375 ± 1.10627	0.273

* Statistically significant ($p < 0.05$).

iliac artery at the midline; the right common iliac vein and artery passed on the anterolateral aspect of the disc with overlap (Figs. 6 and 7; Table 5).

The L-4 lumbar artery sometimes crossed the L4-5 level and coursed near the midline at the disc space (Fig. 8) In all specimens, the median sacral artery crossed the anterior aspect of the L5-S1 disc near the midline travel-

ing with the middle sacral vein (Figs. 6-8). In the prevertebral space, the superior hypogastric plexus was located anterior to the L5-S1 disc (Figs. 6 and 7). The sympathetic chain coursed along the anterolateral aspect of the vertebral bodies along the entire length of the lumbar spine. The lumbar sympathetic chain was in close proximity to the lateral aspect of the intervertebral disc (Fig. 8). At the

TABLE 5: Points A-D on the anterior edge of the intervertebral disc and corresponding structures at risk*

Point & Side	Structures at Risk				
	L1-2	L2-3	L3-4	L4-5	L5-S1
Point A (0°)					
right	IVC, RA	IVC	IVC	IVC, RCIV, L-4 SA	RCIV, SC
left	AA, I, RA	AA, I	AA, I	AA, LCIA, LCIV, I, L-4 SA	LCIV, SHP, SC, LCIA
Point B (20°)					
right	AA	AA	AA, LCIA	AA, LCIA, LCIV, MSA, L-4 SA	LCIV, LCIA, MSA, SHP, I
left	AA	AA, IVC	AA, IVC, LCIA	AA, IVC, LCIV, MSA, L-4 SA	IVC, LCIV, SHP, I
Point C (40°)					
right	AA, RA	AA, I	AA, I, LCIA	AA, LCIA, LCIV, L-4 SA	LCIV, SHP, SC, LCIA
left	IVC, AA, RA	IVC, I	IVC, I	IVC, RCIV, I, L-4 SA	RCIV, SC
Point D (60°)					
right	SC, I	SC, I	SC, I	SC, I	SC, I
left	SC, IVC, I	IVC, SC, I	SC, I	RCIV, SC, I	SC, I

* For definitions of Points A-D, refer to Fig. 2 and *Methods*. Abbreviations: AA = abdominal aorta; I = intestine; IVC = inferior vena cava; LCIA = left common iliac artery; LCIV = left common iliac vein; MSA = median sacral artery; RA = renal artery; RCIA = right common iliac artery; RCIV = right common iliac vein; SA = segmental artery; SC = sympathetic chain; SHP = superior hypogastric plexus.

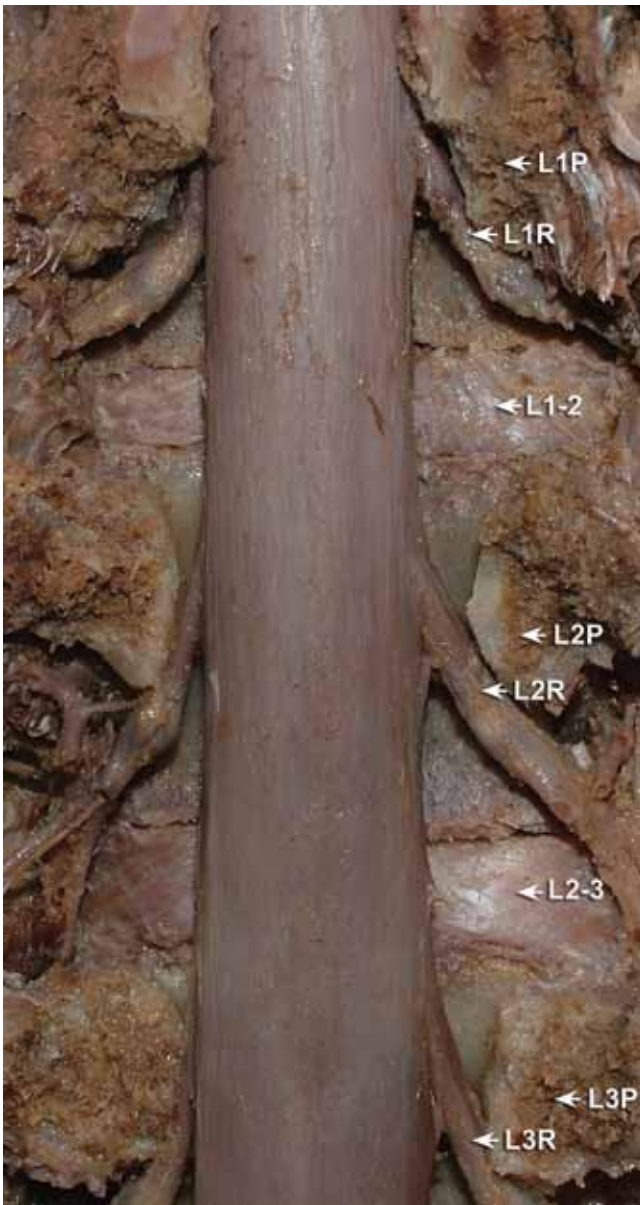


FIG. 3. Photograph showing the L1-2 and L2-3 levels and their relationships. L2P = L-2 pedicle; L2R = L-2 nerve root; L2-3 = L2-3 disc level; L3P = L-3 pedicle; L3R = L-3 nerve root.

L5-S1 level, intestine was found to be closely related to the anterior aspect of the disc in 5 cadavers.

Discussion

Posterior spinal access for lumbar disc herniation can be associated with injury to vascular (aorta, inferior vena cava, left common iliac vein and artery, lumbar artery, median sacral artery) and neural (nerve root, superior hypogastric plexus, sympathetic chain) structures.^{1,6,7,10,12,16,18,19,23} Injury of the great vessels is the most devastating complication of lumbar discectomy and has occurred primarily at the L4-5 and L5-S1 levels.¹⁸

The use of formalin-fixed cadavers can alter anatomical relationships due to decreasing the tension within the

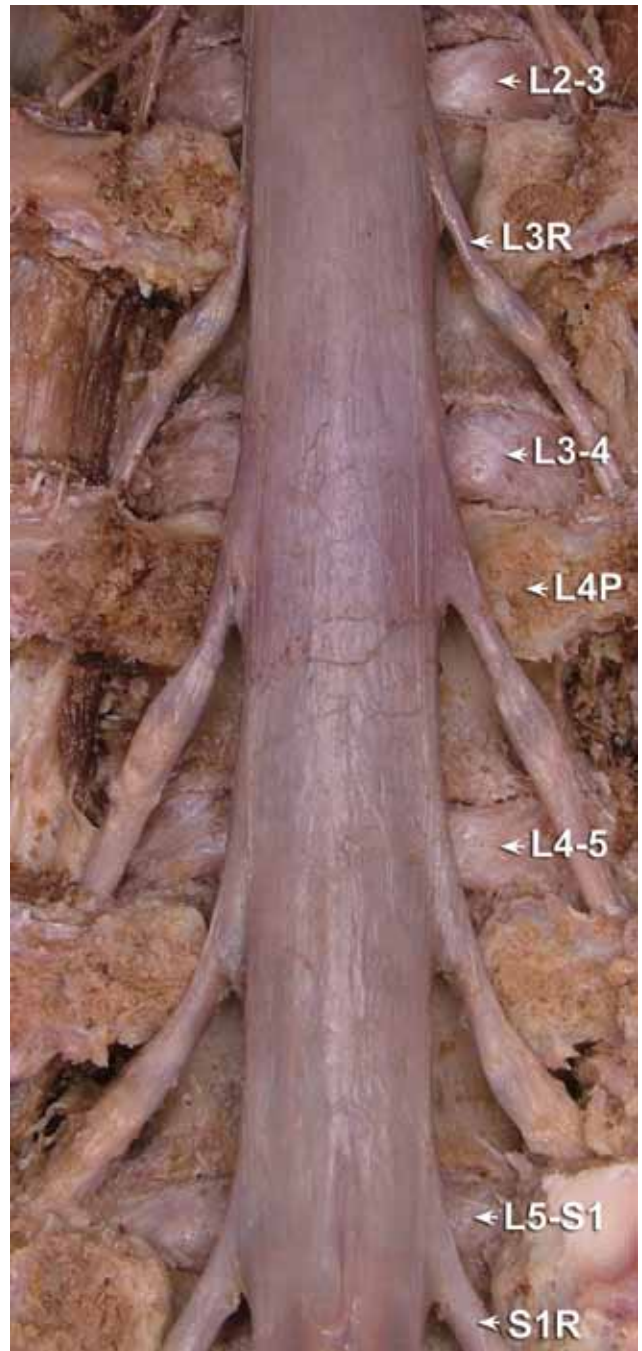


FIG. 4. Photograph showing the lower lumbar levels. In particular, the sites of origin of roots and their angles with disc level that should be kept in mind with respect to surgery. L3-4 = L3-4 disc level; L4P = L-4 pedicle; L3R = L-3 nerve root; L5-S1 = L5-S1 disc level; S1R = S-1 nerve root.

tissues,^{14,15,17} especially the thecal sac and vascular relationships with disc spaces. Therefore, a pilot study was carried out. This study demonstrated that, for 10% formalin fixation, the average linear shrinkage was 4.5%, corresponding to a volume correction factor of 1.15. Whereas, the linear correction factor of 0.9 can be used to correct for fixation with 10% formalin in the brain.^{14,17} Since the reference points and the directions of measurements



FIG. 5. Lateral view demonstrating relationship of L-3 nerve root to L3-4 level. The L-3 nerve root crosses the lateral surface of the L3-4 disc.

varied according to the anatomical structures examined, a constant linear correction factor was not used in this study.

Knowledge of the DIPD and DSPD may be helpful to predict the location of the intervertebral disc in recurrent disc disease. Owing to the presence of fibrosis in the operative field, disc levels may be difficult to identify. Our results indicate that the origin of the L-1, L-2, and L-3 roots correspond to the T12-L1, L1-2, and L2-3 disc levels; in all cadavers, the L-3 nerve root originated inferior to the L2-3 level, the L-4 root commonly originated at L3-4, and the L-5 and S-1 roots always originated superior to their corresponding level. These relationships are important in disc surgery. Compression of the dural sac is common at the L-1 to S-1 nerve roots, but compression of the root sleeve may be found at the S-1 nerve root and sometimes the L-5 nerve root. Herniated discs from L2-3 to L4-5 may compress the bulge of the lower nerve root, and the sleeve of the S-1 root may be compressed by a L5-S1 disc herniation. Therefore, the shoulder type of disc prolapse (posterolateral disc herniation) (Fig. 9) may be more commonly seen in patients with complaints associated with the L3-5 nerve roots, and the axillary type of herniation (Fig. 9) more commonly affects the S-1 nerve root.²² The distance between the point of origin of the root sleeve and the disc level explains this phenomenon. Although the root sleeve originates distal to the corresponding disc levels (the L-3 nerve root corresponds to the L2-3 disc, L-4 to L3-4, L-5 to L4-5, and S-1 to L5-S1), the actual origin of the nerve root sleeve is proximal to the disc level, such as shown in Figs. 3 and 4. The origin of the root ascends according to the corresponding level from L-1 to L-5. Suh et al.²² indicated that, for L-1 to L-4 roots, the origin of the root is always inferior to the corresponding disc level and that the L-5 root commonly originates below the L4-5 disc and that the S-1 root sometimes originates at the L5-S1 level. Our root origins on the left sides of the vertebrae were more inferior than those on the right sides, and this is in contrast to the findings of Suh et al.²² (Table 1). The difference in

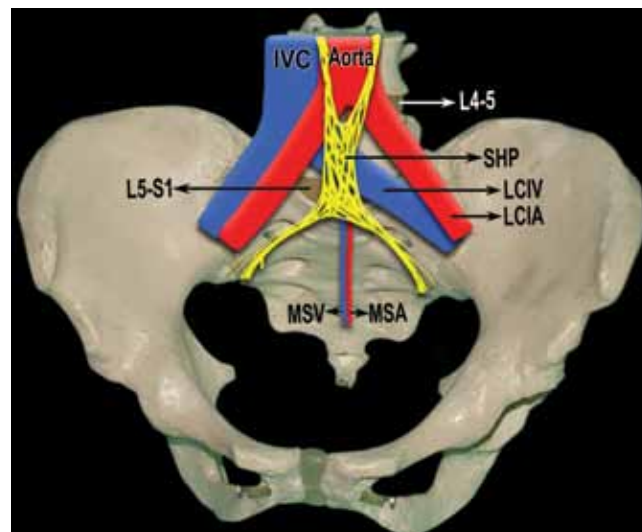


FIG. 6. Drawing showing the anterior area of the lumbosacral region. The L5-S1 space has a very close relationship with various vascular and neural structures. IVC = inferior vena cava; LCIA = left common iliac artery; LCIV = left common iliac vein; MSA = middle sacral artery; MSV = middle sacral vein; SHP = superior hypogastric plexus.

findings in these 2 studies may be due to ethnicity of the cadavers used.

In our study, descending lumbar levels were found to have a decreased DRA (that is, the root crossed the intervertebral disc with a smaller angle). The relationship between the intervertebral disc and the corresponding nerve root changed according to level. Angles with the

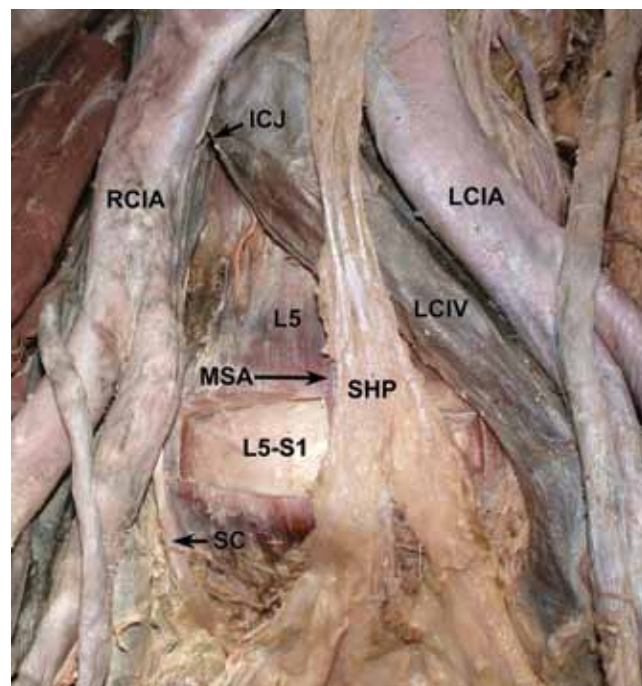


FIG. 7. A view indicating the proximity of the left common iliac vein, middle sacral artery and vein, and superior hypogastric plexus to the L5-S1 space. IJC = ilioacaval junction; RCIA = right common iliac artery; SC = sympathetic chain.

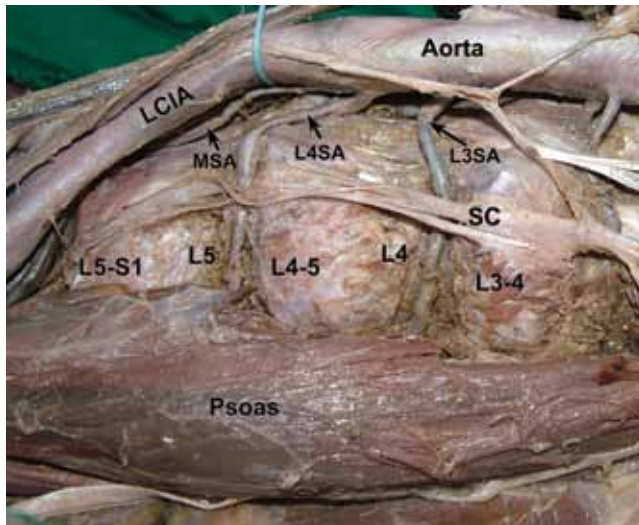


FIG. 8. Lateral view of the lumbar vertebrae after removal of the psoas major muscle. The sympathetic chain and fourth lumbar arteries are seen in proximity to the disc spaces and vertebral bodies. The lumbar arteries have an atypical origin and an atypical course. The right and left lumbar arteries at the L-3 and L-4 levels are seen arising from a single trunk. SA = segmental artery.

corresponding discs did not exist for the L-1, L-2, and L-3 nerve roots. The DRA is an important factor affecting disc surgery because it may guide approaches through the axilla of the nerve root or an approach lateral to the root. For L5–S1 disc herniations, this approach is preferred.

The length, width, and height of the intervertebral disc increased from the L1–2 to the L5–S1 level. Therefore, the disc material removed during decompressive surgery should be less in upper levels than in lower lumbar levels. Anda et al.¹ in a CT study, found that, in a prone position, the mean midsagittal diameters of the L3–4, L4–5, and L5–S1 discs were 43 mm (range 38–56 mm), 44 mm (range 38–51 mm), and 45 mm (range 38–53 mm), respectively. In our study, for L1–2 levels, the mean values for RP–A, RP–B, RP–C, RP–D were 36, 40, 43, and 39 mm; for L2–3 levels, 36, 40, 43, and 38 mm; for L3–4 levels, 38, 42, 45, and 40 mm; for L4–5 levels, 41, 45, 49, and 44 mm; and for L5–S1 levels, 38, 43, 47, and 42 mm, respectively. We propose that instruments inserted into the disc space should not be advanced more than the values described above, and these values should be taken into consideration during disc decompression to avoid complications. Anda et al.¹ stated that “if instruments are advanced less than 3 cm from the posterior disc border, there is no chance of anterior perforation.” We agree with Anda et al.¹ and consider that, for each lumbar level, the instrument should not be inserted into the disc space more than 3 cm. Our results indicate that an aggressive exploration extending more than 3 cm will carry a great risk of injury to adjacent retroperitoneal structures.

The inferior vena cava and the common iliac veins have a larger transverse diameter and lie closer to the discs than do the arteries. They form a broad vascular band, especially at the L4–5 disc level. Because veins have considerably thinner walls than do arteries—particularly the left common iliac vein, which has a very thin wall and

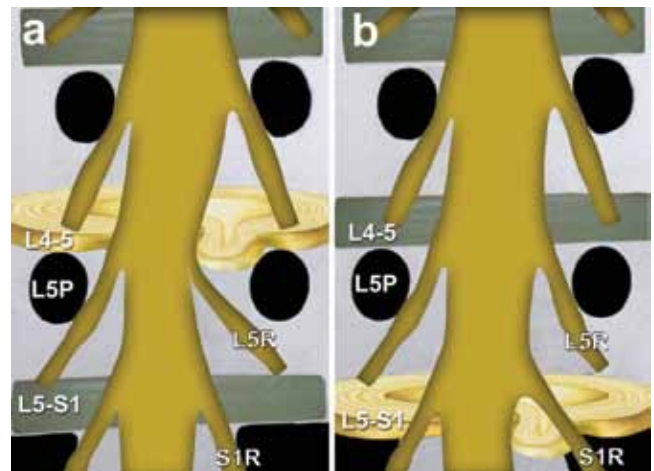


FIG. 9. Illustrations showing the shoulder (a) and axillary (b) types of disc herniation. Compression of the bulge of the lower nerve root is common for L1–5 nerve roots; compression of the root sleeve is common for the S-1 nerve root. Therefore, the shoulder type of disc prolapse (posterolateral disc herniation) is more common for L1–5 nerve roots and the axillary type for S-1. L5P = L5 pedicle.

is adherent to the L5–S1 disc space—it seems probable that veins are more commonly inadvertently punctured in anterior perforations during disc surgery than arteries. A lesion of the major arteries will cause profuse bleeding, which may be rapidly fatal. For the L1–2, L2–3, and L3–4 levels, at angles of 0°, 20°, and 40° to the sagittal plane at the right and left RPs (during midline and paramedian decompression), both the aorta and inferior vena cava can be at great risk of injury. For the L4–5 level, at angles of 20° and 40° from the right RP, and at 0° and 20° from the left RP (during midline and left anterolateral decompression), damage to the left common iliac artery and vein may result in life-threatening retroperitoneal hemorrhage; at 0° and 20° from the right RP and at 20° and 40° from the left RP (during midline and right anterolateral decompression), the inferior vena cava and the right common iliac vein are prone to injury. For the L5–S1 level, the right common iliac vein, which is interposed between the disc and the right common iliac artery, usually courses on the anterolateral aspect of L5–S1 and is adherent to the disc space. At 0° from the right RP and 20° and 40° from the left RP (during right anterolateral decompression), the right common iliac vein may be injured. The left common iliac vein and artery course adjacent with no overlap; at 20° and 40° from the right RP and at 0° and 20° from the left RP (during midline and left anterolateral decompression), injury may occur (Table 5). Because the L-4 lumbar and median sacral arteries pass very close to the disc spaces, they may be sacrificed during removal of the middle portion of the disc substance during L4–5 and L5–S1 disc surgery, respectively. The lumbar sympathetic chain lies in close proximity to the anterolateral aspect of disc spaces and is extremely vulnerable to injury during far-lateral decompression of the disc. Injury to the sympathetic chain results in ipsilateral vasodilation of the lower limb.²¹ The superior hypogastric plexus overlying the L5–S1 disc space is vulnerable in the midline plane. In men, such an injury may result in retrograde ejacula-

tion. Additionally, due to leakage at the internal urethral sphincter, incontinence may occur.²¹

Conclusions

Based on our findings for posterior lumbar approaches to the intervertebral discs, instruments should not be inserted further than 3 cm into the disc space. Injury to the great vessels and sympathetic and superior hypogastric plexus anterior to the intervertebral disc should be always kept in mind during disc surgery. Imaging studies obtained in the patient in the prone position may be more effective in understanding the true relationship of the vascular anatomy with the anterior intervertebral disc space.

Disclosure

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author contributions to the study and manuscript preparation include the following. Conception and design: all authors. Acquisition of data: Arslan, Comert, Acar, Özdemir, Elhan, Tubbs, Ugur. Analysis and interpretation of data: Arslan, Comert, Acar, Özdemir, Tubbs, Ugur. Drafting the article: Arslan, Comert, Tubbs. Critically revising the article: Comert, Arslan, Tubbs, Ugur. Reviewed final version of the manuscript and approved it for submission: all authors. Statistical analysis: Arslan, Comert, Özdemir, Tubbs. Administrative/technical/material support: Comert, Acar, Elhan, Tekdemir, Ugur. Study supervision: Acar, Elhan, Tekdemir, Ugur.

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