REGIONAL ANESTHESIA AND ACUTE PAIN

ORIGINAL ARTICLE

A Cadaveric Study of Ultrasound-Guided Subpectineal Injectate Spread Around the Obturator Nerve and Its Hip Articular Branches

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Background and Objectives: The femoral and obturator nerves are assumed to account for the primary nociceptive innervation of the hip joint capsule. The fascia iliaca compartment block and the so-called 3-in-1-block have been used in patients with hip fracture based on a presumption that local anesthetic spreads to anesthetize both the femoral and the obturator nerves. Evidence demonstrates that this presumption is unfounded, and knowledge about the analgesic effect of obturator nerve blockade in hip fracture patients presurgically is thus nonexistent. The objectives of this cadaveric study were to investigate the proximal spread of the injectate resulting from the administration of an ultrasound-guided obturator nerve block and to evaluate the spread around the obturator nerve branches to the hip joint capsule.

Methods: Fifteen milliliters of methylene blue was injected into the interfascial plane between the pectineus and external obturator muscles in 7 adult cadavers. The spread of the injectate into the obturator canal and around the obturator and accessory obturator nerve branches to the hip joint was evaluated by subsequent dissection.

Results: The injected dye spread into the obturator canal and colored all obturator branches to the hip joint capsule in all 14 sides. Furthermore, the accessory obturator nerve was present in 3 sides (21%), and the nerve and its branches to the hip joint capsule were colored in all cases.

Conclusions: In cadavers, injection of 15 mL of methylene blue into the interfascial plane between the pectineus and the external obturator muscle effectively spreads proximally to reach the obturator canal, as well as the obturator nerve branches to the hip joint capsule and the accessory obturator nerve.

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Hip fracture is a painful condition with the majority of patients experiencing moderate to severe pain.[1] In the literature, the fascia iliaca compartment block (FICB), the "3-in-1-block" and the femoral nerve block are the peripheral nerve block techniques commonly investigated in regard to alleviating preoperative pain in patients with hip fracture.[2]

The FICB and the 3-in-1-block have both previously been reported to anesthetize the obturator nerve, as well as the femoral and lateral femoral cutaneous nerves.[3,4] These presumptions made such high-volume blocks the most appropriate nerve blocks for preoperative analgesia in patients with hip fracture, because both the femoral and obturator nerves have been found to innervate the hip joint capsule.[5]

Several authors have since questioned the reliability of the FICB and the 3-in-1-block to anesthetize the obturator nerve.[6–10] Recently, a study, using magnetic resonance imaging to visualize the spread of the injectate, refuted any spread of local anesthetic to the obturator nerve after either of the 2 nerve block techniques.[11] Consequently, knowledge of the analgesic effect of an obturator nerve block in preoperative patients with hip fracture is nonexistent. To provide such knowledge, a selective obturator nerve block technique with documented spread of injectate around the obturator nerve and its branches innervating the hip joint capsule is warranted.

Different selective ultrasound-guided obturator nerve block techniques have been published within recent years.[12–16] To the best of our knowledge, none of the previous studies of any ultrasound-guided technique, applicable to patients with hip fracture, have investigated the proximal spread of the injectate into the obturator canal and around the obturator nerve branches innervating the hip joint capsule. Furthermore, no studies have investigated spread of injectate to the accessory obturator nerve (AON), which has been reported to innervate the hip joint capsule consistently, when present.[17]

The purpose of the present cadaveric study was to determine the proximal spread of the injectate into the obturator canal and around the obturator nerve and AON branches innervating the hip joint capsule after ultrasound-guided subpectineal injection.

METHODS

Ultrasound-guided dye injections were carried out bilaterally in 7 cadavers (4 female and 3 male cadavers). They were donated to the Division of Clinical and Functional Anatomy of the Medical University of Innsbruck for scientific and educational purposes.[18,19]

All cadavers were preserved using an arterial injection of an ethanol-glycerol solution and immersion in phenolic acid in water for 1 to 3 months.[20,21] The ultrasound scanning was performed using a high-frequency 13–4 MHz linear array probe (AL2442 probe, Esaote MyLab Seven US System; Esaote, Genoa, Italy).

An ultrasound scan was carried out to visualize the optimal location for injection into the interfascial plane between the pectineus and external obturator muscles close to the inferior margin of the superior pubic ramus. The details of the technique have been presented previously by Taha.[16]

A 100-mm, 22-gauge, short-bevel needle (Stimuplex D Plus; B.Braun, Melsungen, Germany) was inserted out-of-plane into the fascial plane between the pectineus and external obturator muscles[16] (Fig. 1, A and B). Fifteen milliliters of methylene blue (2%) was slowly injected interfascially using a 20-mL syringe (Fig. 1B). Subsequent to the injection, the cadaver was carefully dissected.

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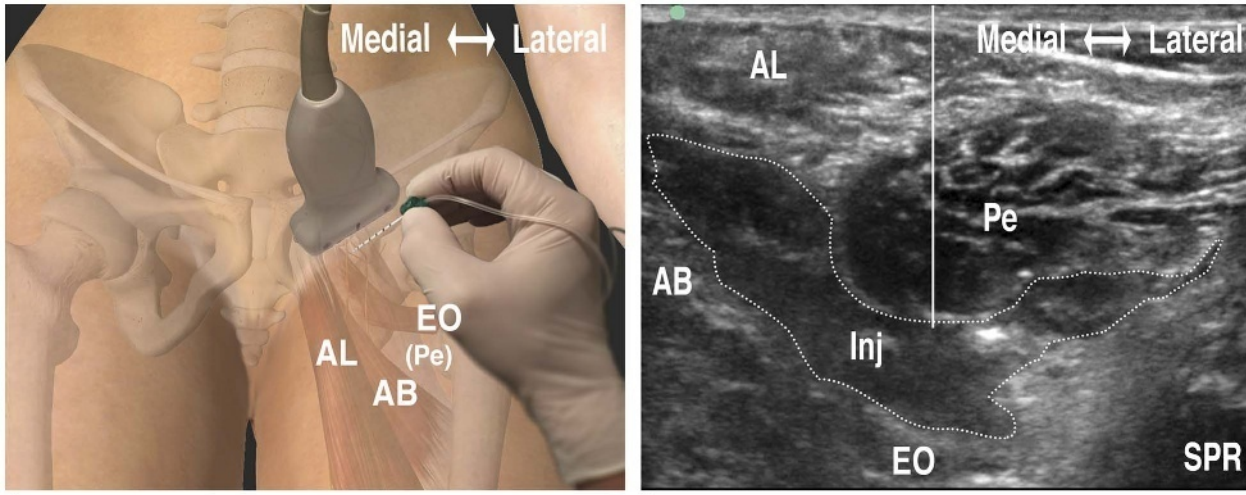

FIGURE 1. A, Transducer position and needle insertion point. AL indicates adductor longus muscle; AB, adductor brevis muscle; (Pe), pectineus muscle (faded); EO, external obturator muscle. The figure is a modified excerpt from Essential Anatomy 5, with permission from 3D4Medical (www.3d4medical.com). B, Ultrasonographic image after the subpectineal injection on the left side. SPR indicates Superior pubic ramus; solid white line, trajectory of the needle.

The injection was defined as successful for spread to the obturator nerve, if the obturator branches to the hip joint capsule were colored by dye or if the dye did spread into the obturator canal, which contains the main trunk of the obturator nerve or the divisions.

Successful spread to the AON was defined as coloring of the AON branches to the hip, when the AON was present, or alternatively spread of the dye along the deep side of the pectineus muscle to its lateral margin at the attachment to the superior pubic ramus.

After completion of each injection, the investigator who performed the injection (T.F.B. or T.D.N.) left the dissecting room, and another investigator (B.M.), who was not present during the injection, carried out the dissection and documented the spread of dye.

The same dissection technique was performed in all 14 sides. This was performed immediately after injection of dye and as quickly as possible to avoid any distortion of results. Accordingly, the 2 initial incisions, 1 proximal incision slightly below the level of the inguinal ligament and a second medial incision along the gracilis muscle, went right through all epimuscular tissue layers. Subsequently, the tissue flap was raised and reflected laterally to expose the iliopsoas, pectineus, and adductor longus muscles, as well as the anterior border of the gracilis muscle. After resection of the superficial neurovascular structures and freeing the fascia covering the pectineus muscle and adductor longus, the gap between the 2 muscles was carefully widened to expose the deeper located adductor brevis muscle (Fig. 2A). Next, the pectineus muscle was transected near its distal attachment and reflected

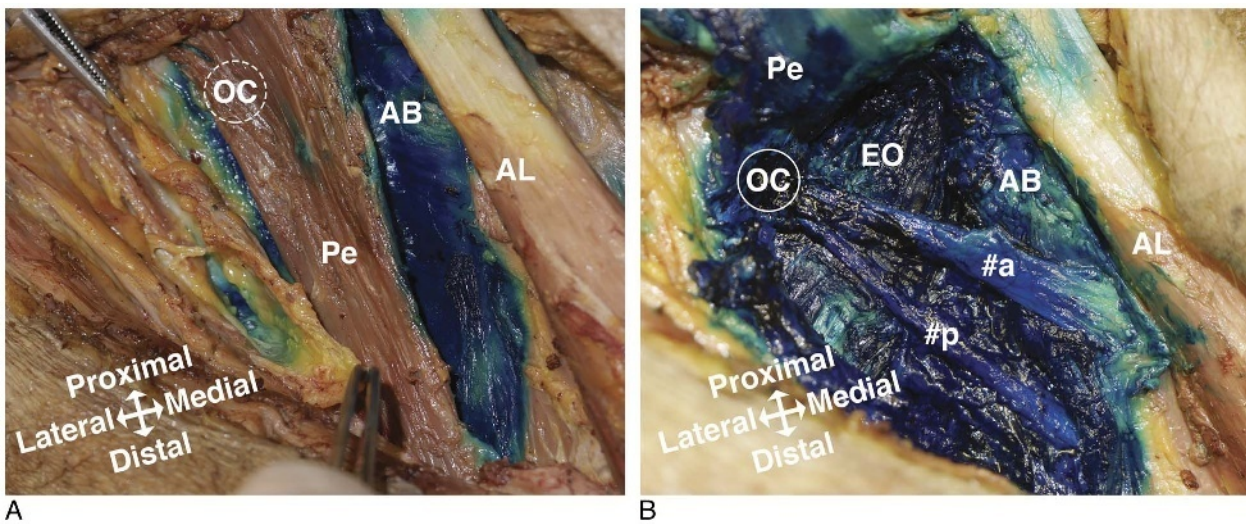

FIGURE 2. A, Exposure of the structures before transection and reflection of the pectineus muscle. OC indicates external orifice of the obturator canal (depiction of the deeper position); Pe, pectineus muscle; AB, adductor brevis muscle; AL, adductor longus muscle. B, After reflection of the pectineus muscle, the anterior (#a) and posterior (#p) divisions of the obturator nerve are visible in their extrapelvic trajectory anterior to the external obturator muscle (EO).Note that the deep surface of the pectineus muscle is stained by methylene blue.

proximally, which exposed the obturator nerve (Fig. 2B). This allowed the obturator nerve to be inspected for perineural spread of dye by following it proximally toward the obturator canal, as well as distally both anteriorly and posteriorly to the adductor brevis muscle.

Finally, the hip articular branches of the obturator nerve, as well as the AON (if present), were identified and followed.

RESULTS

Ultrasonographic identification of the interfascial plane between the pectineus and external obturator muscles close to the inferior margin of the superior pubic ramus was feasible bilaterally in all cadavers. The injected methylene blue spread around the obturator nerve branches to the hip joint in 14 of 14 dissected sides (100%).

The methylene blue solution spread into the obturator canal and colored the trunk of the obturator nerve or its anterior and posterior divisions in 14 of 14 sides (100%).

In addition to spread of dye to the trunk or the divisions of the obturator nerve inside the obturator canal, both the anterior and posterior divisions were also colored in their extrapelvic trajectory by the injection in all cases (100%).

The AON was present in 3 of the 14 dissected sides (21%). Injectate surrounding the AON and its branches to the hip joint capsule was observed in all 3 cases (100%), and methylene blue spread along the deep side of the pectineus muscle to its lateral margin and the attachment to the superior ramus of the pubic bone in all cases when the AON was not present (100%).

DISCUSSION

The present study of 7 cadavers (14 sides) demonstrated that ultrasound-guided injection of 15 mL of dye into the interfascial plane between the pectineus and external obturator muscles, close to the inferior margin of the superior pubic ramus, generates a proximal spread of the injectate into the obturator canal and to the obturator nerve and AON branches to the hip joint capsule with a very high success rate.

The injected methylene blue spread around the AON when present and consistently spread along the deep side of the pectineus muscle to its lateral margin, where the AON lies when present.

The observed pattern of spread of dye around the branches to the hip joint capsule from both the obturator nerve and AON provides evidence in support of the hypothesis that this ultrasound-guided subpectineal single-injection technique would be effective for analgesia as a supplement to a femoral nerve block in patients with hip fracture prior to surgery.

The obturator nerve and the AON both originate from the anterior rami of lumbar plexus spinal nerves L2–L4 (Fig. 3). The variable presence of an AON is 1 of more reasons for the complexity of the innervation of the hip joint capsule. Birnbaum et al[5] reported on the femoral nerve to innervate the anterolateral capsule and the obturator nerve to innervate the anteromedial capsule. Combined innervation of the anterior capsule by 2 nerves was often observed. The posterior and inferior parts of the hip joint capsule were innervated by the sacral plexus. Innervation from the sacral plexus nerves consisted of branches directly from the sciatic or superior gluteal nerves or via the sciatic nerve branch to the quadratus femoris muscle.

A histological study of the hip joint capsule found nociceptive fibers to be predominantly present in the anterior and superolateral parts of the hip joint capsule. Neural fibers found in the posterior and inferior parts were identified as mechanoreceptors.[23] These findings support the assumption that the femoral and obturator nerves are the primary mediators of pain in patients with hip fracture and may thus simplify the innervation of the hip joint capsule from the perspective of analgesia and regional anesthesia.

If these findings are correct, the contribution of this study to a validation of an ultrasound-guided obturator nerve block with spread of injectate to the hip articular branches holds the potential to improve preoperative analgesia in patients with hip fracture.

The present finding of spread of dye into the obturator canal is in good keeping with the result based on dissection of a single cadaver presented by Yoshida et al,[24] who found a similar spread into the obturator canal by using a different technique, not applicable to patients with hip fracture. Yoshida et al[24] did, however, target the same intermuscular space for the injection.

A cadaveric investigation of the proximal spread of injectate after a blind landmark-based injection technique has been conducted previously by Feigl et al,[25] who reported a success rate of

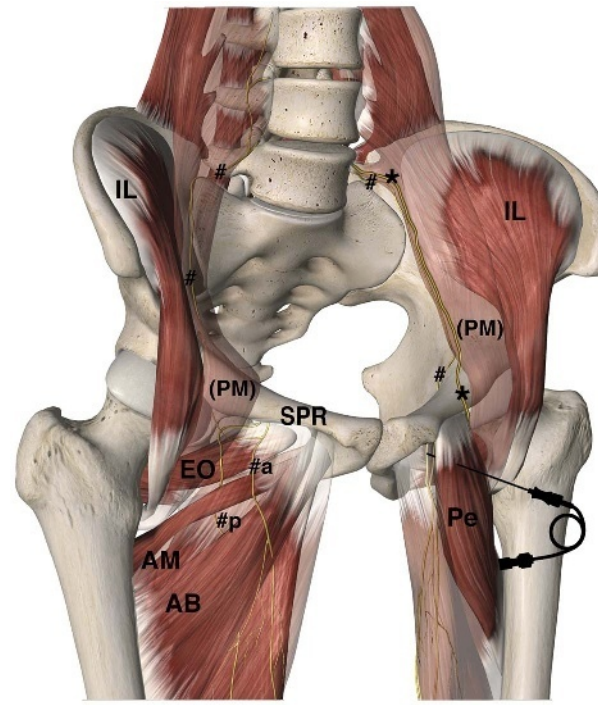

FIGURE 3. The obturator nerve (#) and the AON (*) both originate from the anterior rami of lumbar plexus spinal nerves L2-L4, and both nerves descend along the medial side of the psoas major muscle (PM [faded]). The obturator nerve dives into the lesser pelvis and continues inferiorly to the superior pubic ramus (SPR) and reaches the obturator canal. It branches into an anterior (#a) and a posterior (#p) division, and the hip articular branches originate either from the main nerve trunk or its divisions.[13] All obturator nerve branches leave the pelvis through the obturator canal. The AON lies across the upper surface of the superior pubic ramus and descends directly on the bone deep to the lateral side of the pectineus muscle (Pe).[17,22] The AON has been reported to be present in 13% of sides and, when present, always innervating the hip joint capsule.[17] IL indicates iliac muscle; EO, external obturator muscle; AM, adductor magnus muscle; AB, adductor brevis muscle. The pectineus muscle on the right side and the adductor longus muscle and psoas major muscle bilaterally are faded to make them transparent. The needle and point of injection, just deep to the pectineus muscle, are depicted on the left side. The figure is a modified excerpt from Essential Anatomy 5, with permission from 3D4Medical, San Diego, California.

93% in spread of dye to the trunk of the obturator nerve. However, these authors did not report on the frequency of spread of dye to the obturator canal or the branches to the hip joint capsule.

Previously, other authors have reported effective anesthesia of both the anterior and the posterior divisions of the obturator nerve, using an ultrasound-guided proximal single-injection technique in the interfascial plane between the pectineus and external obturator muscles.[13,16] Our study supports the previously reported effect on both obturator nerve divisions. We observed spread into the obturator canal containing the main obturator nerve trunk or both its divisions. We also documented spread of dye to the anterior and posterior nerve divisions in their extrapelvic trajectory. These findings support the feasibility of this injection technique, also when the indication is to block both of the obturator nerve divisions for more distal analgesic purposes. Total knee arthroplasty is probably the most obvious indication, because the anterior division of the obturator nerve is believed sometimes to supplement the important sensory innervation of the knee from the posterior division of the obturator nerve.[26] Runge et al[27] used the same proximal obturator nerve block technique in a randomized controlled trial on postoperative pain after total knee arthroplasty and showed a significant reduction in morphine consumption when this obturator nerve block was added to a femoral nerve block.

The injection technique used in this study used transverse plane ultrasound imaging and an out-of-plane needle approach. The location of injection most probably corresponds to the location described by Akkaya et al,[12] who used a sagittal scanning technique. The transverse and sagittal approaches can be speculated to be equally effective.

The lumbar plexus block technique also approaches the obturator nerve sufficiently proximal to anesthetize the hip articular branches. In favor of this technique is primarily the concomitant blockage of the femoral nerve. Unfortunately, several issues make the lumbar plexus block less suitable than a more distal approach, including the level of expertise needed to conduct this plexus block without a high incidence of block failures. The predominant drawback is the need for lateral positioning of the patient, which is probably why a randomized controlled trial in patients with hip fracture has never been published. However, in experienced hands and in a selected sample of patients, this plexus block could probably improve preoperative analgesia in patients with hip fracture.

There are certain limitations to our study. First, the present study was conducted as a nonrandomized, nonblinded observational study with the implied limitations of this methodological design. Second, regarding the process of dissection, it can be speculated that the spread of methylene blue could be artifactually enhanced by the dissection itself. This potential bias is always a risk in this type of study, but it can be minimized by meticulous dissection as described in Methods. Third, the spread of methylene blue in a cadaver does not necessarily correspond to the distribution pattern of local anesthetic in living human beings. Finally, the use of embalmed specimens may have facilitated spread of dye that deviates from spread of local anesthetic in the living, but also from spread of methylene blue in either fresh nonembalmed cadavers or cadavers preserved by other techniques. To the best of our knowledge, no existing literature compared the spread of methylene blue injected into cadavers preserved by different techniques. Clinical studies are needed to confirm the potential analgesic effect of a proximal obturator nerve block in patients with hip fracture and other relevant indications.

We conclude from the results of this study of 7 cadavers that a single injection of 15 mL of methylene blue into the interfascial plane between the pectineus and external obturator muscles successfully generated proximal spread of dye into the obturator canal and successfully colored the obturator branches innervating the hip joint capsule. Furthermore, the dye colored the AON and its branches to the hip joint capsule.

Future clinical investigations are mandated to explore the clinical effect of an obturator nerve block as a supplement to a femoral nerve block in patients with hip fracture.

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