Original Article

Dissimilar Planes and Approaches with Common Neural Targets – A Cadaveric Evaluation of Three Different Ultrasound-guided Fascial Plane Blocks for Lumbar Plexus Nerves

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Abstract

Background: The lumbar plexus (LP) is a group of nerves located at the fourth lumbar vertebra level, between the anterior two-thirds and posterior one-thirds of the psoas muscle. In this study, the researchers aimed to investigate the spread of latex in injections of LP, suprainguinal fascia iliaca, and circum-psoas planes to assess the different regional techniques for blocking LP nerves (LPNs). **Methods:** The study involved performing ultrasound-guided injections of three different colored latexes in six cadavers. The researchers observed and compared the spread of latex in each plane by taking cross sections at the levels of L4, anterior superior iliac spine (ASIS), and sacral foramina (SF). The spread of latex and LPN staining was documented and analyzed through photography. **Results:** The results showed that the latex spread within the psoas muscle and fascia iliaca plane (FIP) during LP injections, whereas suprainguinal fascia iliaca injections showed latex dissemination in the FIP at both ASIS and SF levels. On the other hand, circum-psoas injections spread beneath the iliopsoas fascia at both levels and medially toward the external iliac vessels. Despite this spread, there was no communication between the three planes, and there was no mixing of latex from the different injections at any level. **Conclusion:** There are distinct fascial planes, for the three approaches, with no communication between them. While latex diffused from LP plane to FIP, no mixing of dye was observed and also the reverse could not be achieved. These findings suggest that different regional techniques for blocking LPNs have their unique planes of action.

Keywords: Fascial planes block, lumbar plexus nerves block, peripheral nerve block, regional nerve block, ultrasound-guided block

Introduction

The lumbar plexus (LP) is formed within the psoas major (PM) at its junction between the anterior two-third and posterior one-third, in the LP plane (LP-P). The LP nerves (LPNs) emerge at the lateral and medial borders of the PM and are situated in conduits formed between the psoas fascia and the PM, termed as the circum-psoas plane (CP-P). Exiting the psoas fascia, the femoral and lateral femoral cutaneous nerves course laterally in fascia-iliaca plane (FIP), whereas the obturator nerve is positioned medially in a separate muscular fold.

LPNs can be blocked at different levels with varying involvement to provide analgesia and anesthesia to the anterior and medial aspects of lower limb. Injections in the LP-P are termed LP blocks (LPBs) alias the psoas compartment block, in the FIP is the suprainguinal fascia iliaca block (SIFI-B), and in the CP-P is the circum-psoas block (CPB). The LPB has been utilized as an anesthetic and analgesic for unilateral hip surgery,[1] whereas the CPB and SIFI-B are analgesic techniques.[2,3] The LPB is a proximal block targeting the LP before the nerves take their individual courses. The latter two blocks are fascial plane blocks relying on spread and diffusion

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of local anesthetic to optimally block LPNs, where the spread and involvement of the obturator nerve have been unpredictable and inconsistent.[4,5] Since the LPNs can be approached at different positions due to their topography, we hypothesized that three different fascial planes, the LP-P, CP-P, and FIP, all of which host the LPNs, might communicate, change, or limit the drug spread pattern or even make it predictable. It is to be recollected that the FIP is the large fascia, also known as the iliopsoas fascia encasing both PM and iliacus muscles.[6]

Hence, this study was designed to observe and compare latex spread within three injection techniques, namely, LP injection (LP-I), circum-psoas injections (CP-Is), and suprainguinal fascia iliaca injection (SIFI-I), whether the planes intersect at any point (revealed if any by an intermix of the dye). In addition, we wanted to evaluate if there was subparaneural intraneural deposition of dye and if there were unnecessary or unusual spreads in different planes.

Materials and Methods

Six bodies donated to science falling under the strict rules of the donation program of the Department of Macroscopic and Clinical Anatomy of the Medical University of Graz and the Styrian burial law was investigated. The cadavers were embalmed with Thiel's method which provides very lifelike conditions for investigations of regional anesthesia backgrounds including ultrasound-guided techniques.[7-14] Six cadavers were randomly selected to receive 18 injections – 6 on the left and 12 on the right [Table 1].

Block techniques

Ultrasound-guided injections of the latex were performed in three different fascial planes. In each of the six cadavers, a curvilinear probe was deployed for LP-I (2-4 mHz, M turbo Fuji-Sonosite, Frankfurt am Main, Germany), whereas linear transducer (13-5 mHz, M turbo Fuji-Sonosite, Frankfurt am Main, Germany) was for SIFI-I and CP-I. Green latex was used for LP-I, blue for SIFI-I, and yellow latex for CP-I so that intermingling of different colors can be visualized easily. A 100-mm insulated needle (22 G, Stimuplex Ultra 360; B.Braun Melsungen AG, Germany) was used for all injections. Before latex injection, hydrodissection with 3 mL 0.9% saline injection in real-time ultrasound confirmed the target areas (LP-P, SIFI-P, and CP-P), followed by an injection of 20 mL of colored latex. The latex used was a diluted latex which is regularly used for intra-arterial injections[7] and has been described for the assessment of a simulated lumbar artery spread.[7,8,12,15] The injection techniques for all three approaches followed standard descriptions in the literature.[4,16,17] The nerve block descriptions are detailed in Table 2 [Figures 1-3].

Table 1: The injections performed and the total number

Cadaver number	Left single injection	Right combination injections	Total number of injections
1	LP-I	LP-I + SIFI-I	LP-I=8
2	LP-I	LP-I + SIFI-I	
3	SIFI-I	LP-I + SIFI-I	SIFI-I=5
4	SIFI-I	LP-I + CP-I	
5	CP-I	LP-I + CP-I	CP-I=5
6	CP-I	LP-I + CP-I	

LP-I: Lumbar plexus injection, SIFI-I: Supra-inguinal fascia iliaca injection, CP-I: Circumpsoas injection

Postinjection, all cadavers were frozen at − 20° centigrade for 2 weeks, after which cross sections were executed with a band saw. Markings were accomplished by ultrasound with a linear probe at L4 spinous process, the level of anterior superior iliac spine (ASIS), and sacral foramina (SF) for cross sectioning. The yielded specimens were analyzed for spread of injectate at the above levels. The latex spread through the planes was evaluated in all cadaver specimens (left and right sided), and LPN staining was observed and compared (right sided).

Results

Ultrasound findings

Ultrasound scan identified all planes appropriately and aided correct needle tip placement in all the blocks. A hyperechoic spread was visualized after latex injections in all fascial planes.

In the LP-P, lumbar nerve roots appeared as hyperechoic structures arising from within the intervertebral foramina. After LP-I was performed (2 left sided in CAD 1 and CAD 2 and 6 right sided in CAD 1-6), the latex spread was visualized within the substance of the PM muscle (PMM), in a cleavage plane at the junction of the anterior two-third and posterior one-third of the muscle in all eight injections.

Five SIFI-I were executed (2 left sided in CAD 3 and CAD 4 and 3 right sided in CAD 1-3), and upon injection, although there was a caudal hyperechoic spread, the cephalad dispersion was predominant. Latex disseminated between the fascia iliaca and iliacus muscle.

CP-I was accomplished in five cadavers (2 left sided in CAD 5 and CAD 6; 3 right sided in CAD 4-6). Latex injections were implemented in the CP-P (beneath the psoas fascia and superficial to the psoas muscle). Following injection, the latex distributed below the psoas fascia and superficial to the PM.

Cross-section findings

Cross sections at the level of L4, divulged the green latex in the LP-P and travelling lateral, through a cleavage between the anterior two-third and posterior one-third, and exuding in the FIP [Figure 4] and had dissected in the intraneural-extra fascicular region of the femoral nerve [Figure 5a]. The green latex was in close approximation with the LP on its anterior, posterior, and lateral aspect [Figure 6a]. Latex was distributed on the medial aspect of the LP in close vicinity of the intervertebral foramina [Figure 6a]. Transverse section at ASIS revealed the green latex in the FIP near the FN [Figure 6b]. However, no green latex was visible at the SF level. There was no intraneural, intervertebral foraminal, and epidural deposition of latex in any cadaver [Figures 4, 5a and 6a].

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Table 2: Block description

Block	Cadaver position	Block technique	Probe placement	Internal target	Needle tip position	Anticipated spread
LPB	Lateral	Shamrock[16] LP-I in the LP-P	Curvilinear probe placed axially just above iliac crest at the mid-point of line joining subcostal and iliac crest at the mid-axillary line	LP at the junction between anterior 2/3rd and posterior 1/3rd of PM muscle	LP [Figure 1]	In the LP-P
SIFI-B	Supine	Desmet's[2] modified SIFI-B in the SIFI-P	Linear probe placed sagittal over the midpoint of the inguinal ligament, just medial to the ASIS Identification of "Bow-Tie" sign formed by perimysium of sartorius, iliopsoas, and internal oblique	Beneath the fascia iliaca (in the FIP) at the tip of the internal oblique	Below the fascia iliaca [Figure 2]	In the SIFI-P
CPB	Supine	Circumpsoas block[4] as described by Diwan CP-I in the CP-P	Linear probe placed sagittal further medially of the SIFI Identification of psoas muscle along with the psoas fascia	Beneath the psoas fascia above the inguinal ligament	Below the psoas fascia [Figure 3]	In the CP-P

LP: Lumbar plexus, SIFI: Supra-inguinal fascia, LP-P: LP plane, SIFI-P: SIFI iliaca plane, CP-P: Circumpsoas plane, LP-I: LP injection, SIFI-I: SIFI iliaca injection, CP-I: Circumpsoas injection, SIFI-B: SIFI iliac block, ASIS: Anterior superior iliac spine, FIP: Fascia-iliaca plane, LPB: LP block, CPB: Circum-psoas block, PM: Psoas major

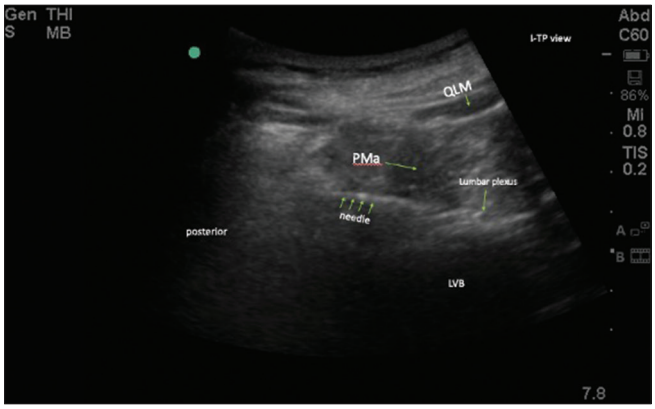

Figure 1: The sonoanatomy of the injection plane for the Lumbar plexus block. PMa: Psoas Major muscle, LVB: Lumbar vertebral body, QLM: Quadratus lumborum muscle, I-TP: Inter transverse process view

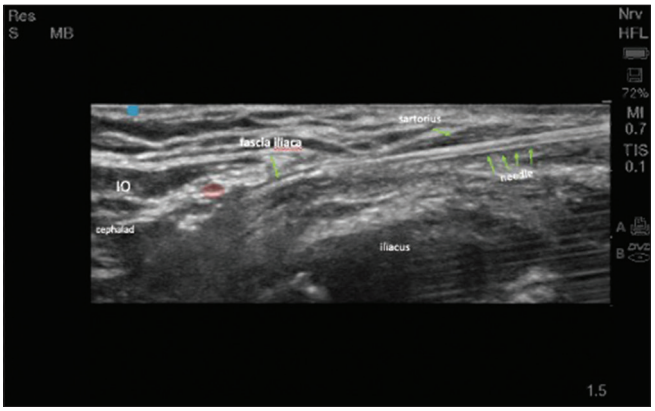

Figure 2: The sonoanatomy of the injection plane of the suprainguinal facia iliac block. IO: Internal oblique

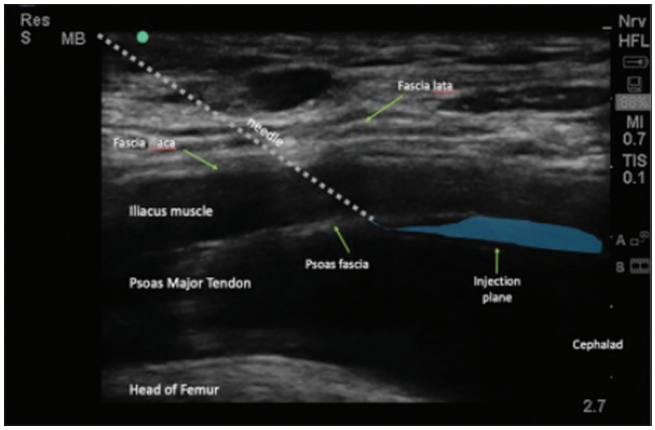

Figure 3: The sonoanatomy of the injection plane in the circus poses block

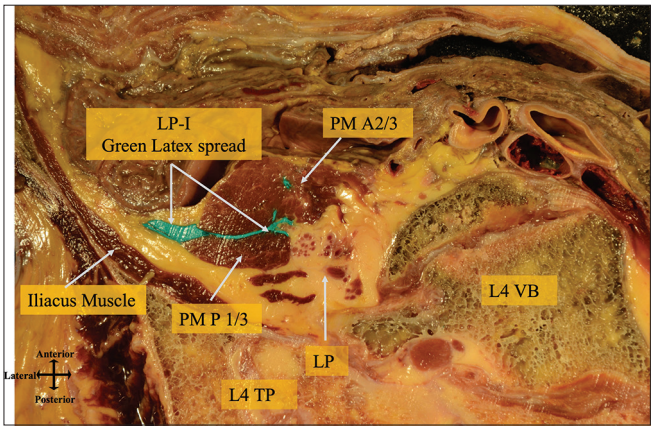

Figure 4: Image showing cadaver section at L4 level on the left side following lumbar plexus injection. L4 VB: L4 vertebral body, L4 TP: L4 transverse process alias costal process, LP: Lumbar plexus, LP-I: Lumbar plexus injection, PM A 2/3: Psoas major anterior 2/3, PM *P* 1/3: Psoas major posterior 1/3

Cross section at the level of ASIS, where SIFI-I was executed, revealed spread of the blue latex in the FIP, bounded by the superficial and the deep layers, which also engulfed the FN [Figure 7]. Anterior to the superficial layer of FIP was the branches of the LFCN and beneath the fat pad was the FN resting on the iliacus muscle [Figure 7]. At L4 level, the latex was visualized lateral and anterior to the PM but never breached

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the fascia lining of the PM [Figure 6a]. We did not observe the different colored latex (Green and Blue), intermingling with each other in any of the injections [Figures 4, 5a and 6a].

Five CP-I were performed, wherein latex spread was observed below the iliopsoas fascia, anterior, and medial to the PM [Figure 8], in all cadavers, at ASIS and SF levels. It thus highlighted the FN in the sulcus between the iliacus and the psoas muscles [Figures 6b and 8] anterior and medial to the psoas the GFN and reached lateral until the LFCN [Figures 5a, 6b and 8]. The medial spread extended to the external iliac vessels, by a latex distribution above the psoas fascia [Figures 6b and 8]. However, the ON was not reached in the lesser pelvic area. The dye involving or reaching the nerve is described in Table 3 [Figure 5b].

Discussion

In our study, three different 20 mL colored latex injections were performed at three different sites that host the course of the LPN. Based on latex spread, we investigated whether the injection planes intersect at any point and stain the LPNs which has not been performed to our knowledge.

The ventral rami of the lumbar spinal nerves exit the intervertebral foramen forming the final nerve arrangements of the LP within the PMM in its posterior one-third. The LPNs eventually exit the lateral and medial borders of PM and are situated in the various planes: The LP in the LP-P (within the PM), the LPNs in the CP-P (between the psoas fascia and the PM), and the SIFI (beneath the fascia iliaca and superficial to the iliacus muscle) planes. The ON is located within the LP-P and the CP-P but very medial and cranial. The FN and LCFN exit the lateral border of the PM and therefore must pass the CP-P in their lateral course. However, the SIFI-P hosts exclusively the LFCN and the FN.

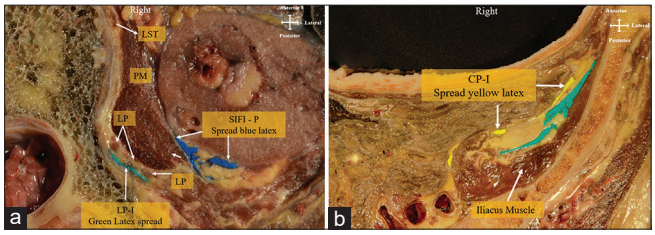

Figure 5: (a) Cross section at level of L4 right sided LP-I (green) and SIFI-I (blue) spread illustrates diffusion in the LP-P and the SIFI-P respectively. Note the thin band of green latex spread medial the LP in the LP-P. Green latex is in close vicinity of the lumbar plexus. (Identified is the blue latex lateral to the psoas muscle which is injected in the SIFI-P). (b) Cross section at level of ASIS right sided CP-I (yellow) and LP-I (green) spread illustrates diffusion in the CP-P. Diffusion occurs beneath the ilio-psoas fascia, medial and reaching the external iliac vessels. It engulfs the GFN, skirts superficial to FN and reaches the site of LFCN. LP: Lumbar plexus, LP-I: Lumbar plexus injection, PM: Psoas major, SIFI: Supra-inguinal fascia iliaca, LP-I: Lumbar plexus injection, CP-I: Circum-psoas injection, FN: Femoral nerve, LST: Lumbosacral trunk

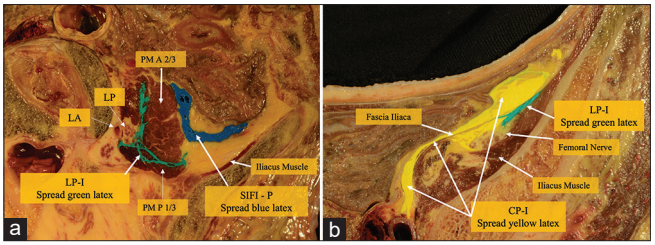

Figure 6: (a) Cross section at level of L4 right sided LP-I (green) and SIFI-I (blue) spread illustrates diffusion in the LP-P and the SIFI-P respectively. Note the posterior to anterior medial to lateral spread inside the psoas muscle. Green latex is in close vicinity and lateral to the LP. (Thick band of blue latex SIFI injection at ASIS spreads cephalad till the L4, is anterior and lateral to the PM. (b) Cross section at level of ASIS right sided CP-I (yellow) and LP-I (green) spread illustrates diffusion in the CP-P. Diffusion occurs beneath the ilio-psoas fascia, medial and reaching the external iliac vessels, it skirts superficial to femoral nerve and reaches the site of lateral femoral cutaneous nerve. LP: Lumbar plexus, LNR: Lumbar nerve root, LP-I: Lumbar plexus injection, PM A 2/3: Psoas major anterior two-thirds, PM P 1/3: Psoas major posterior two-thirds, LA: Lumbar artery, SIFI: Supra-inguinal fascia iliaca, CP-I: Circum-psoas injection, FN: Femoral nerve

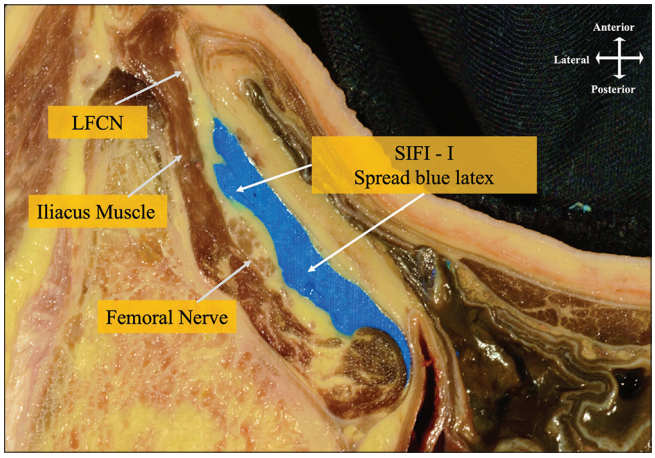

Figure 7: Image showing the dye spread following SIFI plane injections. SIFI: Supra-inguinal fascia iliaca, FN: Femoral nerve, LFCN: Lateral femoral cutaneous nerve

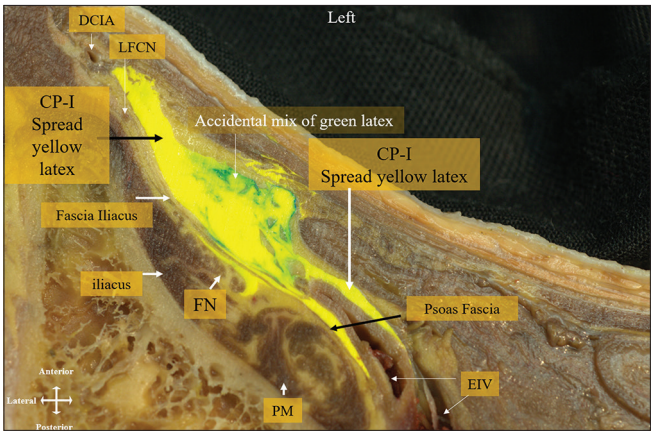

Figure 8: Image showing the dye spread following a circum-psoas injection. CP-I: Circum-psoas injection, FN: Femoral nerve, PM: Psoas major, EIV: External iliac vessels, LFCN: Lateral femoral cutaneous nerve, DCIA: Deep circumflex iliac artery

Table 3: The involvement of lumbar plexus nerves stained with each approach

Nerves involved	LP-I ($n=8$)	CP-I ($n=5$)	SIFI-I ($n=5$)
Femoral	100% (8/8)	100% (5/5)	100% (5/5)
LFCN	Reached the LFCN* - 100% (8/8)	Reached the LFCN* - 80% (4/5)	Reached the LFCN* - 80% (4/5)
Obturator	Reached the ON** - 100% (8/8)	Reached the ON** - 80% (4/5)	Reached the ON** - 0% (0/5)

*Reached the LFCN: Defined as latex reaching the ASIS in the FIP, **Reached the ON: Defined as latex spread on the medial aspect of LP. LP: Lumbar plexus, LFCN: Lateral femoral cutaneous nerve of thigh, ON: Obturator nerve, LP-I: LP injection, SIFI-I: Supra-inguinal fascia iliaca injection, CP-I: Circumpsoas injection, ASIS: Anterior superior iliac spine, FIP: Fascia-iliaca plane

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Based on the previous clinical dose finding study,[16] we injected 20 mL of latex in the LP-P and followed same volumes in the SIFI-P and the CP-P. However, the volumes injected in the latter two planes are very high.[18-20] Between the LP-I and the SIFI-I, it was observed that the LP-I spreads caudal and lateral into the SIFI-P. Undescribed earlier, the pathway from LP-P into the SIFI-P may be possible through a cleavage from medial to lateral at the junction of the posterior one-third and the anterior two-third. Although there was no intermix of the dye, higher volumes between 30 and 40 mL would probably would have led to a mix. Interestingly, the LP-I deposition which was subparaneural in the LP-P, after descending caudal and lateral in the SIFI-P was found to be intraneural and extrafascicular in the femoral nerve [Figure 5b]. However, with injections of latex in the SIFI-P, the dye ascended cephalad and was lateral and anterior to the PM, without penetrating the psoas fascia, which was astonishing. It probably means the nerves with their paraneural sheath are imbibed in the fascial planes. Thus, our injections in the subparaneural LP-P reached intraneural area of FN in the SIFI-P; however, dye injection in the SIFI-P, never breached the psoas fascia to reach the subparaneural area of the LP-P.

As the FN and LFCN course distally, they cross the iliac fossa deep to the fascia iliaca and superficial to the iliacus muscle. In SIFI-I, the latex involved the FN and the LFCNs; however, the ON was spared.

According to Hafferl, the psoas fascia fuses together with the fascia iliaca to form a potential huge compartment beneath the iliopsoas fascia.[6] After the SIFI-I and the CP-I, the dye was totally contained and restricted in the SIFI-P and the CP-Ps. There was never an intermix between the two planes, suggesting that the iliacus and psoas fasciae though blended together are separate.

Apart from the other locations of LPNs as mentioned earlier, the GFN is on the superior surface of the PM.[4] With CP-I, widespread latex was observed at the level of ASIS, involving the femoral and lateral femoral cutaneous nerve, and though latex reached the external iliac vessels, it did not appear to stain the obturator nerve. We postulate that volumes more than 20 ml might reach the obturator nerve. In the CP-I, the yellow latex was confined to CP-P and did not ascend up to level of L4.

The obturator nerve descends from the anterior divisions of L3-4 and is situated medial to the FN. Between L5 and S1, the nerve surfaces on the medial aspect of the PM, piercing the psoas fascia, at times, it is known to be situated in a separate muscular plane. Cadaveric studies with dye injections deep to the fascia iliaca, above the level of inguinal ligament, highlighted involvement of the FN, LFCN, and ON, with very high volumes (40–62.5 mL) of injectate;[2,18-20] however, others have refuted this possibility.[5] Moreover, in our study, 20 mL of latex did not stain the ON in any of the cadavers with the CP-I and the SIFI-I. Based on our study, we reckon a volume more than 20 mL would be prudent to stain the ON, which is integral for an adequate LPB.

We postulate that two interventions may be necessary to completely block the LP in clinical practice either by increasing the volumes of local anesthetic or perform isolated obturator nerve block separately. However, high volumes can tilt the balance in favor of local anesthetic toxicity.

Latex injections with cross sections provide important information considering the spread across the nerve pathways and fascial planes.[4] Since we recognize the definitive course of the nerve arising from the LP, obtaining cross sections at definitive levels such as the L4, ASIS, and SF as is in the current study allowed us to decipher the dye dispersion. As opposed to the dissection of cadaver causing dye dissemination in unwanted areas with staining of unnecessary structures, cross sections provide decisive knowledge concerning the dispersal of injectate to the deeper layers and relation of the injectate to the surrounding structures. Moreover, antithetical to methylene blue dye which percolates through tissue layers and stains everything in the vicinity of the injection point; the latex is confined to the injected area, in the connective tissue, and in approximation with the nerve. Dye spread to other planes such as the transversus abdominis plane, Quadratus, and the Erector spinae plane were not visualized.

The limitations of this study include the small cadaver sample size. Furthermore, the fixed volumes of injectate used which may influence the spread and involvement of the LPNs through their planes. The use of liquid latex (viscous solution) as opposed to nonviscous dye solutions may have differed spread properties through the tissue planes. In addition, dye diffusion in cadaver cannot be extrapolated to local anesthetics spread, limiting the interpretation to clinical outcomes.

Conclusion

Based on our cadaveric study, we conclude that separate fascial planes exist for the three approaches with no communication between LP and the SIFI or CP planes. Although latex disseminated from LP to SIFI plane, vice versa was not true.

The three LPNs are stained by LP-I, but the obturator nerve is spared with SIFI-I or CP-I, however, might be reached with the use of very large volumes or separate injections.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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References

1. Mannion S, Barrett J, Kelly D, Murphy DB, Shorten GD. A description of the spread of injectate after psoas compartment block using magnetic resonance imaging. Reg Anesth Pain Med 2005;30:567-71.
2. Desmet M, Vermeylen K, Van Herreweghe I, Carlier L, Soetens F, Lambrecht S, *et al*. A longitudinal supra-inguinal fascia iliaca compartment block reduces morphine consumption after total hip arthroplasty. Reg Anesth Pain Med 2017;42:327-33.
3. Feigl GC, Dreu M, Ulz H, Breschan C, Maier C, Likar R. Susceptibility of the genitofemoral and lateral femoral cutaneous nerves to complications from lumbar sympathetic blocks: Is there a morphological reason? Br J Anaesth 2014;112:1098-104.
4. Diwan S, Nair A, Gawai N, Shah D, Sancheti P. Circumpsoas block. An anterior myofascial plane block for lumbar plexus elements: Case report. Braz J Anesthesiol 2023;73:689-94.
5. Bendtsen TF, Pedersen EM, Moriggl B, Hebbard P, Ivanusic J, Børglum J, *et al.* Anatomical considerations for obturator nerve block with fascia iliaca compartment block. Reg Anesth Pain Med 2021;46:806-12.
6. Bein HA. Lehrbuch Der Topographischen Anatomie. 2nd ed. Springer: Springer Verlag; 1957
7. Thiel W. An arterial substance for subsequent injection during the preservation of the whole corpse. Ann Anat 1992;174:197-200.
8. Thiel W. Ergänzung für die Konservierung Ganzer Leichen Nach W. Thiel. Ann Anat 2002;184:267-9.
9. Feigl GC, Anderhuber F, Dorn C, Pipam W, Rosmarin W, Likar R. Modified lateral block of the suprascapular nerve: A safe approach and how much to inject? A morphological study. Reg Anesth Pain Med 2007;32:488-94.
10. Feigl G, Fuchs A, Gries M, Hogan QH, Weninger B, Rosmarin W. A supraomohyoidal plexus block designed to avoid complications. Surg Radiol Anat 2006;28:403-8.
11. Feigl GC, Rosmarin W, Stelzl A, Weninger B, Likar R. Comparison of different injectate volumes for stellate ganglion block: An anatomic and radiologic study. Reg Anesth Pain Med 2007;32:203-8.
12. Feigl GC, Ulz H, Pixner T, Dolcet C, Likar R, Sandner-Kiesling A. Anatomical investigation of a new vertical obturator nerve block technique. Ann Anat 2013;195:82-7.
13. Benkhadra M, Faust A, Ladoire S, Trost O, Trouilloud P, Girard C, *et al.* Comparison of fresh and Thiel's embalmed cadavers according to the suitability for ultrasound-guided regional anesthesia of the cervical region. Surg Radiol Anat 2009;31:531-5.
14. Munirama S, Eisma R, Columb M, Corner GA, McLeod GA. Physical properties and functional alignment of soft-embalmed Thiel human cadaver when used as a simulator for ultrasound-guided regional anaesthesia. Br J Anaesth 2016;116:699-707.
15. Feigl G, Aichner E, Mattersberger C, Zahn PK, Avila Gonzalez C, Litz R. Ultrasound-guided anterior approach to the axillary and intercostobrachial nerves in the axillary fossa: An anatomical investigation. Br J Anaesth 2018;121:883-9.
16. Sauter AR, Ullensvang K, Niemi G, Lorentzen HT, Bendtsen TF, Børglum J, *et al.* The Shamrock lumbar plexus block: A dose-finding study. Eur J Anaesthesiol 2015;32:764-70.
17. Diwan S, Nair A, Gawai N, Sancheti P. Flow dynamics of ultrasound-guided lumbar plexus block in adults. J Anaesthesiol Clin Pharmacol 2021;37:565-8.
18. Winnie AP, Ramamurthy S, Durani Z, Radonjic R. Plexus blocks for lower extremity surgery: New answers to old problems. Anesthesiol Rev 1974;1:11-6.
19. Vermeylen K, Soetens F, Leunen I, Hadzic A, Van Boxtael S, Pomés J, *et al.* The effect of the volume of supra-inguinal injected solution on the spread of the injectate under the fascia iliaca: A preliminary study. J Anesth 2018;32:908-13.
20. Kantakam P, Maikong N, Sinthubua A, Mahakkanukrauh P, Tran Q, Leurcharusmee P. Cadaveric investigation of the minimum effective volume for ultrasound-guided suprainguinal fascia iliaca block. Reg Anesth Pain Med 2021;46:757-62.