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ORIGINAL ARTICLE

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Spread of injectate around hip articular sensory branches of the femoral nerve in cadavers

N. D. Nielsen[1,2,3] | M. Greher[4] | B. Moriggl[5] | R. Hoermann[5] | T. D. Nielsen[3] | J. Børglum[6] | T. F. Bendtsen[2,3]

[1]Elective Surgery Centre, Silkeborg Regional Hospital, Silkeborg, Denmark

[2]Department of Clinical Medicine, Health, Aarhus University, Aarhus, Denmark

[3]Department of Anaesthesiology, Aarhus University Hospital, Aarhus, Denmark

[4]Department of Anaesthesiology, Intensive Care and Pain Therapy, Sacred Heart of Jesus Hospital, Vienna, Austria

[5]Division of Clinical and Functional Anatomy, Medical University of Innsbruck (MUI), Innsbruck, Austria

[6]Department of Anaesthesiology and Intensive Care Medicine, Zealand University Hospital, University of Copenhagen, Roskilde, Denmark

Correspondence
T. F. Bendtsen, Department of Anaesthesiology, Aarhus University Hospital, Aarhus, Denmark.
Email: tfb@dadlnet.dk

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Background: Anatomical knowledge dictates that regional anaesthesia after total hip arthroplasty requires blockade of the hip articular branches of the femoral and obturator nerves. A direct femoral nerve block increases the risk of fall and impedes mobilisation. We propose a selective nerve block of the hip articular branches of the femoral nerve by an ultrasound-guided injection in the plane between the iliopsoas muscle and the iliofemoral ligament (the iliopsoas plane). The aim of this study was to assess whether dye injected in the iliopsoas plane spreads to all hip articular branches of the femoral nerve.

Methods: Fifteen cadaver sides were injected with 5 mL dye in the iliopsoas plane guided by ultrasound. Dissection was performed to verify the spread of injectate around the hip articular branches of the femoral nerve.

Results: In 10 dissections (67% [95% confidence interval: 38-88%]), the injectate was contained in the iliopsoas plane staining all hip articular branches of the femoral nerve without spread to motor branches. In four dissections (27% [8-55%]), the injection was unintentionally made within the iliopectineal bursa resulting in secondary spread. In one dissection (7% [0.2-32%]) adhesions partially obstructed the spread of dye.

Conclusion: An injection of 5 mL in the iliopsoas plane spreads around all hip articular branches of the femoral nerve in 10 of 15 cadaver sides. If these findings translate to living humans, injection of local anaesthetic into the iliopsoas plane could generate a selective sensory nerve block of the articular branches of the femoral nerve without motor blockade.

1 | INTRODUCTION

Providing postoperative regional anaesthesia for major hip surgery patients is challenging, as the hip joint is innervated by multiple nerves. The anterior aspect of the hip joint is innervated by the femoral and obturator (and accessory obturator) nerves all originating from the lumbar plexus.[1,2] The posterior aspect of the hip joint is innervated by the superior and inferior gluteal nerves from the sacral plexus as well as a sacral plexus branch via the nerve to the quadratus femoris and in some cases branches directly from the sciatic nerve.[1,2] However, the nociceptors of the capsule are mainly situated in the anterolateral and anteromedial part of the capsule,[3,4] which is innervated by the femoral and obturator nerves as well as the accessory obturator nerve when present.[2,5]

A femoral nerve block is known to provide some degree of analgesia after total hip arthroplasty.[6] However, a femoral nerve block for pain relief after hip surgery is controversial, as it is associated with an increased risk of fall,[7,8] as well as an hindrance to early mobilisation.

The sensory branches of the femoral nerve to the hip joint either penetrate or innervate the iliopsoas muscle or wind around the lateral margin of the muscle before innervating the anterolateral part of the hip joint capsule.[2,5] All sensory hip branches of the femoral nerve must thus pass through the anatomical plane between the iliopsoas muscle and the iliofemoral ligament—the so-called iliopsoas plane. We suggest, that an injection of local anaesthetic in this plane, will provide regional analgesia of the sensory articular branches from the femoral nerve to the hip joint without spread to any motor branches.

The primary aim of the study was to assess the spread of injectate in the iliopsoas plane in a cadaver model and to assess if the sensory branches from the femoral nerve to the hip joint were stained by the injectate without staining of the motor branches.

Editorial Comment

Selective blockade of hip articular sensory branches of the femoral nerve would be advantageous for post-operative analgesia after hip arthroplasty, where one wants to try to preserve motor function. In this cadaver dye study, the authors showed that it is possible in this model to get spread of injectate in the iliopsoas plane to achieve this goal.

2 | METHODS

Cadavers were donated to the Division of Clinical and Functional Anatomy at the Medical University of Innsbruck for scientific and educational purposes.[9] Ethical approval was not necessary according to Austrian law. The cadavers were preserved by arterial injection of an ethanol-glycerol solution followed by 1-3 months of immersion in diluted phenolic acid.[10,11]

We performed ultrasound-guided injections of 1% methylene blue between the iliopsoas muscle and the hip joint capsule on both sides of 8 cadavers except in 1 cadaver side that was unsuitable for injection due to the postmortem excision of the hip joint. Fifteen cadaver sides were thus included in the study.

The ultrasound-guided injections were performed using an 8-1 MHz curved array probe with a Esaote MyLabSeven ultrasound system (Esaote SpA, Genoa, Italy). All injections were performed by one of the authors (TFB). The dissections were carried out by two other authors (BM and RH), who were not present during the injection of the dye.

The outcomes were (1) the frequency of staining of all hip articular branches of the femoral nerve (2) the frequency of staining of some of the motor branches of the femoral nerve (3) the frequency of ultrasonographic identification of the iliopsoas muscle and the iliofemoral ligament (4) the distance from the skin to the target iliopsoas plane (5) the distance from the point of needle insertion to the horizontal plane intersecting the anterior superior iliac spine (ASIS) (6) the distance from the point of needle insertion to the sagittal plane intersecting the ASIS (7) the length of the needle trajectory (8) the frequency of injection in the iliopectineal bursa.

2.1 | Injection procedure

The cadaver was positioned supine and the probe was oriented in the transverse plane and placed at the level of the inguinal crease to identify the femoral nerve lateral to the femoral vessels. The lateral margin of the femoral nerve was marked on the skin to avoid piercing the nerve. The probe was then oriented in the sagittal plane across the ASIS, and slided medially along the inguinal ligament until the anterior aspect of the head of femur was identified, where it enters the acetabulum (Figure 1A). The iliofemoral ligament was identified as a hyperechoic structure extending from the rim of the acetabulum and superficial to the head of femur (Figure 1A,D). An 80 mm, 22-gauge Ultraplex needle (B.Braun, Melsungen, Germany) was inserted from the distal end of the probe (and lateral to the skin marking indicating the femoral nerve) with the bevel facing downwards and advanced in-plane until the needle tip reached the anatomical plane between the iliopsoas muscle and the iliofemoral ligament (Figure 1C,D). At this location, 5 mL of methylene blue was injected, and the spread of dye was observed between the iliopsoas muscle and the iliofemoral ligament.

After completing the injection, we gauged the target depth (distance from skin to the iliopsoas plane on the ultrasonogram), the length of the needle trajectory, as well as the distance from the ASIS to the point of needle insertion in the sagittal as well as the transverse plane.

2.2 | Dissection procedure

The following procedure was employed in all 15 cadaver sides. Two initial incisions were made through all epimuscular tissue layers including the strong fascia lata: The first incision was extended from a point three fingerbreadths lateral to the superficial inguinal ring from where it was continued cranially and parallel to the inguinal ligament to be terminated laterally above the ASIS. The second incision was extended obliquely from above the ASIS approximately following the sartorius muscle to the medial side of the thigh. The resulting tissue flap was raised and reflected medially to expose the muscular boundaries of the iliopsoas muscle. If necessary, the incisions were extended slightly. The hip joint was flexed and the iliopsoas muscle was mobilised and lifted to allow identification of the hip articular branches of the femoral nerve in their path through the iliopsoas plane. In some cadaver sides the iliopsoas muscle was cut —after careful registration of the staining of the articular branches— for better photo-documentation.

2.3 | Statistics

Continuous data are presented as mean and range. Proportions are presented as number with percentage of all 15 cadaver sides and a

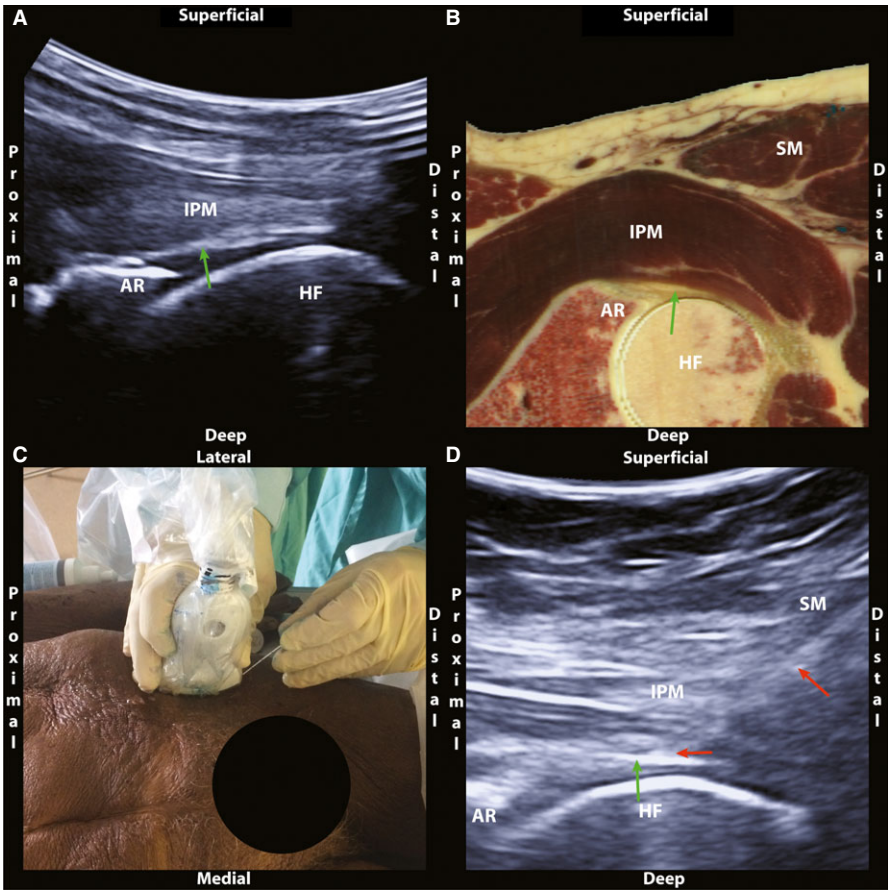

FIGURE 1 A, Sagittal ultrasonogram showing the head of femur (HF) as it dives into the acetabulum. The iliofemoral ligament (green arrow) is visualised as a hyperechoic structure extending from the acetabular rim (AR) deep to the iliopsoas muscle (IPM). B, Sagittal section at the approximate level of A. The Sartorius muscle (SM) overlays the IPM. C, Sagittal ultrasound scan with a curved array probe at the approximate level of A. The needle is inserted in-plane at a steep angle from the distal end of the probe. D, Sagittal ultrasonogram showing the needle (red arrows) positioned for injection of dye between the IPM and the iliofemoral ligament (green arrow). Modified excerpt from VH Dissector with permission from Touch of Life Technologies Inc (www.toltech.net). Built on real anatomy from the National Library of Medicine's Visible Human Project

95% two-sided confidence interval. For proportions on 100% a 97.5% one-sided confidence interval is reported.

3 | RESULTS

Eight cadavers (7 females and 1 male) with an age range from 81 to 98 years were used for this study. Ultrasonographic identification of the iliofemoral ligament, the iliopsoas muscle, and the iliopsoas plane was feasible in all 15 investigated cadaver sides.

The distance from the skin to the target iliopsoas plane was 2.5 (*1.4-3.5*) cm (mean (*range*)). The point of needle insertion was 9.8 (*6.0-12.0*) cm distal and 1.7 (*0-4.5*) cm medial to the horizontal and sagittal planes intersecting the ASIS. The length of the needle trajectory was 4.4 (*2.0-6.0*) cm.

In all 15 dissections (*100% [97.5% one-sided confidence interval (97.5CI): 78-100%]*), the branches from the femoral nerve to the hip joint were identified. In all 15 dissections (*100% [97.5CI: 78-100%]*), some or all branches from the femoral nerve pierced the iliopsoas muscle to reach the iliofemoral ligament and the hip joint. In four dissections (*27% [95% two-sided confidence interval (95 CI): 8-55%]*), we identified femoral nerve branches that winded around the lateral margin of the iliopsoas muscle and reached the hip joint capsule by crossing the iliopsoas plane.

In 10 dissections (*67% [95 CI: 38-88%]*), the spread of the injected dye was contained in a well-defined anatomical compartment deep to the iliopsoas muscle and superficial to the iliofemoral ligament. The compartment was delimited laterally by the rectus femoris muscle and its tendon and medially by the iliopectineal bursa, which was consistently tightly adherent to the iliofemoral ligament as well as to the tendon of the iliopsoas muscle. Five milliliter of dye injected into this compartment resulted in staining of all articular branches from the femoral nerve without staining any motor branches (Figure 2). In all 10 dissections, we observed spread of dye deep to the iliopsoas muscle and cranial to the inguinal ligament, but without staining of any intrapelvic nerves.

In one dissection (*7% [95 CI: 0.2-32%]*), the lateral part of the iliopsoas muscle was found to be firmly adherent to the iliofemoral ligament. The hip articular branches of the femoral nerve that pierced the iliopsoas were stained, but the adherence limited the lateral spread of dye and thereby prevented the staining of articular branches that winded around the lateral margin of the iliopsoas.

In four cadaver sides (*27% [95 CI: 8-55%]*), the dye was injected into the iliopectineal bursa. This resulted in rupture of the bursa: In three dissections (*20% [95 CI: 4-48%]*), the dye reached all the articular sensory branches and some of the motor branches of the femoral nerve. In one dissection (*7% [95 CI: 0.2-32%]*), the dye spread

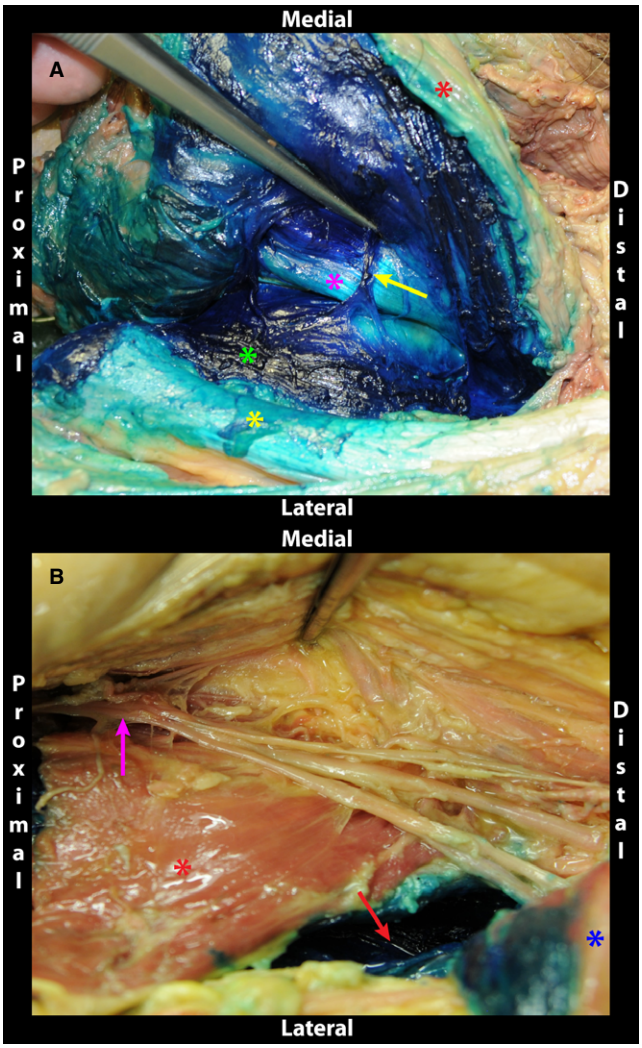

FIGURE 2 A, Spread of dye in the compartment between the iliopsoas muscle (red asterisk) and the iliofemoral ligament (green asterisk) colouring a branch from the femoral nerve to the hip joint (yellow arrow). The iliopsoas muscle is cut proximally and flipped medially. The iliopsoas compartment is bordered laterally by the rectus femoris muscle (yellow asterisk) and medially by the iliopectineal bursa deep to the tendon of the iliopsoas (magenta asterisk). B, The femoral nerve (magenta arrow) and its major mixed sensory and motor branches are not dyed after injection in the iliopsoas plane, as the iliopsoas muscle (red asterisk) obstructs the spread of dye (red arrow). The sartorius muscle (blue asterisk) is cut from its origin and flipped laterally. The faint staining of the distal branches of the femoral nerve is an artefact of the dissection

laterally and reached some of the articular sensory branches as well as a small motor branch to the rectus femoris muscle.

4 | DISCUSSION

The present cadaver study demonstrated that 5 mL of dye injected in the iliopsoas plane between the iliopsoas muscle and the iliofemoral ligament exclusively stained all sensory branches from the femoral nerve to the hip joint in 10 of 15 injections. The employed technique entailed injection into the iliopectineal bursa (medially in the iliopsoas plane) in four of 15 injections, causing spread of dye to sensory branches as well as some of the motor branches of the femoral nerve. The sole unsuccessful injection, with spread to only some of the sensory branches of the femoral nerve, was due to adherences between the iliopsoas muscle and the iliofemoral ligament, which could not be explained by disease or previous surgery of the deceased.

Hip capsule nociceptors are almost exclusively located anterolaterally and anteromedially.[3,12] The anterolateral area of the capsule is innervated by the femoral nerve, while the anteromedial area is innervated by the obturator nerve, and the accessory obturator nerve—when present.[5,13,14] The majority of intracapsular nociceptors are located in the synovium and the labrum.[15,16] These structures are innervated by the obturator nerve and a branch from the nerve to the quadratus femoris (from the sciatic nerve).[16] It can be speculated that selective regional anaesthesia of the sensory branches from the femoral and obturator nerves innervating the hip joint, will alleviate most pain after total hip arthroplasty originating from the hip joint and its capsule.

We have previously demonstrated that a sub-pectineal obturator nerve block will reach all branches from the obturator nerve to the hip joint, including the accessory obturator nerve when present.[17] The only muscles innervated by the obturator nerve are hip adductors, and our research group has demonstrated that total knee arthroplasty patients with an obturator nerve block has the same ability to ambulate as control patients despite hip adductor paralysis due to obturator nerve blockade.[18] Femoral nerve block—on the contrary—increases the risk of fall after hip as well as knee arthroplasty[7,19] and thus prevents early ambulation. If regional anaesthesia were to be used for postoperative analgesia after total hip arthroplasty, it would be imperative to be able to block the sensory branches from the femoral nerve to the hip joint without causing motor blockade.

To the best of our knowledge, this is the first study to demonstrate that the spread of injectate in the plane between the iliopsoas muscle and the iliofemoral ligament effectively reaches all sensory hip branches of the femoral nerve without spread to the motor branches. These encouraging results leads us to hypothesise, that it might be possible to achieve blockade of all sensory branches from the femoral nerve to the hip joint with an injection of local anaesthetic in the iliopsoas plane. This nerve block could probably relieve pain from the hip joint without causing any motor blockade. We have coined this novel peripheral nerve block *the iliopsoas plane block*.

This study has certain limitations. First, postmortem changes might cause a different pattern of the spread of injectate compared to the living. Second, it is possible, that the dissection by itself has caused artefactual spread of methylene blue. This is always a potential bias in dissection studies. We endeavoured to minimise accidental spread of dye by meticulously performing the dissection as

described in the Methods section. Third, 27% of the injections were unintentionally made into the iliopectineal bursa. The iliopectineal bursa cannot be visualised with ultrasound under normal circumstances—not even in the living.[20] Our results indicate that an injection into the bursa entails spread not only to hip sensory branches from the femoral nerve but also spread to some of the motor branches, which would work against the intention of exclusive sensory blockade in the living patient of this technique. A possible alternative approach to avoid bursal injection would be to use a transverse orientation of the ultrasound probe combined with an insertion of the needle in the lateral aspect of the iliopsoas plane just deep to the lateral part of the iliopsoas muscle, which is lateral to the iliopsoas tendon and medial to the rectus femoris tendon.[21] This would minimise the risk of injecting into the iliopectineal bursa, as the iliopectineal bursa is consistently located between the iliopsoas tendon and the iliofemoral ligament in the most proximal and medial part of the space between the capsule and the muscle (ie the iliopsoas plane). Finally, this was an observational study without any blinding or randomisation.

Further studies are warranted to investigate an improved injection technique as described above, to demonstrate the spread of injectate in the iliopsoas plane in living humans, to confirm the lack of motor blockade from the iliopsoas plane block, as well as to confirm that the block indeed provides sensory nerve blockade of the hip joint in patients after hip surgery.

5 | CONCLUSIONS

This study demonstrates that dye injected in the anatomical plane between the iliopsoas muscle and the iliofemoral ligament—the iliopsoas plane—can spread to all articular sensory branches from the femoral nerve to the hip joint. The employed technique, however, caused 4 of 15 injections to be accidentally made into the iliopectineal bursa. One of 15 injections into the iliopsoas plane lateral to the bursa did not reach all branches from the femoral nerve due to fibrous adhesions. Assuming that these findings in cadavers translate to living humans, injection of local anaesthetic into the iliopsoas plane could provide sensory nerve blockade of the articular branches of the femoral nerve without any motor blockade. We have coined this nerve blockade the iliopsoas plane block.

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CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

ORCID

N. D. Nielsen http://orcid.org/0000-0002-5326-5729
T. F. Bendtsen http://orcid.org/0000-0001-5800-386X

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