

# The Safe Entry Zones through the Transpsoas Approach to Lumbar Discs: A Cadaver Study

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## ABSTRACT

**Background Data:** Low back pain (LBP) is a common musculoskeletal disorder. In Egypt, patients with LBP constitute a high percentage of patients seeking medical care at outpatient clinics. Spinal fusion is a common treatment for spinal disorders such as disc degeneration, deformity, spondylolisthesis, or fracture. The minimally invasive lateral retroperitoneal transpsoas approach is a recent technique developed to avoid complications associated with traditional or minimally invasive anterior or posterior approaches to the lumbar spine. This technique provides a small incision that avoids significant abdominal muscle injury and lateral access to the disc space from L1-L2 to L4-L5.

**Purpose:** To define a safe entry zone in the psoas muscle to prevent lumbar plexus injury during the transpsoas approach.

**Study Design:** A descriptive cadaveric study.

**Material and Methods:** A total of 30 cadavers were used in this study where each cadaver was dissected from both sides. Each cadaver was placed in lateral decubitus and a skin incision in the midaxillary line from the last rib to iliac crest was made. Then, the peritoneum was dissected, psoas muscle was exposed, and nerve roots were identified and reported at each disc space from L1-L2 to L4-L5. The safe entry zone was defined by the absence of crossing of a lumbar plexus branch.

**Results:** Each disc space was divided into four zones: zone 1, the posterior quadrant; zone 2, the middle anterior quadrant; zone 3, the middle posterior quadrant; zone 4, the posterior quadrant. The safe working zone includes zones 2 and 3 at level L1-L2, zone 3 at level L2-L3, zone 3 at level L3-L4, and zone 2 at level L4-L5. There was no variance observed between either side regarding the relationships between the lumbar plexus and the intervertebral disc.

**Conclusion:** Knowledge of the anatomy of lumbar plexus roots in psoas muscle is mandatory to prevent injury to lumbar plexus roots during entry of dilator through psoas muscle. This anatomical study suggests that there are certain safe zones at the lumbar disc spaces that allow passage of dilator inside psoas muscle to reduce direct nerve injury of the lumbar plexus. (2020ESJ200)

**Keywords:** Retroperitoneal; Transpsoas approach; Lumbar disc; Cadaver dissection; Anatomical study.

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## INTRODUCTION

Lumbar Degenerative Disc Disease (DDD) is the leading cause of low back pain (LBP) in adults. The lumbar levels L5–S1 and L4–L5 are more frequently affected.<sup>6</sup> LBP is the second most frequent complaint in people seeking medical help.<sup>1</sup>

The lateral transpsoas approach was developed to access the lumbar spine as an alternative to the anterior and posterior approaches. It was popularized by Ozgur. It is a novel technique by which a minimally disruptive lateral, retroperitoneal, transpsoas approach to the spine achieves access to the disc space.<sup>9,14</sup> This approach has many advantages over the anterior approach since it prevents damage of abdominal contents and great vessels. Moreover, this approach often avoids all the complications associated with the posterior approach since it eliminates significant muscle stripping and denervation, neural retraction, and the risk of neurological and dural complications associated with it. However, the main concern with this approach is the potential complications related to lumbar plexus nerves due to its presence in the psoas muscle.<sup>4</sup>

The lumbar plexus nerves are located inside the substance of the psoas muscle. It is made up of ventral rami of the first four lumbar nerves and a contribution of the last thoracic nerve. Several motor and sensory nerves arise from the plexus. The femoral (L2-L4) and obturator (L2-L4) nerves are the main motor branches. The main sensory branches are the iliohypogastric (L1), ilioinguinal (L1), genitofemoral (L1-L2), lateral femoral cutaneous (L2-L3), and anterior femoral cutaneous (L2-L4) nerves. Most nerves are mixed motor and sensory. The intrinsic nerves of the psoas are the only pure motor nerves, whereas the pure sensory nerve is the lateral femoral cutaneous nerve.<sup>5</sup> Those nerves are our target in this study as they are also liable for injury during other anterolateral approaches.

This study was designed to study the course of lumbar plexus through the psoas muscles to define a safe entry zone in psoas muscle during the transpsoas approach to prevent lumbar plexus injury.

## CADAVERS AND METHODS

This study was conducted on thirty cadavers: 28 in the Anatomy Department at Alexandria University and 2 in a regional workshop. Each cadaver was dissected from both sides counting to 60 samples. All cadavers should fulfill the following criteria. Inclusion criteria included all lumbar spine and sacrum intact, psoas muscle intact with its sheath, and no deformity (scoliosis or kyphosis). Exclusion criteria included all spinal deformities and lumbar spine or sacrum fractures. An X-ray image was obtained before working on the cadavers to make sure that they met the inclusion criteria.

All cadavers were placed on lateral decubitus on the dissection table. A skin incision was made at the midaxillary line from the last rib till iliac crest and the abdominal wall muscles were dissected (external, and internal obliques and transverse abdominis muscles). The peritoneum was dissected anteriorly; then, the last 2 ribs were removed. After that, the psoas muscle was exposed and the nerve roots were identified after exiting from the psoas muscle and then dissected inside the muscle. A radioopaque marker was placed at the posterior end of the disc level and the anatomical level was identified.

Every disc space from L1-L2 to L4-L5 was defined, its length was measured, and nerve crossing over the disc was identified. Each disc space was divided into four quarters: the anterior quarter is zone 1; the middle anterior quarter is zone 2; the middle posterior quarter is zone 3; the posterior quarter is zone 4 (Figure 1). Each nerve crossing over disc space was identified and reported with its corresponding zone of disc space.

At each disc space, the psoas muscle, lumbar plexus, and nerve roots were dissected. Each specimen was photographed and analyzed. The distribution of the lumbar plexus roots and nerves at each lumbar disc level was evaluated and recorded. L5-S1 disc level is usually inaccessible due to the presence of the iliac crest and is already out of our scope. A safe entry zone was defined by the absence of crossing of any neural structure.

## RESULTS

The lumbar plexus consists of nerves that originate from the anterior divisions of the 1<sup>st</sup>, 2<sup>nd</sup>, and 3<sup>rd</sup> with a greater part of the 4<sup>th</sup> lumbar nerve roots with T12 contribution.

The plexus is a retroperitoneal network in the psoas muscle substance. It is also placed in front of the lumbar vertebral transverse processes. Viewed from the lateral position, the lumbar plexus is located at zone 4. The nerves of the plexus descend obliquely outward, beyond, and throughout the psoas muscle fibers. The gradual anterior migration of the lumbar plexus nerves and their relation to the coherent zones of the disc were accessed during their course of descent as it descends within the muscle at each disk space was noted.

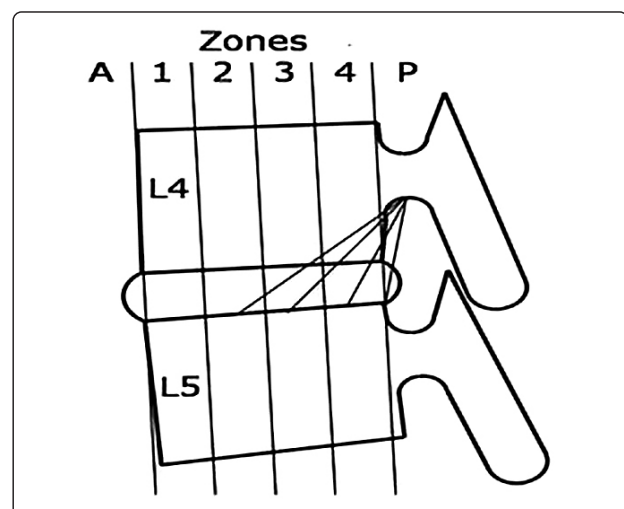
The nerves of the lumbar plexus are the ilioinguinal, iliohypogastric, genitofemoral, obturator, femoral nerve, and lateral cutaneous nerve of thigh. The femoral nerve, developed from divisions of the roots L2, L3, and L4, is the greatest branch of the lumbar plexus. At level L3-L4, it was found in zone 4 in all cadavers, whereas at level L4-L5, it was found in 36 sides of cadavers at zone 3 and in the other 24 sides of cadavers at zone 4 (Figures 2 and 7). The obturator nerve also arises from L2, L3, and L4 roots. It is found in zone 4 at both levels L3-L4 and L4-L5 in all cadavers (Figure 8). The sensory nerves of the lumbar plexus are the ilioinguinal, iliohypogastric, and the lateral cutaneous nerve of the thigh. The ilioinguinal and iliohypogastric nerves arise from root L1 and they

were found in zone 4 at level L1-L2 in all sides of cadavers (Tables 1 and 2; Figure 9).

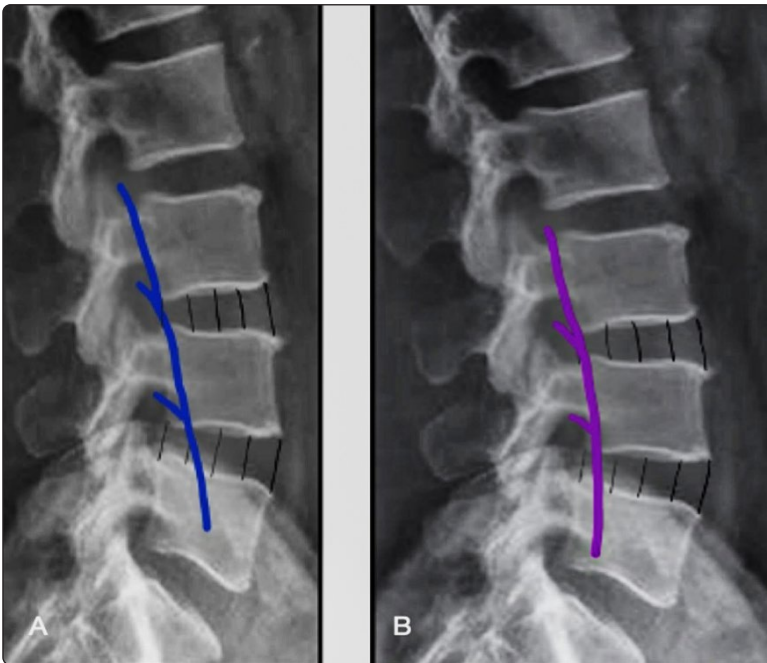
The genitofemoral nerve passes obliquely from its origin at root L1 into the substance of the psoas muscle. It was found in zone 4 at level L1-L2 in all cadavers; then, it descends with ventral migration to reach zone 2 at level L2-L3 in 48 sides of cadavers and zone 1 in 12 sides of cadavers. At levels L3-L4 and L4-L5, the nerve is found in zone 4 on all sides of cadavers (Figures 3 and 5).

The lateral cutaneous nerve of thigh was found in zone 4 in all sides at level L3-L4. However, at level L4-L5, it was found in zone 3 in 42 sides and zone 4 in the other 18 sides of cadavers (Figure 6).

Our results showed that dissection of the psoas muscle is safer anteriorly than posteriorly for fear of injury of femoral or lumbar roots. However, in case of injury of the genitofemoral nerve, if dissection is more anterior in psoas muscle, it will result in some tactile disturbances on the medial thigh skin, scrotum/labia majora, and the abdominal wall below the inguinal ligament. The cremasteric reflex can also be missing in males due to damage to the branch of the motor that is more accepted than weakness in the lower limb as a complication of lumbar fusion surgery. Dissection of cadavers on both sides showed that there was no difference in either side of the cadavers.



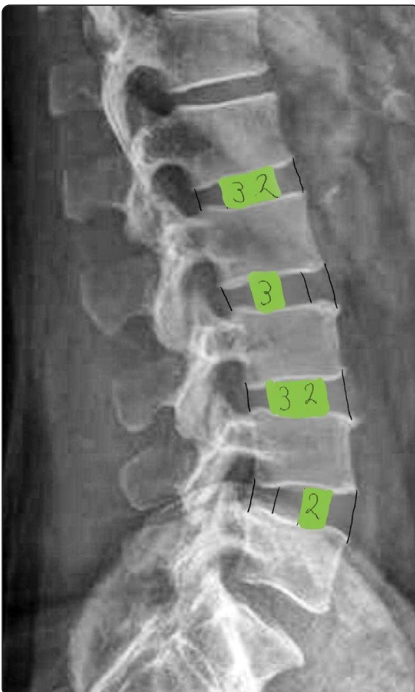
**Figure 1.** An illustration showing the division of each lumbar disc into four anatomical zones.



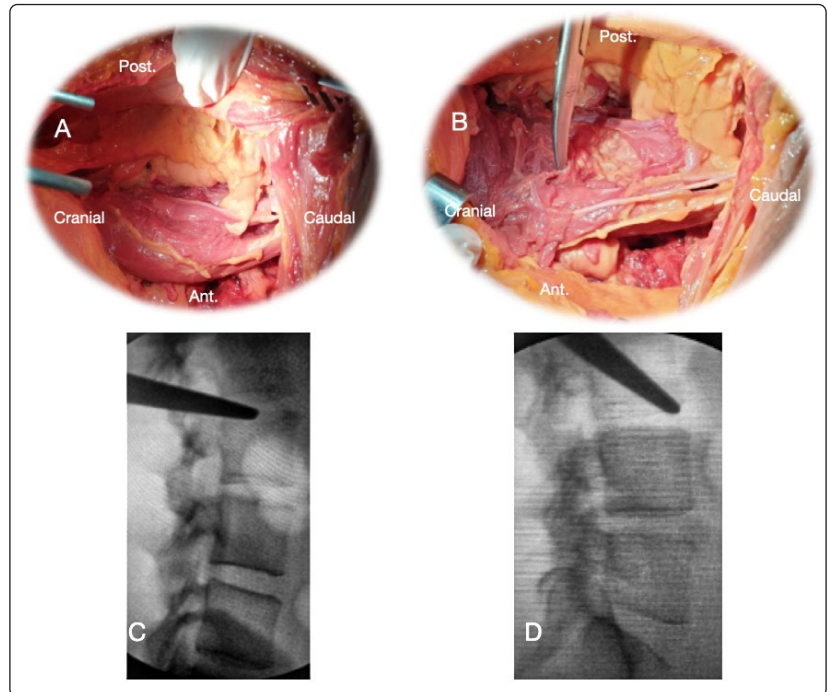
**Figure 2.** Lateral X-rays image of the lumbar spine showing (A) the path of the femoral nerve (blue line) and (B) \ obturator nerve (purple line) across L3-L4 and L4-L5 disc levels.



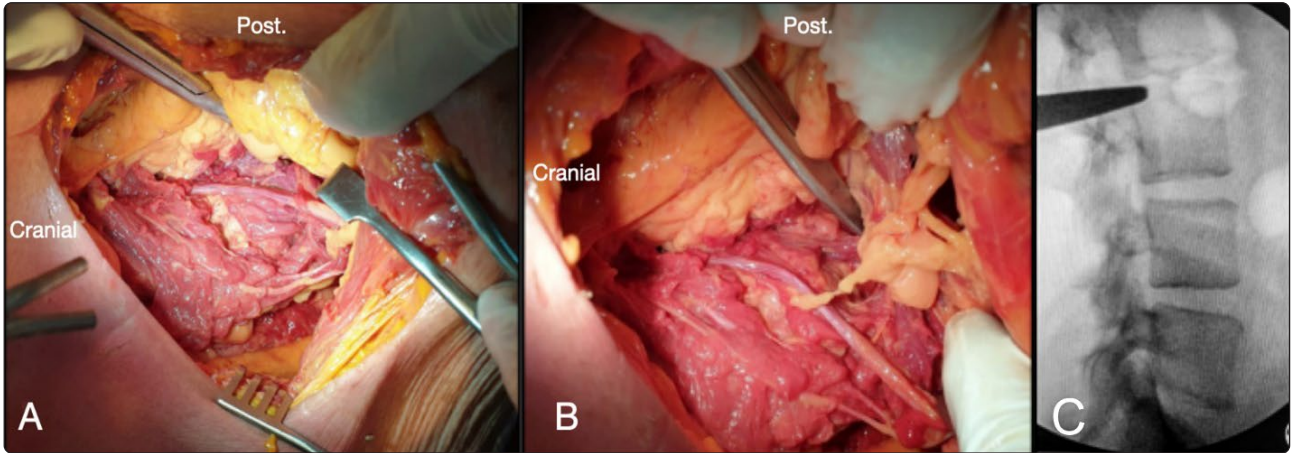
**Figure 3.** Lateral X-ray image of the lumbar spine showing the pathway of genitofemoral nerve across L2-L3, L3-L4, and L4-L5 disc levels.



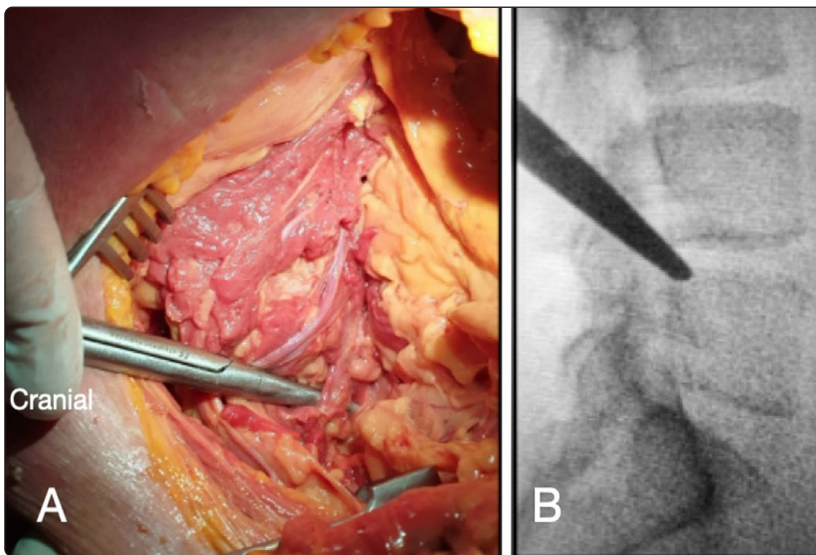
**Figure 4.** Lateral X-ray image of the lumbar spine illustrating the safe zones at each level from L1-L2 to L4-L5 disc level shown in green color with the zone number written on it.



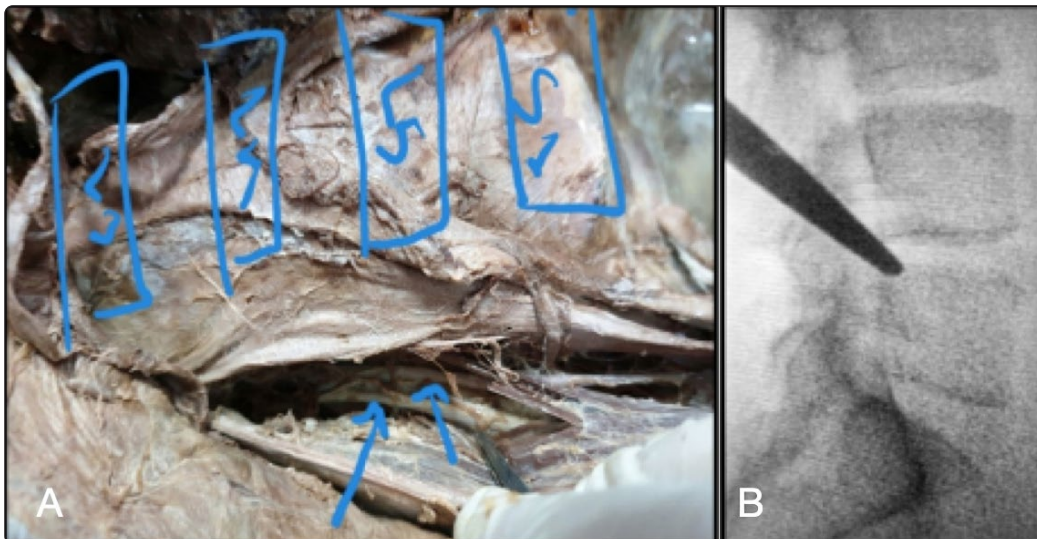
**Figure 5.** Images showing the genitofemoral nerve (A) before dissection on the surface of the psoas muscle and (B) after dissection. Plain lateral X-ray of the lumbar spine showing the location of the genitofemoral nerve (C) at disc level 2-3 and (D) at disc level 3-4.



**Figure 6.** Cadaver photo showing (A,B) lateral cutaneous nerve of thigh traversing above the L3-L4 disc level. (C) Lateral X-ray of the lumbar spine showing the location of the nerve at L2-L3 level.



**Figure 7.** Cadaver photo (A) showing the lumbar roots forming femoral nerve at L4-L5 disc level (the scissor is opposite to L4-L5 level). (B) Lateral X-ray of the lumbar spine showing femoral nerve location at L4-L5 disc level.



**Figure 8.** Cadaver image (A) showing lumbar roots forming femoral nerve and obturator nerve (blue arrows). (B) Lateral X-ray of the lumbar spine showing the location of the nerve at L4-L5 disc level.



**Figure 9.** Cadaver photo showing iliohypogastric nerve (green arrows) and femoral nerve (red arrows).

**Table 1.** Summary of our results where each disc level from L1-L2 to L4-L5 was divided into four zones anteriorly (zone 1) to posteriorly (zone 4) and reporting the zone where each lumbar nerve was passing through.

Disc level	Length	Zone 1	Zone 2	Zone 3	Zone 4
L1-L2	39	Sympathetic chain (60)			Root L1 (60) Ilioinguinal N (60) Iliohypogastric N (60) Genitofemoral N (60)
L2-L3	38.5	Sympathetic chain (60) Genitofemoral N (12)	Genitofemoral (48)		Root L2 (60)
L3-L4	39.5	Sympathetic chain (60) Genitofemoral N (60)			Root L3 (60) Lateral cutaneous N (60) Femoral N (60) Obturator (60)
L4-L5	40	Sympathetic chain (60) Genitofemoral N (60)		Femoral N (36) Lateral cutaneous N (42)	Root L3 (60) Femoral (24) Obturator (60) Lateral cutaneous (18)

NB: the number between brackets represents the number of cadaver sides.

**Table 2.** Our findings according to each nerve and its pathway through disc levels from L1-L2 to L4-L5.

Nerve	L1-L2	L2-L3	L3-L4	L4-L5
Sympathetic chain	Zone 1 (60)	Zone 1 (60)	Zone 1 (60)	Zone 1 (60)
Genitofemoral nerve	Zone 4 (60)	Zone 2 (12) Zone 1 (48)	Zone 1 (60)	Zone 1 (60)
Ilioinguinal and iliohypogastric nerves	Zone 4 (60)			
Lateral cutaneous nerve		Zone 4 (60)	Zone 4 (60)	Zone 3 (42) Zone 4 (18)
Femoral nerve			Zone 4 (60)	Zone 3 (36) Zone 4 (24)
Obturator nerve			Zone 4 (60)	Zone 4 (60)

NB: the number between brackets represents the number of cadaver sides.

## DISCUSSION

Several approaches were developed to treat degenerative lumbar disc after the failure of conservative treatment. The lateral transpsoas approach has an advantage over the other posterior or anterior approaches since it avoids their complications. However, the presence of the lumbar plexus and its branches within the psoas muscle makes them at potential risk of injury during this approach.<sup>8,12</sup>

In this cadaveric study, a safe working zone for performing the transpsoas approach was defined as the disc space quarter in which the crossing nerve fibers were absent in all cadavers. We found zones 2 and 3 in L1-L2 and L3-L4 to be safe zones. The location of the genitofemoral nerve was liable for a narrowing of the safe zone at L2-L3 level making zone 2 not safe and risky to injure the genitofemoral nerve. Therefore, zone 3 is only safe at disc level L2-L3. However, at disc level L4-L5, the slight ventral migration of the lumbar plexus, mainly the femoral nerve is responsible for making zone 2 a safe zone at this level (Tables 1 and 2; Figure 4).

A similar study was done by Guerin et al.<sup>7</sup> that was conducted on 60 cadaveric lumbar plexuses with similar methods and exclusion of spine deformity cases to our study. They reported that at disc level L1-L2, zones 2 and 3 were safe whereas at disc levels L2-L3 and L3-L4, only zone 3 was safe. The slight ventral migration of the femoral nerve makes zone 2 at disc level L4-L5 a safe zone. Our findings regarding an endoscopic retroperitoneal transpsoas technique were similar to those reported by Moro et al.<sup>13</sup> who investigated the distribution of the lumbosacral plexus in the axial plane and found that there were some “safe zones” at each lumbar disc space where nerve structures were unlikely to be positioned. They dissected 6 cadavers and suggested that the psoas should be separated ventrally from the lumbar vertebral body of L3 and then the dorsal quarter of the lumbar vertebral body to avoid nerve damage.

In another cadaveric study on 50 cadavers, Matejcik et al.<sup>11</sup> dissected the lumbosacral plexus in each cadaver and described structural variations in the structure of neural root and lumbar nerves in the plexus. They reported that these differences can indicate where the safe zone is situated.

Benglis et al.<sup>2</sup> reported moderate ventral migration of the lumbar plexus to disc space from L1-L2 to L4-L5. In their analysis, they recorded the findings as the proportion of the distance of the plexus from the posterior endplate to the intervertebral disc's total length of space, which differs from our recording method. They determined that L4-L5 is the risky level that may lead to an injury to the plexus during the transpsoas route and that setting the dilators and the retractor in a more posterior location is much risky. These findings match ours. Uribe et al.<sup>17</sup> described a safe zone in their study regarding the divisions of the lumbar plexus. They dissected five cases of the cadavers and reported that the secure zones at the intervertebral disc from L1-L2 to L3-L4 were at the midpoint of zone 3 and the secure zone at L4-L5 was at the demarcation of zones 2 and 3. The findings reported in this study were very close to ours.

Different imaging studies were conducted reporting the anatomy of the lumbar plexus. In a morphometric evaluation of MR scanning, Regev et al.<sup>15</sup> described the anatomical place of the lumbar ventral roots in a typical position in deformed lumbar spines and the retroperitoneal vessels. They concluded that the secure path for discectomy success and installation of cage narrows from level L1-L2 down to level L4-L5. In spinal rotational deformity, this passage is further narrowed. The authors suggested preoperative preparation utilizing MRI analysis to determine the neurovascular structures' relation to the lower vertebral endplate.

We reported several variations regarding the safe working region or zone through the psoas muscle. Possibly, the limited scale of cadaver specimens used in anatomical research can provide us with an understanding of these variations. Another relevant aspect is the possibility that there might be

variations in tissue planes and sensitivity between cadaveric specimens and patients. Anatomical landmarks have been defined in standard oriented or positioned lumbar spine; however, further anatomical researches are truly warranted to determine the anatomical position of the plexus on the scoliotic spine.

Previous studies have studied the adverse effects correlated with minimally invasive transpsoas spine surgery. Tonetti et al.<sup>16</sup> identified three instances of femoral nerve damage after a minimally invasive transpsoas procedure, in which they related the issue to nerve stretch during the psoas muscle retraction. After an endoscopic transpsoas procedure, Bergey et al.<sup>3</sup> identified several patients with temporary tactile abnormalities (30%). Manzano et al.<sup>10</sup> also reported temporary anterolateral lower limb thigh numbness and dysesthesias on the side of the approach.

Electrophysiological monitoring is a vital tool for avoiding nerve damage when traversing the muscle of the psoas and during retractor placement. Ozgur et al.<sup>14</sup> reported that threshold stimulus values >10 mA are secure to push into the disk space of interest.

This study has some limitations such as the small number of cadavers and most of our cadavers were preserved with formalin and not fresh frozen cadavers making the psoas muscle rigid and its dissection so hard. Also, we did not include or dissect cadavers with spinal deformity. That is why we recommend conducting more studies with a large sample size including cadavers with spinal deformity to see if there are differences in the anatomy of lumbar plexus and safe zones.

## CONCLUSION

The minimally invasive transpsoas approach is developed to prevent major complications of traditional approaches. However, the proximity of the lumbar plexus is the main limitation of the approach. Knowledge of the anatomy of lumbar

plexus roots in psoas muscle is mandatory to prevent injury to lumbar plexus roots during entry of dilator through psoas muscle. This anatomical study suggests that there are certain safe zones at the lumbar disc spaces that allow passage of dilator inside psoas muscle to reduce direct nerve injury of the lumbar plexus.

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## الملخص العربي

### دراسة لمناطق الدخول الآمنة للغضروف القطني عبر نهج العضلة القطنية ( دراسة تشريحية )

**البيانات الخلفية:** نهج العضلة القطنية هو نهج جديد و تقنية جديدة لعلاج مرض القرص القطني التنكسي ، حيث تمكن من الوصول إلى القرص القطني دون تعطيل عضلة الحوض والعناصر الخلفية. المشكلة من هذا النهج هو الضفيرة القطنية التي يتم تضمينها داخل عضلة القطنية. إن معرفة تشريح الضفيرة القطنية ومتابعة تخطيط الاعصاب أثناء الجراحة هي ضرورة أثناء تنفيذ هذا النهج.

**الغرض:** تهدف هذه الدراسة إلى تحديد منطقة دخول آمنة في عضلة القطنية لمنع إصابة الضفيرة العصبية القطنية.

**تصميم الدراسة:** هذه الدراسة هي دراسة وصفية للجثث.

**الجثث والطرق:** عدد الجثث: 10 جثث، تم تشريح كل جثة من كلا الجانبين. يتم وضع كل جثة في استلقاء جانبي، شق جلدي في خط منتصف الفك العلوي من الضلع الأخير إلى قمة الحرقفي. شق عضلة البطن ثم تراجع الصفاق، تعرض عضلة القطنية. يتم تشريح العضلة القطنية، ويتم تحديد جذور الأعصاب والإبلاغ عنها في كل مساحة قرص من L1\_2 إلى L4\_5. يتم تعريف منطقة الدخول الآمنة من خلال عدم وجود عبور لفرع الضفيرة القطنية.

**النتائج:** نتائجا قابلة للمقارنة مع الدراسات التشريحية السابقة. تنقسم كل مساحة قرص إلى أربع مناطق ؛ المنطقة 1 الربع الخلفي ، المنطقة 2 الربع الأمامي الأوسط ، المنطقة 3 الربع الخلفي الأوسط ، المنطقة 4 الربع الخلفي. تشمل منطقة العمل الآمنة على المنطقتين 2 و 3 على المستوى L1L2 والمنطقة 3 على المستوى L2L3 والمنطقة 3 على المستوى L3L4 والمنطقة 2 على المستوى L4L5. لم يلاحظ أي تباين بين أي من الجانبين فيما يتعلق بالعلاقات بين الضفيرة القطنية والقرص الفقري.

**الخلاصة:** نهج العضلة القطنية هو نهج طفيفة التوغل تم تطويره لمنع المضاعفات الرئيسية للنهج التقليدية. ومع ذلك ، فإن القرب من الضفيرة القطنية هو الحد الرئيسي للنهج. معرفة تشريح جذور الضفيرة القطنية في العضلة القطنية إلزامية لمنع إصابة جذور الضفيرة القطنية أثناء دخول الموسع من خلال العضلة القطنية.