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Is There Any Need for Expanding the Perineural Space Before Catheter Placement in Continuous Femoral Nerve Blocks?

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Background and Objective: There is debate regarding the benefit of perineural space expansion before catheter placement in continuous femoral nerve block. This question is addressed in this prospective, comparative, and randomized study.

Methods: Sixty patients scheduled for total knee replacement were randomly assigned to receive continuous femoral nerve block with or without perineural space expansion using 10 mL dextrose 5% in water (D5W) flush before stimulation-guided catheter placement. Femoral block was initiated with a 5-mL bolus followed by an infusion of 5 mL/h ropivacaine 0.2% during the 2-hour surgery. The number of attempts before successful placement of the stimulating catheter and the resistance during its insertion were assessed. Patients also received obturator nerve blocks by using ropivacaine 0.75% (10 mL) and sciatic nerve blocks (20 mL). The number of boluses of ropivacaine 0.2% needed to achieve zero VAS scoring was recorded in the postanesthesia care unit during the 2-hour stay. Images of the contrast spread were also studied.

Results: There were 30 patients in each group. The number of successful catheter placements at the first attempt was higher with expansion than without (22 vs. 8, $P = .007$). The resistance felt during insertion was lower with than without expansion ($P = .01$). More boluses of ropivacaine were required postoperatively without expansion ($P = .03$). No difference between groups was found regarding the images of the contrast spread.

Conclusion: Expansion of the perineural space with D5W is useful for catheter placement in continuous femoral nerve block. *Reg Anesth Pain Med 2006;31:393-400.*

Key Words: Continuous block, Femoral, Dextrose 5% in water, Stimulating catheter.

Continuous nerve blocks place a catheter into a perineural space. Some practitioners use saline flushes to expand the perineural space to facilitate catheter passage,[1,2] whereas others do not.[3] The aim of this study is to assess the usefulness of expanding the perineural space before catheter placement. The study used a stimulating catheter as a means of assessing accurate catheter position[3] and of dextrose 5% in water (D5W) as an optimal fluid medium for neurostimulation.[4,5] The study also incorporates findings from previous studies[6,7] that show analgesia in total knee replacement surgeries can be optimized by the addition of an obturator nerve block to a combined femoral and sciatic nerve block. We therefore assumed that after having achieved successful single-shot blocks of the obturator and sciatic nerves, problems relating to continuous femoral nerve block would be isolated and could be specifically investigated. Our hypothesis is that preplacement expansion offers technical advantage and improves the quality of analgesia after total knee replacement surgery.

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Methods

After local ethics committee approval and informed consent, 60 patients of both genders and American Society of Anesthesiologists physical status I-II scheduled for total knee replacement were enrolled in a comparative, prospective, and randomized study. Exclusion criteria were coagulation disorders, infection at the puncture site, allergy to local anesthetics, allergy to contrast media, and preexisting neurologic dysfunction. The study was conducted in a regional hospital and in a university hospital. Randomization by means of sealed envelopes assigned the patients to receive a continuous femoral nerve block, either with (group E) or without (group nE) expansion of the perineural space. The attending anesthesiologist opened the envelope when the patient arrived in the operating room. Perineural space expansion used D5W, as 10 mL glucose 5% (Aguettant, Lyon, France).

Midazolam 0.10 mg/kg was given orally 30 minutes before the patients arrived in the operating room. An additional 1 to 2 mg intravenous midazolam was administered if needed. All regional techniques were conducted in conscious patients by using neurostimulation and Stimulong-Plus Set (Pajunk, Geisingen, Germany), available in a 21-gauge × 50-mm insulated needle with an 18-gauge × 50-mm plastic cannula (short set) or in a 21-gauge × 80-mm insulated needle with an 18-gauge × 75-mm plastic cannula (long set) and a polyamid stimulating catheter 20 gauge × 50 cm (gold-plated, atraumatic, rounded tip, central opening, stimulating stainless steel wire built into the catheter wall).

The femoral nerve was electrolocated by using the Winnie approach.[7,8] The following unique protocol was applied: after raising a skin wheal with 2 mL lidocaine 1%, the skin was preincised with the 18-gauge needle, and the introducer needle assembly was then inserted and directed toward the femoral nerve with the neurostimulator initially set at 1.5 mA (1-2 Hz, 0.1 millisecond) in search of typical quadriceps contraction (patella dancing). Vastus medialis quadriceps contraction was accepted only in case of difficulty. In group E, as soon as patella dances were obtained, amperage was decreased to ≤0.5 mA, occasionally after slight redirection of the needle, and then 10 mL D5W were flushed through the needle in order to expand the perineural space. After verifying correct stimulation, notably after having slid the cannula 5 mm forward when using the long set, the needle was pulled out and the stimulating catheter was threaded through the plastic cannula while stimulating. The catheter was advanced 3 to 5 cm beyond the cannula tip. The intensity of stimulation via the catheter at its final position had to be as close as possible to that obtained from the needle. In group nE, this identical procedure was followed without preplacement expansion.

During catheter placement, 3 atypical scenarios can be encountered: (1) no motor response at all up to 5 mA, (2) initial motor response disappears after 1 to 2 cm of catheter advancement, or (3) motor responses requiring an intensity higher than 1.5 mA. In these conditions, the anesthesiologist rolled the catheter between thumb and index finger, moving it backward and forward through the plastic cannula, in search for a motor response with low amperage. If no quadriceps contraction appeared or if it appeared with an amperage >3 mA, the anesthesiologist was then allowed to repeat the procedure. This consisted of pulling out the catheter and repositioning the introducer needle assembly by using the same or a different puncture site. In group E, additional 2 mL of D5W was allowed for expansion in each try, without exceeding a total volume of 20 mL. A maximum of 5 tries was allowed, after which the catheter was left in place, no matter whether the motor responses were absent or present at high amperage.

Muscular twitches, amperage during catheter passage, and at final catheter position, the depth at which the catheter was secured, and the resistance during catheter insertion (0 = no resistance, 1 = mild, and 2 = high resistance) were recorded by the attending anesthesiologist. All catheters were secured by surgical sutures and adhesive. Femoral block was initiated with 5 mL ropivacaine 0.2% followed by infusion of 5 mL/h during surgery (mostly 2 hours). Femoral block was followed by obturator and sciatic nerve blocks, which were always successful blocks. Obturator nerve was electrolocated using techniques described elsewhere,[6,7,9] and ropivacaine 0.75% 10 mL was injected after eliciting thigh adduction at appropriate amperage. Sciatic nerve was electrolocated by using the lateral midfemoral approach,[10-13] and ropivacaine 0.75% 20 mL was injected after eliciting plantar or dorsiflexion of the foot at appropriate amperage. Electrolocation of these nerves was recorded by the attending anesthesiologist.

No preoperative evaluation of block extent was performed in order to avoid introducing any bias into postoperative assessment and to avoid delaying the surgery. The 3 nerve blocks preceded surgery, which was performed under general anesthesia induced with propofol, remifentanil, and atracurium before intubation for controlled ventilation. General anesthesia was maintained with sevoflurane and remifentanil.

Postoperatively, patients were transferred to the postanesthesia care unit (PACU). At the same time as radiologic controls of the knee prostheses were performed, 5 mL contrast media (Omnipaque; Iohexol 180, Nycomed Amersham, Paris, France) were injected via the catheters and anterior-posterior radiography of the pelvis was obtained for interpretation.

The femoral catheters were connected to a patient-controlled analgesia device delivering ropivacaine 0.2% (5 mL/h continuous infusion, 5 mL bolus, and 15-minute lockout). After extubation, pain was assessed at rest by a nurse blinded to the regional technique at 30-minute intervals, during the 2 hour stay in the PACU, by using the visual analog scale VAS (0 = no pain and 100 mm = maximum pain). At the same time as the VAS scores were collected, motor and sensory extent of the blocks was examined by the nurse, based on the grading scale M S (M for motor and S for sensory). Motor block was defined as M_0 (no contraction), M_1 (isometric contraction but no motion), M_2 (complete motion possible without the action of gravity), M_3 (complete motion against gravity), M_4 (complete motion against resistance), and M_5 (normal). Sensory block was defined as S_0 (no sensation at all), S_1 (sensation but inability to distinguish application of the head or point of a pin), S_2 (sharp tingling and stinging sensation), S_3 (localization correct of 2 points within 2 cm distance), and S_4 (normal sensation accurately localized using response to pinprick). Femoral block was examined based on the ability to raise the extended leg from the bed (motor testing) and to feel a pinprick on the anterior aspect of the thigh. Sciatic block was examined based on motor and sensory tests on the foot. Obturator nerve block was tested principally based on the ability to adduct the operated thigh.

In the case of VAS scores >40 mm, the nurse was instructed to deliver 1 bolus of 5 mL ropivacaine 0.2% every 15 minutes. If the VAS score remained >40 mm after 2 boluses, intravenous morphine boluses of 2 mg were supplemented and repeated every 10 minutes and the attending anesthesiologist was consulted. The latter had to re-examine the patient, particularly the operated limb and the radiography of the contrast media spread. More boluses of ropivacaine in combination with intravenous morphine could be administered depending on this examination.

A successful femoral block was defined by M_0S_0 and VAS = 0, 60 minutes after extubation including blocks that had required some local anesthetic boluses. A failed block was defined by an incomplete femoral nerve block with VAS score ≥0 at the time of discharge from the PACU. Data were collected during the PACU stay. No further investigation was made after patients' discharge from the PACU.

The primary outcomes relating to the technical aspects included the number of attempts before successful electrolocation of the femoral nerve via the stimulating catheter and the resistance encountered during its insertion. The primary outcome related to quality aspects of analgesia, as indicated by the number of boluses needed to achieve zero VAS score during PACU stay. Secondary outcomes included the images of contrast spread and various characteristics of neurostimulation. An extra anatomic study, based on dissection of 2 fresh cadavers, was performed to attempt to correlate ease of catheter passage with anatomy.

Statistical Analysis

The sample size of patients per group was calculated based on results from a preliminary study[14] showing that expansion resulted in a 40% reduced likelihood of needing more than 1 catheter pass attempt. It was estimated that 30 patients per group were required to detect this difference with $\alpha = 5\%$ and power = 80%. Qualitative data were presented as number (%) and analyzed by chi-square and Fisher exact tests. Quantitative data were expressed as mean ± standard deviation and analyzed by a Student *t* test. A nonparametric test was used if the distribution of variables was not normal. Independence of data was also tested. S-PLUS version 6.2 for Windows 2001 (Insightful Corporation, Seattle, WA) was used. The performance of the stimulating catheter in determining successful blocks was studied, based on parameters such as sensitivity, specificity, positive predictive value, and negative predictive value.[15]

Results

A regional hospital enrolled 33 patients, and a university hospital enrolled 27 patients. Thirty pa-

Table 1. Demographics, Characteristics of Electrolocation, and Femoral Nerve Block Success

	Group E	Group nE
Age (y)	68 ± 13	70 ± 8
Weight (kg)	77 ± 14	84 ± 14
Height (cm)	164 ± 10	161 ± 7
Gender (f/m)	15/15	17/13
Stimulation from needle (mA)	0.4 ± 0.1	0.4 ± 0.1
Stimulation from catheter in place (mA)	0.5 ± 0.3	0.6 ± 0.4
Stimulation during catheter insertion (mA)	0.5 ± 0.3	0.5 ± 0.3
Needle depth (cm)	4.0 ± 1.0	4.0 ± 0.9
Catheter depth (cm)	8.5 ± 1.9	8.5 ± 2.0
Muscular twitches elicited by needles		
Patella dances (n)	30	28
Muscular twitches elicited by catheters		
Patella dances (n)	24	22
Vastus medialis	6	6
None		2
Quality of blocks (success/failure)	29/30	26/30

NOTE. All comparisons found no significant difference.
Abbreviations: f, female; m, male.

Table 2. Results of Neurostimulation

Minimum intensity of femoral nerve stimulation (Mean ± SD)		
Needle	Catheter (insertion)	Catheter (in place)
0.37 ± 0.15 mA*	0.53 ± 0.38 mA	0.54 ± 0.36 mA
0.36 ± 0.15 mA†	0.50 ± 0.29 mA	0.48 ± 0.28 mA
Obturator nerve blocks		
Amperage (mean ± SD)	0.6 ± 0.3 mA	
Depth (mean ± SD)	4.5 ± 1.0 cm	
Motor scores (centiles)	10th = 0; 25th = 0; 50th = 0; 75th = 1; 90th = 2	
Sciatic nerve blocks		
Amperage (mean ± SD)	0.4 ± 0.1 mA	
Depth (mean ± SD)	7.5 ± 2.0 cm	
- Motor-sensory scores (centiles)	0 for all centiles	

Abbreviation: SD, standard deviation.

*Analysis on 60 patients, difference ($P < .0001$) between needles and catheters.

†Analysis on 44 patients with typical blocks, difference ($P < .0002$).

Table 4. Primary and Secondary Outcomes

	Group Expansion	Group Nonexpansion	*P* Value
Primary outcomes			
Attempts (n)			.007
1	22	8	
2	6	16	
3	1	4	
5	1	2 (failed)	
Resistance during catheter insertion (n)			.01
0	17	9	
1	10	11	
2	3	10	
Boluses of ropivacaine (n)			.03
0 bolus	27	20	
1 bolus	1	5	
2 boluses	2	4	
3 boluses	0	1	
Secondary outcomes			
Images of contrast spread			NS
Typical	23	21	
Atypical	6	6	
Lateral	1	3	

NOTE. Resistance scoring; 0, no resistance; 1, mild resistance; and 2, very resistant.

Abbreviation: NS, not significant.

tients were assigned to receive expansion (group E) and 30 to receive no expansion (group nE). The 2 groups were comparable regarding demographics, characteristics of electrolocation, and quality of the femoral nerve block (Table 1). Successful electrolocation was obtained from 60 needles and from 58 catheters. In 2 patients from group nE, electrolocation through the catheter was unsuccessful after 5 attempts. These 2 catheters were left in place, and data were considered in an intent-to-treat analysis. Overall, the intensity of stimulation of the femoral nerve was significantly lower ($P < .0001$) through the needles than through the catheters during insertion or at final position. This was still true on selected patients (Table 2). Obturator and sciatic nerves were successfully blocked in all patients (Table 2). Examination of the femoral nerve block at 30 minutes after extubation found a score M_0S_0 in 26 of 28 successful electrolocations in group nE. Two patients of the group nE had failed blocks (M_3S_2 and VAS = 40 mm) despite successful electrolocation (details reported in Table 3). One of them required 3 ropivacaine boluses and 6 mg intravenous morphine to improve the scoring before discharge from the PACU (M_2S_2, VAS = 20 mm), whereas the second patient required only 2 ropivacaine boluses before reaching M_2S_2 and VAS = 0. Two patients of the group nE (124 kg and 163 cm, 100 kg and 158 cm) had unsuccessful electrolocation and failed blocks (M_3S_2, VAS = 40 mm) and received 2 boluses of ropivacaine 0.2%. One of them received 8 mg intravenous morphine. At discharge from the PACU, both had zero VAS and M_2S_0 scoring. In group E, a score M_0S_0 was found 30 minutes after extubation in 29 of 30 successful electrolocations. A score M_2S_2 and VAS = 30 mm was obtained in 1 case and decreased to M_1S_0 and VAS = 0 at discharge from the PACU, after 1 ropivacaine bolus and without morphine supplementation.

The primary outcomes are reported in Table 4. The number of successful catheter placements at first attempt was higher with expansion than without ($P = .007$). The resistance encountered during catheter insertion was significantly higher without than with expansion ($P = .01$).

The number of patients who required >1 ropiva-

Table 3. Individual Values of Electrolocation in Failed Femoral Blocks

Technique	Needle Stimulation	Needle Depth	Catheter Stimulation (insertion)	Catheter Stimulation (in place)	Catheter Depth
nE	0.2 mA	3 cm	0.5 mA	0.6 mA	7 cm
nE	0.6 mA	4 cm	None	None	8 cm
nE	0.4 mA	6 cm	None	None	12 cm
nE	0.6 mA	4 cm	0.5 mA	0.5 mA	15 cm
E	0.3 mA	4 cm	2 mA	1.4 mA	7 cm

Abbreviations: nE, no expansion; E, expansion.

caine 0.2% bolus to reach zero VAS scoring was significantly higher in group nE (P = .03). Five milliliters followed by 2 hours of infusion with 5 mL/h of ropivacaine 0.2% were enough to block the femoral nerve in 47 out of 60 patients, regardless of the technique used.

As secondary outcomes, the radiologic interpretation of contrast spread found 3 types of images (i.e., typical, atypical, and lateral). The typical image is defined by a contrast spread that goes proximal, crosses the acetabulum, and rises oblique and cephalad toward the vertebra (Fig 1). The atypical image corresponds to a contrast spread, which does not cross the acetabulum proximally but goes downward and distal (Fig 2). The lateral image (Fig 3) is characterized by a contrast spread going laterally toward the iliac crest. Expansion or no expansion did not influence the frequency of the types of images encountered (Table 4). The types of contrast spread were significantly correlated to the need for postoperative boluses ($R = -0.6$, $P < .0001$). Typical images were associated with no need for postoperative bolus, in contrast to atypical and lateral images being associated with need for postoperative boluses. There was no correlation between stimulation intensity via the catheter and types of contrast-spread images. Catheter stimulation with low intensity resulted in 44 typical images but also in 11 atypical images. Intensity of stimulation higher than 1 mA or absence of stimulation resulted in 4 lateral images and 1 atypical image. Two lateral images were associated with failed blocks (group nE). Three atypical images were associated with failed blocks (2 in group nE and 1 in group E).

Fig 1. Anteroposterior radiography of pelvis showing a typical image of contrast spread (arrows).

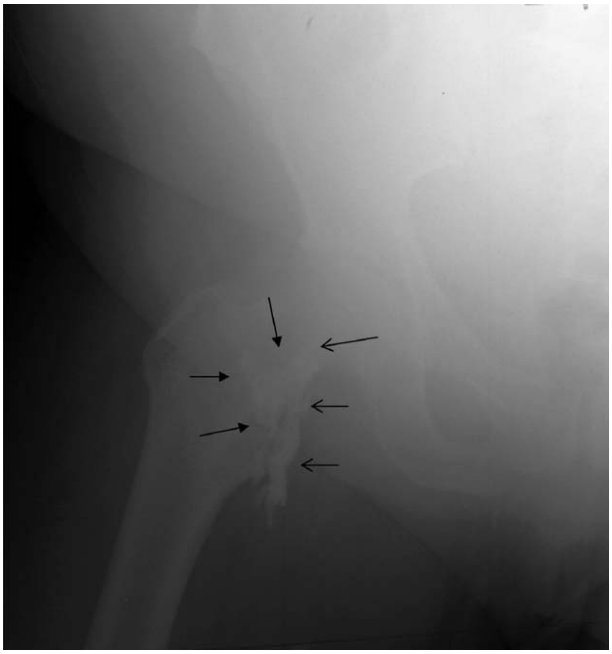

Fig 2. Anteroposterior radiography of pelvis showing an atypical image of contrast spread (arrows).

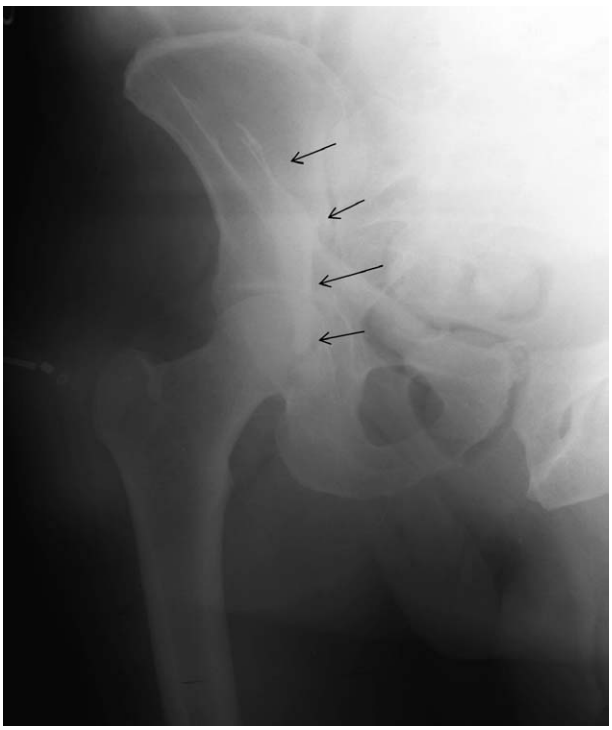

Fig 3. Anteroposterior radiography of pelvis showing a lateral image of contrast spread (arrows).

Table 5. Quality of Blocks and Catheter Stimulations

	Successful Block (B+)	Failed Block (B−)	Totals
Successful stimulation (S+)	55	3	58
Failed stimulation (S−)	0	2	2
Totals	55	5	60

The overall results (Table 5) of catheter stimulation as effective (labelled as S+) or ineffective (labelled as S−) and the resulting successful or failed blocks (labelled as B+ and B−, respectively) noted 55 true positives (S+, B+), 3 false positives (S+, B−), 2 true negatives (S−, B−), and 5 failed blocks. In total, there were 58 effective catheter stimulations (55 true positives plus 3 false positives) and 2 ineffective catheter stimulations associated with failure (true negative). There were no false negatives (S−, B+). Hence, the performance of the stimulating catheter in guaranteeing continuous femoral nerve block success was assessed by the following parameters. The accuracy (true positives + true negatives divided by the total number of patients, 57/60) was 95%. The sensitivity (true positives divided by the number of successful blocks, 55/55) was 100%. The specificity (true negatives divided by the failed blocks, 2/5) was 40%. The positive predictive value (true positives divided by the number of effective electrolocations, 55/58) was 96%. The negative predictive value (true negative divided by the number of the ineffective electrolocations, 2/2) was 100%.

Discussion

We believe this is the first study designed to determine the need for perineural space expansion before catheter placement. The primary outcomes in this study advocate in favor of expansion because the latter resulted in more successful catheter first-pass placement and less resistance to insertion, although we acknowledge the weakness because of nonblinded data collection. Such a condition of investigation is difficult to avoid. We concede that the higher resistance found in group nE during catheter insertion, a subjective but nonetheless technical parameter that has been disregarded by some authors[16] because of its inability to predict correct or incorrect catheter positioning, might be invalidated for this methodological reason. However, the number of first-pass catheters reflecting the utility of preplacement expansion was a solid finding, thanks to the objectivity from neurostimulation, to randomization, and to regional techniques being classically blind anatomic techniques. Furthermore, the fewer boluses needed in group E to achieve zero VAS scores show that expansion was advantageous. This issue was strenghtened by a blinded collection of data.

The secondary outcomes also raise interesting issues. The 3 radiologic types of contrast spread were not a surprise regarding the typical and lateral images of contrast spread; however, the atypical image was unexpected. The results on typical images confirmed what has been found in previous studies.[1,2] They guarantee good femoral block quality, which, combined with effective obturator and sciatic nerve blocks, provides a surgical quality of analgesia.[6,7] Failed electrolocation via the stimulating catheters obviously resulted in lateral images and in failed blocks. The atypical images with distal spread of contrast surprisingly have not been identified and reported in previous studies.[1,2,16] They were obtained after successful electrolocation and associated with some block failure. They highlighted some problems concerning a possible misuse of the stimulating catheter and neurostimulation. An interview of anesthesiologists made clear that some practitioners tend to direct the introducer needle assembly toward the femoral nerve at a steep angle, which facilitates nerve location but makes the catheter curl and go distally. Catheter insertion to an excessive distance also favored catheter curling. We unfortunately did not observe any catheter curling because the catheter is insufficiently radio-opaque, and its placement was not performed under fluoroscopic guidance; thus, we can only speculate that, under the conditions of this study, catheter curling resulted in distal spread of contrast. Perhaps catheter curling was the reason for a failed block reported in Table 2. This failed block had an atypical image, and the catheter was advanced to 15 cm. We suggest that steep angulations of the needle and such a depth of catheter insertion should be avoided.

The possibility of aberrant migration of the catheters from an initially correct point of needle insertion and indicated by low amperage of stimulation requires explanation. We suggest a speculative anatomical explanation through the dissection of 2 fresh cadavers. Under the fasciae lata and iliaca, we found a true labyrinth with several passageways around the femoral nerve (Fig 4). One passageway was along the femoral nerve, whereas the others diverged. These normally virtual passageways became visible after tissue separation, as shown in Figure 4. We speculate that the preplacement expansion with D5W widens the correct passageway for the catheter to go straight in. However, the catheter can pierce the loose walls and snake into a wrong passageway or it may instead curl down. This might explain why we lost initial stimulation when we advanced the catheter, even after manip-

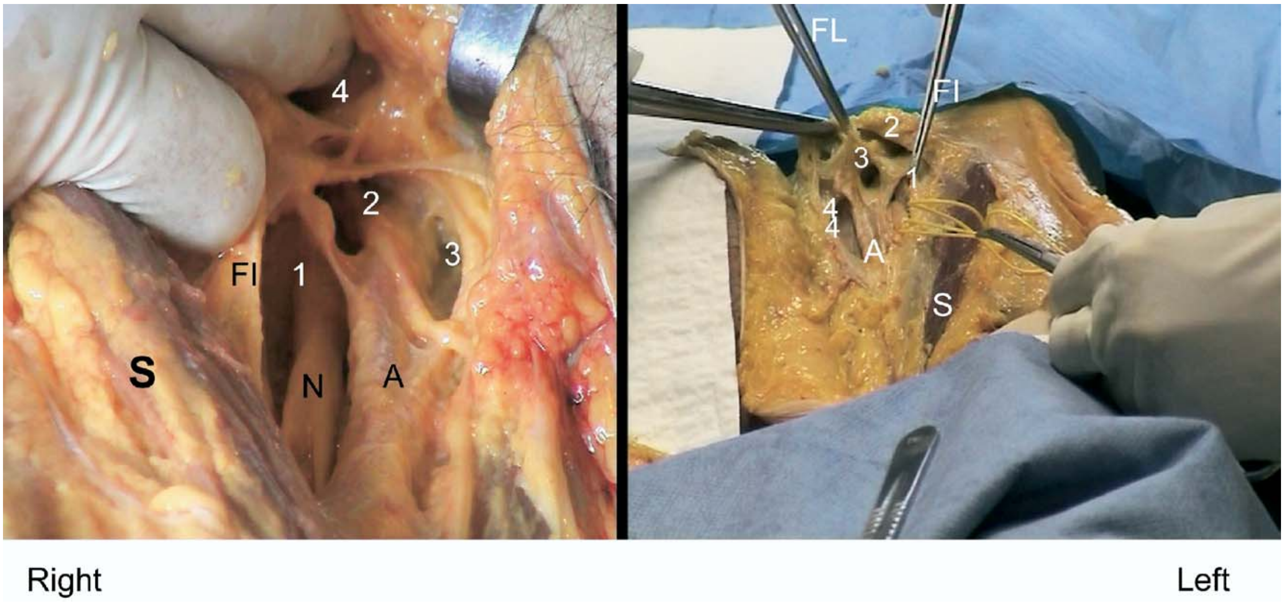

Fig 4. Dissection of the right inguinal zone (right) of a fresh cadaver (male, 70 kg, 175 cm) and of the left inguinal zone (left) of another fresh cadaver (female, 55 kg, 156 cm) showing existence of a labyrinth with many passageways. 1 is the correct passageway containing the femoral nerve. 2,3, and 4 are the incorrect ones. S, sartorius; N, femoral nerve (marked by yellow string on the left photo); A, femoral artery; FL, fascia lata; FI, fascia iliaca. Clamps carrying FL or FI on the left photo point out these fascias.

ulation. Without expansion, these passageways, including the correct one, remain shut or collapsed. The aforementioned aberrant catheter migrations might be more likely to happen in, and could explain the higher number of attempts in, group nE.

The low doses of ropivacaine 0.2% (5 mL bolus followed by 5 mL/h infusion) purposefully chosen in this study merit comment. They confirm that accurate placement of the stimulating catheter results in substantial decrease in local anesthetic consumption. This decrease has been reported in previous studies[1,2] and supported by others of continuous sciatic nerve blocks.[17,18] This appeared as a solution to avoid the high plasma concentrations (reaching 6,201 ng/mL) reported by some authors after 48 hours of infusion of ropivacaine 2% at 12 mL/h around the femoral nerve.[19] It is the low doses of ropivacaine that probably unmasked the difference between the various positions of the femoral catheters in this study. Finally, this decrease in anesthetic consumption indirectly shows the high accuracy of stimulating catheters by high sensitivity and high predictive values as calculated in this study. This could mean that we can now predict the analgesic consumption and obtain significant accuracy with the technique of catheter placement, but this observation must be subject to rigorous study.

Although it was not the purpose of this study, the absence of difference in characteristics of electrolocation between groups confirmed that D5W was an optimal fluid medium for expansion as D5W maintained the electrolocation.[4,5] However, the results showed that catheters still required more current than did needles to stimulate. In the conditions of our study, this difference could be a matter of distance, which, on the basis of electrophysical laws, might be different between the nerve and the needle or the catheter. Having said this, these data appear within the ranges reflecting appropriate catheter–nerve proximity.

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