Localization of the Lumbar Plexus in the Psoas Muscle: Considerations for Avoiding Lumbar Plexus Injury during the Transpsoas Approach

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Abstract:

Introduction: Transpsoas lumbar spine surgery is minimally invasive and has very good corrective effects. However, approach-side nerve complications delay post-operative rehabilitation. We anatomically investigated the localization of the lumbar plexus running in the psoas muscle.

Methods: We examined 27 formalin-fixed cadavers. The left-sided psoas muscle was extracted and cut parallel to the intervertebral disc at the L2/3, L3/4, and L4/5 disc levels. Using digitized photographs, we calculated the ratio of the distance from the front edge of the psoas muscle to the center of the lumbar plexus in the anteroposterior diameter of the psoas muscle (%). Then, we calculated the ratio of the distance from the lateral edge of the psoas muscle to the center of the lumbar plexus in the lateral diameter of the psoas muscle (%).

Results: The anterior-posterior lumbar plexus localization was 74.5 at L2/3, 74.7 at L3/4, and 81.2 at L4/5. There was a significant difference between L2/3 and L4/5 and between L3/4 and L4/5, but not between L2/3 and L3/4 (P=0.02, 0.01, and 0.94, respectively). The lateral and medial lumbar plexus localization was 85.4 at L2/3, 83.9 at L3/4, and 77.7 at L4/5. There was a significant difference between L2/3 and L4/5 and between L3/4 and L4/5, but not between L2/3 and L3/4 (P= 0.01, 0.04, and 0.41, respectively).

Conclusions: The lumbar plexus was localized in the posterior one-third and medial one-third of the psoas muscle and moved to a posterolateral location at L4/5. To avoid neuropathy, consider the psoas muscle's position relative to that of the intervertebral disc. It is essential to understand lumbar plexus localization in the psoas muscle when looking directly at this muscle to enter the pricking point or route with a lower risk of nerve damage.

Keywords:

localization, lumbar plexus, psoas muscle, transpsoas approach, nerve complication, lumbar spine surgery, cadaver, anatomy

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Introduction

Low back pain and/or lower limb pain due to degenerative lumbar disease or adult spinal deformity lowers patients' activities of daily living and quality of life. Surgical treatment may be necessary for intractable pain; minimally invasive surgery facilitates early post-operative recovery. In recent years, fusion surgery, using a lateral approach to the lumbar spine, has been widely used because it is minimally invasive and has marked corrective and decompression effects[1,2]. However, there are complications associated with this procedure. Among them, the development of perifemoral symptoms on the approach side, also called lumbar plexus syndrome, reportedly occurs quite frequently, and some patients may develop permanent neuropathy[3-5]. These post-operative neurological symptoms can lead to delayed

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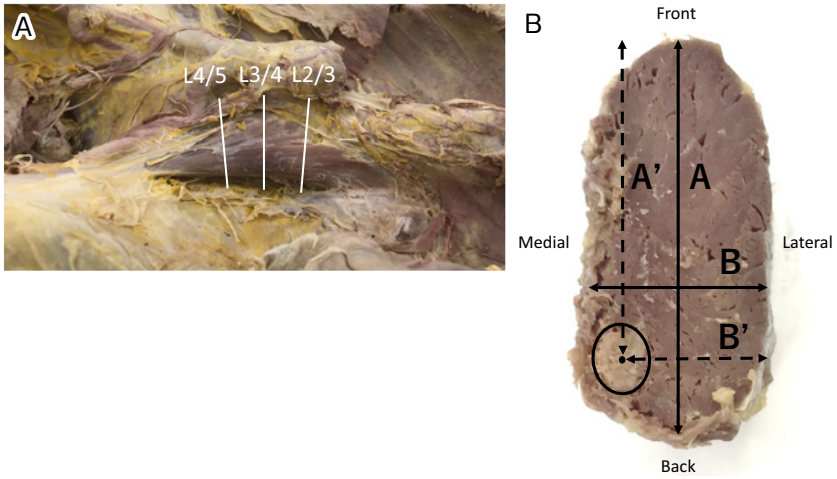

Figure 1. (A) The left psoas muscle was dissected from the lumbar vertebra, and a sharp split was made at the L2/3, 3/4, and 4/5 disc heights parallel to the disc. (B) Digitized images of each section plane were used to evaluate the position of the lumbar plexus in the psoas muscle. This figure shows the anterior–posterior position in the psoas muscle, calculated as A'/A×100 (%) [lumbar anterior–posterior diameter of the psoas muscle (A px), distance from anterior margin of the psoas muscle to the center of lumbar plexus (A' px)] and inner and outer positions, calculated as B' / B× 100 (%) [lateral diameter of the psoas muscle (B px), distance from the outer edge of the psoas muscle to the center of lumbar plexus (B' px)].

rehabilitation and lasting distress. Therefore, surgical approaches must be reconsidered.

Because the lateral approach to the lumbar spine either enters the psoas muscle or advances in front of the psoas muscle, the running position of the lumbar plexus within the psoas muscle must be understood to prevent damage to the lumbar plexus. Several reports have described the lumbar plexus location relative to the vertebral body[6-8], but few have mentioned the plexus location within the psoas muscle[9,10]. We herein report lumbar plexus localization in the psoas muscle using human cadavers.

Materials and Methods

The study used 27 formalin-fixed cadavers. The left psoas muscle (psoas major and psoas minor), which is typically entered by the lateral approach in lumbar spine surgery, was dissected from the lateral side of the vertebral body and transverse process, and the spinal nerves were dissected at the foramen. The released psoas was cut parallel to the disc at the L2/3, L3/4, and L4/5 disc levels (Fig. 1A). The localization of the lumbar plexus was measured on a digitized image of a photograph of the psoas muscle cross-section. Using Microsoft Paint (Microsoft Corp., Redmond, WA, USA), the distance in pixels (px) from the anterior margin of the psoas muscle to the center of the lumbar plexus (A' px) at the anterior-posterior (AP) diameter of the psoas muscle (A px) and the distance from the lateral edge of the psoas muscle to the center of the lumbar plexus (B' px) at the lateral-medial (LM) diameter of the psoas muscle (B px) was calculated as the AP position [A'/A×100 (%)] and the LM position [B'/B×100 (%)], respectively, in the psoas muscle (Fig. 1B). The localization was compared among the levels using the t-test after confirmation of normal distribution, and $P<0.05$ was considered statistically significant. The Ethics Committee of our institution approved this study.

Results

The mean location of the lumbar plexus in the AP direction was 74.5±11.4 at L2/3, 74.7±9.9 at L3/4, and 81.2±9.3 at L4/5. There was a significant difference between L2/3 and L4/5 and between L3/4 and L4/5, but not between L2/3 and L3/4 (P=0.02, 0.01, and 0.94, respectively) (Fig. 2A). The mean location of the lumbar plexus in the LM direction was 85.4±6.4 for L2/3, 83.9±7.4 for L3/4, and 77.7±13.2 for L4/5. There was a significant difference between L2/3 and L 4/5 and between L3/4 and L4/5, but not between L2/3 and L3/4 (P=0.01, 0.04, and 0.41, respectively) (Fig. 2B). These findings indicate that the lumbar plexus is located at the posterior one-third part and the medial one-third part of the psoas muscle and that the lumbar plexus shifts to the posterolateral side in the psoas muscle at the L4/5 level.

Discussion

The spinal nerves of the lumbar spine form the lumbar plexus in the psoas muscle after exiting the foramen. The localization of the lumbar plexus in the psoas muscle is often unclear even on a preoperative cross-sectional magnetic

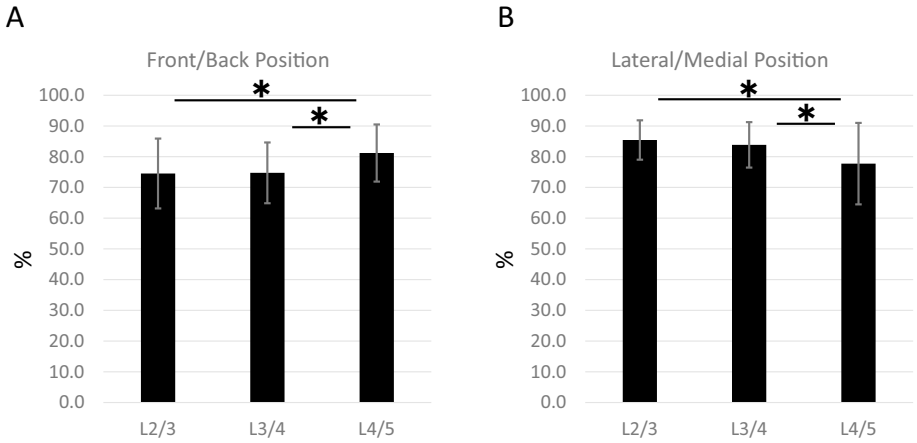

Figure 2. (A) Localization of the lumbar plexus in the anterior–posterior direction was significantly different between L2/3 and L4/5 and between L3/4 and L4/5 (P=0.02 and 0.01, respectively). (B) In the inward and outward directions, significant differences were observed between L2/3 and L4/5 and between L3/4 and L4/5 (P=0.01 and 0.04, respectively). The localized lumbar plexus in the posterior one-third and inward one-third of the psoas muscle and L4/5 shifted posteriorly and laterally compared with other high places.

resonance (MR) image. The psoas muscle entry point is identified during the operation in a narrow field of view without looking at the nerve. This procedure causes lower limb weakness and impaired perception from the groin to the thigh due to lumbar plexus injury, causing decreased post-operative satisfaction and delayed recovery[4].

Direct damage of the lumbar plexus or traction of it to the back (indirect damage) may cause neuropathy. Placement of the psoas muscle entry has been recommended between the middle and anterior third of the psoas muscle[11]; however, there was a limit in preventing complications[12]. It is necessary to understand lumbar plexus localization within the psoas muscle when looking directly at it and to modify the approach path to decrease the risk of nerve damage. At the same time, it is also necessary to reduce the amount of muscle to be pulled to reduce the traction force. The anterior two-thirds of the psoas muscle is a safe zone, where the lumbar plexus does not pass. Entry from the anterior one-third point of the psoas muscle and minimal opening of the retractor to posterior are recommended.

Several cadaver studies have focused on the lumbar plexus localization associated with lateral transpsoas entry[13]. At the L4/5 level, the plexus runs more anteriorly than at the other levels on the lateral side of the vertebral body[14-16], indicating a narrow safety zone at the AP diameter of the vertebral body and a high risk of nerve damage. Clinical reports suggest that lumbar plexus damage increased at the L4/5 level[17-19] because the lumbar plexus emerges anterior to the vertebral body as it courses toward the caudal side, increasing the incidence and severity of nerve damage during entry or manipulation. However, even in the L4/5 level, the lumbar plexus, which is localized in the posterior one-third of the psoas muscle, shifts further to the posterior in the psoas muscle. Nerve damage must be avoided by looking directly at the muscular surface and confirming a safe entry point around the anterior one-third point of the psoas muscle. Then, while looking through the fluoroscopy, proceed toward the anterior one-third point of the intervertebral disc (Fig. 3A). We can safely manipulate the intervertebral disc by pulling the psoas muscle backward from the anterior one-third point of the intervertebral disc in both the direct lateral approach and oblique approach (Fig. 3B).

During surgical planning, the lateral approach's suitability should be evaluated on the cross-sectional MR image. The relative position of the psoas muscle and the lumbar spine differs among individual MR image cross-sections[20]. Localization of the psoas muscles in a more forward position relative to the disc is called the rising psoas sign and is a risk factor for nerve damage[21]. Changes in the psoas muscle position with spinal deformities, such as scoliosis, can occur[22].

A limitation of the present study is that neither the relative position between the vertebral body and the psoas muscle nor the spinopelvic alignment could be evaluated because the cadavers' images were not examined. Based on this study's results, the transpsoas approach might be contraindicated if the posterior one-third line of the psoas muscle is ahead of the anterior one-third line of the intervertebral disc in the MR image cross-section. To avoid lumbar plexus injuries when entering the psoas muscle, it is necessary to evaluate both the position of the lumbar plexus in the vertebral body coordinate system and the relative position of the posterior one-third line of the psoas muscle in its cross-section.

Conclusion

In the present study, the lumbar plexus was localized in the posterior one-third and medial one-third part of the psoas muscle and moved toward the dorsal and lateral direc-

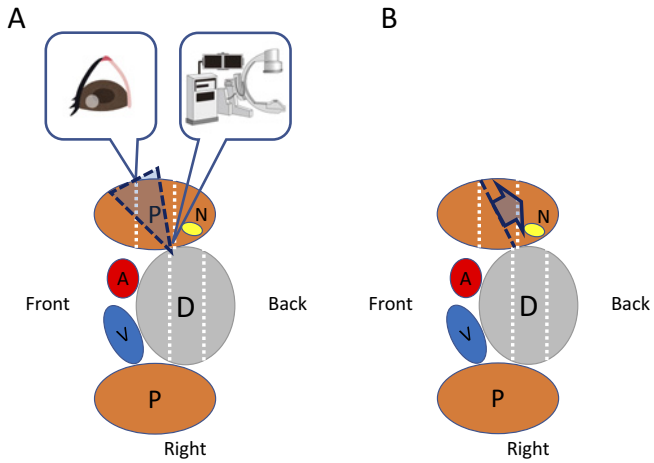

Figure 3. (A) The operative field is drawn in the cross-section (right lateral position). The relative position of the posterior one-third line of the psoas muscle and the intervertebral disc is essential for judging the suitability of the approach. To avoid damaging the lumbar plexus, it is necessary to confirm the anterior-posterior diameter and the anterior one-third point of the psoas muscle by direct vision. We can safely proceed from the entry point, around the anterior one-third point of the psoas muscle, toward the anterior one-third point of the intervertebral disc while checking fluoroscopy (the dotted triangle is a safe area). (B) We can manipulate the intervertebral disc safely by pulling the psoas muscle backward from the anterior one-third point of the intervertebral disc. P: psoas muscle, D: disc, N: lumbar plexus, A: artery, V: vein

tion at L4/5. Neuropathy may be avoided by considering both the psoas muscle morphology and the relative position between the psoas muscle and the lumbar spine.

Conflicts of Interest: The authors declare that there are no relevant conflicts of interest.

Ethical Approval: The Ethics Committee of our institution approved this study.

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Author Contributions:

Study conception and design: HN, TO, YO, TS, KK

Acquisition of data: HN, KM, NK, TS, TH, HK

Analysis and interpretation of data: HN, KM, NK, TS, TH

Drafting of the manuscript: HN

Critical revision: HN, TO, YO, KK

Informed Consent: This is a cadaver study.

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