

Original article

Use of ultrasound to facilitate femoral nerve block with stimulating catheter

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Keywords: *ultrasonography; nerve block; catheterization*

Background The adjunction of ultrasound to nerve stimulation has been proven to improve single-injection peripheral nerve block quality. However, few reports have been published determining whether ultrasound can facilitate continuous nerve blocks. In this study, we tested the hypothesis that the addition of ultrasound to nerve stimulation facilitates femoral nerve blocks with a stimulating catheter.

Methods In this prospective randomized study, patients receiving continuous femoral nerve blocks for total knee replacement were randomly assigned to either the ultrasound guidance combined with stimulating catheter group (USNS group; $n=60$) or the stimulating catheter alone group (NS group; $n=60$). The primary end point was the procedure time (defined as the time from first needle contact with the skin until correct catheter placement). The numbers of needle passes and catheter insertions, onset and quality of femoral nerve blocks, postoperative pain score, and early knee function were also recorded.

Results The procedure time was significantly less in the USNS group than in the NS group (9.0 (6.0–22.8) minutes vs. 13.5 (6.0–35.9) minutes, $P=0.024$). The numbers of needle passes and catheter insertions were also significantly less in the USNS group. A greater complete block rate was achieved at 30 minutes in the USNS group (63.3% vs. 38.3%; $P=0.010$). The postoperative pain score, the number of patients who required bolus local anesthetic and intravenous patient-controlled analgesia, and knee flexion on the second postoperative day were not significantly different between the two groups of patients.

Conclusions Ultrasound-assisted placement of a stimulating catheter for femoral nerve blocks decreases the time necessary to perform the block compared with just the nerve-stimulating technique. In addition, a more complete blockade is achieved using the ultrasound-assisted technique.

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Total knee replacement causes severe postoperative pain. Previous studies have proven that continuous femoral nerve block provides effective analgesia, facilitates early intensive physiotherapy and rehabilitation, and shortens hospital stay.¹⁻⁴

The positions of the needle and catheter are crucial for the success of continuous femoral nerve blocks.⁵ A common method of locating the target nerve is to elicit a motor response with a nerve-stimulation technique.¹⁻⁵ Although nerve stimulation is safer than traditional paresthesia techniques, it is still a blind technique using the pulse of the femoral artery as a landmark to guide its insertion. The variation in human anatomy may challenge this technique. Moreover, it has been reported that the false-negative rate of nerve stimulation may result in an unnecessary redirection of the already-positioned needle.^{6,7}

In recent years, ultrasound guidance has been introduced into clinical practice. This guidance offers unique advantages by showing the direct image of the nerve structures and guiding the advancement of the needle in real time.^{8,9} Although it has been proven that the adjunction of ultrasound to nerve stimulation improves single-injection nerve block quality,¹⁰⁻¹⁴ there have been

few reports on whether ultrasound can influence the performance of continuous nerve blocks. Therefore, the aim of this study was to observe whether the addition of ultrasound to nerve stimulation facilitates femoral nerve blocks with a stimulating catheter, with end points defined as the time to complete the procedure, the efficacy of the block, and quality of postoperative analgesia.

METHODS

Patients

The study protocol was approved by the hospital ethics committee, and written informed consent was obtained from all patients. A total of 120 ASA physical status I to III inpatients, aged 50 to 80 years, undergoing unilateral total knee arthroplasty (TKA) were included in this prospective randomized study. Patients with coagulation

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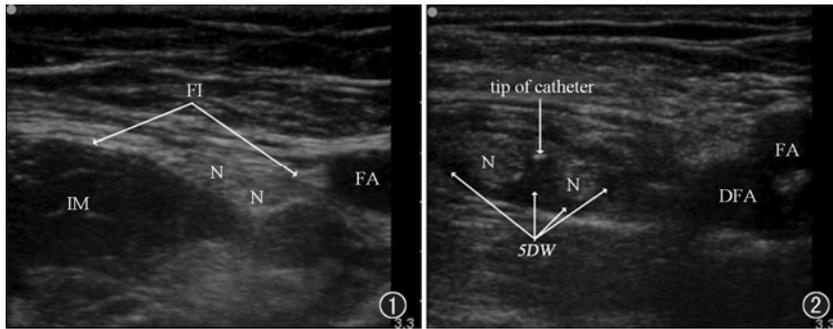


Figure 1. Ultrasound images of the femoral nerve: femoral artery (FA), femoral nerve (N), fascia iliaca (FI), and iliacus muscle (IM).

Figure 2. Ultrasound images of the femoral nerve after injection of 5DW through the catheter: femoral artery (FA), deep femoral artery (DFA), femoral nerve (N). After injecting the test 5DW through the catheter, the spread of the solution around the nerve can be seen.

disorders, infection near the injection site, hypersensitivity or known allergy to any of the study drugs, difficulties in comprehending visual analog scale (VAS) pain scores or in using an intravenous patient-controlled analgesia (PCA) device, or preexisting neurologic disorders, as well as patients receiving opioids for chronic analgesic therapy, were excluded.

Using a computer-generated sequence of random numbers and a sealed envelope, patients were randomly assigned to the neurostimulation group (NS group, $n=60$) or the ultrasound-neurostimulation group (USNS group, $n=60$). Upon arrival at the preparation room, the sealed envelope was opened, revealing the group assignment.

Protocol

Before the procedure, intravenous access was established. Continuous electrocardiography, noninvasive blood pressure, and pulse saturation were monitored during the nerve block performance and throughout surgery. Patients received intravenous midazolam (1–2 mg) for sedation when necessary. In both groups, the procedures were performed by two anesthesiologists experienced in ultrasound-guided peripheral nerve blocks and the use of nerve stimulators. In both groups, a Stimulong Plus Plexolong Catheter Set (Pajunk, Germany) was used with a 19-G \times 50-mm stimulating needle and 20-G \times 50-cm stimulating catheter.

In the NS group, the femoral nerve was identified 1 to 2 cm lateral to the femoral artery below the inguinal ligament. A stimulating needle was advanced with the initial stimulator current set at 1 mA, 2 Hz, and 0.3 ms (Stimuplex HNS11; Braun, Germany) until quadriceps femoris muscle contractions were elicited (cephalad patellar movements). The needle was repositioned until the stimulating current was 0.5 mA or less. A total of 5 ml 5% dextrose (D5W) was injected to facilitate catheter insertion. The nerve stimulator clip was then removed from the needle and attached to the proximal end of the stimulating catheter, and the neurostimulator was set to 1.0 mA to obtain muscle contraction while advancing the catheter. The stimulating catheter was gradually advanced approximately 3 to 5 cm beyond the needle tip, and the current was reduced to test the minimal current necessary to elicit a muscle response through the catheter. If muscle twitching disappeared while advancing the catheter, the needle and catheter were withdrawn and reinserted. After

either 5 attempts or 40 minutes after the initial attempt to insert the catheter, the catheter was left in place even if no response was obtained.

In the USNS group, the femoral nerve was identified in the short axis using a 5-cm, 8- to 12-MHz linear probe (HFL38e, MicroMaxx; SonoSite, USA). The ultrasound probe was positioned at the inguinal crease and adjusted to obtain the best image of the femoral nerve. The stimulating needle was inserted with an out-of-plane technique under ultrasound guidance toward the femoral nerve (Figure 1). The needle was kept in place if quadriceps muscle contractions were elicited at a current of 0.5 mA or less. Next, 1-ml increments of D5W were injected under ultrasound visualization. The needle was further adjusted until the spread of fluid within the fascia iliaca triangle around the femoral nerve was observed. The stimulating catheter was placed in the same manner as in the NS group. If no quadriceps contraction appeared after catheterization at 1 mA, then 5 to 10 ml of D5W were flushed through the catheter. If there was a typical image of 5DW spread (the spread of liquid was directly adjacent to or completely surrounding the nerve) (Figure 2), then the catheter was kept in place. Otherwise, the needle and catheter were withdrawn and reinserted. The above steps were repeated until quadriceps twitches by the catheter appeared at 1 mA or less, or until the correct spread of liquid was demonstrated. The time limit was the same as that in the NS group.

In both groups, after finishing the placement of the catheter, the catheter was fixed onto the skin with sutures and adhesive tape. A total of 20 ml of 1% lidocaine was slowly injected through the catheter after negative aspiration. The sensory block was tested every 5 to 30 minutes after injection by an independent observer who was not present during the procedure and was blind to the group assignment. Sensory block of the femoral nerve was assessed by evaluating the presence or loss of a sharp sensation with pinprick testing (20-G needle) delivered at the central sensory region of the femoral nerve, anterior to the patella. The sensory block rating was quantified as follows: normal sensation = 0 (no block), reduced sensation = 1 (partial block), and total loss of sensation = 2 (complete block).

After 30 minutes of observation, a continuous infusion of 0.2% ropivacaine (Baxter Healthcare Corporation,

Deerfield, IL) was started with an elastic pump at the rate of 5 ml/h and continued for the next 48 hours (250 ml total volume). After completion of the 30-minute testing phase, all patients underwent general anesthesia using fentanyl, propofol, and rocuronium for induction. After intubation, anesthesia was maintained with sevoflurane, remifentanyl, and rocuronium.

Postoperative analgesia

Both groups received 5 mg hydrocodone and 500 mg acetaminophen 4 times daily. The nurses, who were blind to the group assignments, visited the patients every 2 hours (as long as the patients were not sleeping) to assess the patients' pain intensity by VAS. A scale of 0 (no pain) to 10 (worst pain) was used. If the patient's VAS at rest was greater than 4, a 7-ml bolus of 0.2% ropivacaine would be administered through the femoral catheter. If the bolus of local anesthetic did not reduce the pain to less than 4, intravenous PCA with sulfentanil would be provided as rescue analgesia (loading dose 1.5 µg, constant infusion rate 1.5 µg/h, bolus dose 1.0 µg, and lockout interval 15 minutes). Physiotherapy was standardized. At 48 hours postoperatively, a physiotherapist measured the passive range of knee movement. Patients' average pain intensity for the whole day at rest and during physical therapy was recorded for further analysis.

Data collection

Data collected during the procedure included the number of needle passes (a pass was defined as a needle redirection); number of catheter placements; procedure time (defined as the time from the first needle contact with the skin until correct catheter placement); minimal stimulating current of the needle and catheter; incidence of paresthesia; quality of ultrasound femoral nerve image (good = nerve outline clearly circumscribed, fair = nerve outline not entirely visualized, poor = doubt as to the nature of the image); quality of ultrasound image of the spread of 5DW (good = directly adjacent to and completely surrounding the nerve, fair = directly adjacent to but not entirely surrounding the nerve, and poor = not adjacent to nerve); and incidence of accidental vascular puncture.

Data collected in the postoperative assessment included patients' average pain intensity for the whole day at rest recorded by the nurse each day and maximum pain during physical therapy on the second postoperative day; the number of patients who required boluses of ropivacaine and supplemental PCA; and the incidence of nerve irritation or neurologic complications.

Statistical analysis

The primary study end point was procedure time. On the basis of data from a previous study using a stimulating femoral catheter, the procedure block time was approximately (15±6) minutes. The assumption was that the combination of neurostimulation and ultrasound guidance could reduce the procedure time by 25%.

Assuming a type I two-tailed error of 5% and power of 0.80, a sample size of 51 patients per group was calculated. To compensate for dropouts, 60 patients per group were included.

Discrete categorical data were presented as the number or percent of total patients in each group; continuous data were given as mean ± standard deviation (SD) if distributed normally, or median (10th–90th percentiles) if not distributed normally. Categorical differences were tested using Fisher's exact test. Analyses of parametric data were performed using an unpaired two-tailed *t* test if distributed normally, or the Mann-Whitney *U* test if not distributed normally. The differences between the groups and time profiles of pain scores were analyzed by analysis of variance (ANOVA) with the "repeated measures" concept. A *P* value of <0.05 was considered significant. Data analysis was performed using SPSS version 11.0 (SPSS Inc., Chicago, USA).

RESULTS

There were no significant differences between the NS and USNS groups in terms of age, sex, body mass index, or surgery duration (Table 1).

Table 1. Demographic and operative data

Items	NS	USNS	<i>P</i> values
Age (years)	68 (55–74)	68 (57–75)	0.447
Height (cm)	159.5 (153.1–168.0)	162.0 (154.0–174.0)	0.071
Weight (kg)	69.5±8.2	70.2±11.7	0.693
Body mass index (kg/m ²)	27.2±2.9	26.5±3.3	0.245
Gender (male/female)	13/47	17/43	0.528
Surgical duration (minutes)	90 (67–164)	101 (68–160)	0.129

Values expressed as median (10th–90th centiles), mean ±SD or numbers.

Quadriceps contraction could not be obtained in 1 patient in the NS group by either needle or catheter. After first-time catheter insertion, muscular twitches could be elicited in 52% (31/60) and 47% (28/60) of the patients in the NS and USNS groups, respectively (Table 2). The procedure time was significantly less in the USNS group than in the NS group (9.0 (6.0–22.8) vs. 13.5 (6.0–35.9), *P*=0.024). The numbers of needle passes and catheter insertions were also significantly less in the USNS group. The minimal stimulating current by the needle and catheter was similar between the two groups. At 30 minutes, 38.3% of the patients in the NS group had a complete sensory block and 90.0% had a partial or complete sensory block; 58.3% of the patients in the USNS group had a complete sensory block and 98.3% had a partial or complete sensory block.

There was no significant difference in the VAS at rest or during physiotherapy postoperatively (Figure 3) between the two groups. The number of patients requiring boluses of ropivacaine or PCA and knee flexion on the second postoperative day was similar in the two groups. Five patients in the NS group and one patient in the USNS group had inadvertent arterial punctures, but none of

Table 2. Characteristics of femoral blockade, number of patients required bolus ropivacaine and PCA, and postoperative maximum knee flexion

Items	NS	USNS	P values
Procedure time (minutes)	13.5 (6.0–35.9)	9.0 (6.0–22.8)	0.024
Number of needle passes (<i>n</i>)	8.0±0.7	5.5±0.3	0.007
Number of patients with 1/2/3/5 times of catheter placement (<i>n</i>)	31/18/9/2	46/12/2/0	0.014
Electrical threshold-needle (mA)	0.34 (0.23–0.51)	0.32 (0.21–0.51)	0.313
Electrical threshold-catheter (mA)	0.54 (0.27–0.86)	0.54 (0.29–0.94)	0.056
Muscular twitches elicited by catheters after first time insertion (%)	52%	47%	0.715
Complete sensory block at 30 minutes (%)	38.3%	63.3%	0.010
Partial or complete sensory block at 30 minutes (%)	90.0%	98.3%	0.051
Accidental vascular puncture (<i>n</i>)	5	1	0.207
Number of patients receiving bolus ropivacaine (<i>n</i>)	16	9	0.177
Number of patients receiving PCA (<i>n</i>)	5	3	0.717
Postoperative knee flexion on POD2	50±13	53±15	0.191

Values expressed as median (10th–90th centiles), mean ±SD or percentage (%). PCA: patient controlled analgesia; POD: postoperative day.

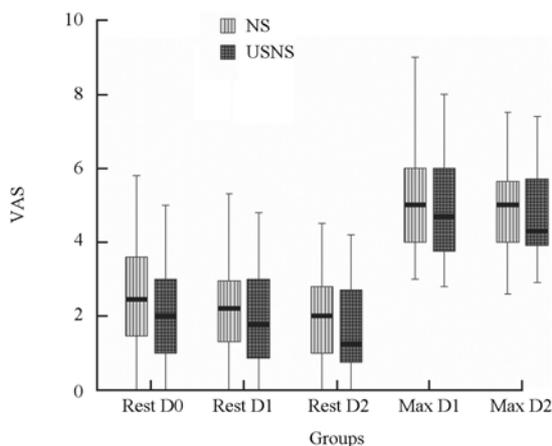


Figure 3. Average pain values at rest and maximum pain values during physiotherapy. Data expressed as median (horizontal bar) with 25–75th (boxes) and the 2.5–97.5th (whiskers) percentiles. Repeated measures ANOVA showed significant time effect ($P=0.000$), but did not show significant group effect ($P=0.431$). Rest, at rest; Max, maximum pain; D0, on the day of operation; D1, the first day after surgery; D2, the second day after surgery; VAS, visual analogue scale.

DISCUSSION

This is the first randomized controlled study to examine whether or not ultrasound assistance is useful in improving the performance of a continuous femoral nerve block by a stimulating catheter. The results show that concomitant use of ultrasound and a stimulating catheter reduces the number of needle passes, number of catheter insertions, and time required for executing the block. The onset of the sensory block is shorter and the proportion of successful blocks was higher in the USNS group, but the overall analgesic effect was not significantly different between the two groups, which may be explained by the multimodal analgesic effect.

them developed hematomas or other bleeding complications. No signs of nerve irritation or neurologic complications were observed.

The ultrasound image of the femoral nerve was either good or fair in 93% of patients in the USNS group (Table 3). After successful quadriceps muscle contractions were elicited at the desired current, the image quality of the spread of 5DW after injection through the needle was poor in 8% of the patients; the spread was actually above the fascia iliaca. The image quality of 5DW spread was either good or fair in 18 of the 32 patients whose muscle response was not elicited after first-time catheter insertion.

Table 3. Image quality in USNS group

Groups	Good	Fair	Poor
Femoral nerve	45% (27/60)	48% (29/60)	7% (4/60)
Dexterous spread through needle*	52% (31/60)	40% (24/60)	8% (5/60)
Dexterous spread through catheter†	31% (10/32)	25% (8/32)	44% (14/32)

*The image quality of dexterous spread through needle right after muscle response elicited with 0.5 Am or less current. †The image quality of dexterous spread in those whose muscle response was not elicited after first time catheter insertion with 1.0 Am current.

During the past two decades, peripheral nerve stimulation has been considered to be a standard technique for most peripheral nerve blocks, including femoral nerve blocks.¹⁻⁵ Desired muscle stimulation observed during needle or catheter advancement is considered to be an indication that the needle or catheter tip is in close proximity to the nerves. Sometimes, however, despite obtaining an adequate motor response, block failure occurs. In the USNS group of the present study, after successful quadriceps muscle contractions were elicited at the desired current, hyperechoic fluid expansion above the fascia iliaca was observed in five patients. This observation is in accordance with others who showed that the needle location was incorrect even though a motor response was elicited.¹⁵⁻¹⁸ The needle tip may be located intravascularly, intraneurally, on the other side of the fascia, or even in the subarchnoid space. In our study, under real-time ultrasound guidance, the needle was gently adjusted if the tip was not in the fascia iliaca triangle. The shorter onset of the sensory block and the greater successful block rate in the USNS group contributed to the optimized needle position, which in turn enabled a better catheter position.

On the other hand, studies have shown that in some patients, a motor response may not occur even when proper needle–nerve contact is suggested by elicitation of paresthesia or ultrasound visualization.^{7,18} In the present study, motor contraction was not elicited in 1 patient in

the NS group by either needle or catheter, but the block was proven to be satisfactory by a later test.

Therefore, perhaps it is necessary to double-confirm, using both ultrasound and nerve stimulation, the needle and/or catheter position. Many studies have advocated the combination of ultrasound and nerve stimulation.^{10-14,19,20} The results of several randomized controlled trials that evaluated the concomitant use of ultrasound and nerve stimulation for single-injection nerve blocks showed that the quality of the sciatic sensory block^{10,19} and the tolerance to the pneumatic tourniquet was improved¹⁹ and that the success rate of axillary blocks was increased.^{11,14} Additionally, the time to perform nerve blocks by the residents was decreased.¹²

Although meta-analysis showed that using ultrasound alone can guide peripheral nerve blocks,²¹ the nerve image was not satisfactory in some patients.²²⁻²⁴ In our study, the ultrasound image of the femoral nerve was not satisfactory in four (7%) of the patients in the USNS group, while Marhofer et al²² reported that the femoral nerve could not be identified in 15% of patients. Muscle atrophy due to chronic myositis and/or muscle degeneration in the elderly can create low-quality imaging.^{25,26} The majority of patients undergoing TKP are elderly. Muscle degeneration makes it harder to identify the boundary of the iliopsoas muscle, which is crucial for identification of the fascia iliaca triangle. The success rate of sensory blocks guided by ultrasound alone for femoral blocks varied from 53.1% to 88.1%.²⁷⁻²⁹ It is probably still advisable to use a nerve stimulator either as a backup or concomitantly when performing an ultrasound-guided nerve block due to the uncertainty of ultrasonographic findings.

Until now, there have been few studies on ultrasound-guided catheter insertion. In a descriptive study,²⁰ the combination of ultrasound guidance and nerve stimulation for the insertion of subgluteal sciatic catheters in children ensured successful sciatic blocks. Our study is the first controlled study to examine the rationality of using ultrasound to facilitate stimulating catheter insertion. The main concern of catheter placement is that although the catheter is still within the perineural compartment, it fails to elicit motor responses due to increased distances or additional tissue layers between the stimulating point and the target nerve. In this study, after first-time catheter insertion, motor responses were elicited in only 52% (31/60) and 47% (28/60) of the patients in the NS and USNS groups, respectively. The failure rate was similar to those of previous studies on stimulating catheters.^{30,31} In the USNS group, the typical image of the liquid spread was evaluated as good or fair in 18 of the 32 patients in whom a muscle response was not elicited after first-time catheter insertion. By avoiding reinsertion of the catheter, the numbers of needle passes and catheter insertions in the USNS group were reduced, and the procedure time was decreased as well.

The use of stimulating catheters is still controversial in the literature. One semiquantitative systematic review²¹ concluded that compared with nonstimulating catheters, stimulating catheters improved nerve block efficacy (judged by reduction in the need for rescue analgesics, complete surgery blocks, or median effective local anesthetic volume blocking the nerve). However, another review³² stated that stimulating catheters provided limited clinical benefits because of their minimal impact on patient satisfaction, procedural pain, and performance time, success rate of the block, static/dynamic pain scores, and physiotherapy performance.

Most of the previous studies failed to illustrate the clinical benefits of stimulating catheters, including improved analgesia and a decrease in oral analgesic requirements, for continuous femoral nerve blocks. However, these results should be evaluated cautiously. Because the pain following TKA involves areas dominated by different nerves, femoral nerve blocks do not cover all potential sites of pain.³³ Multimodal analgesia with oral analgesics and intravenous PCA were implemented in most studies, which might mask the difference in analgesia between stimulating and nonstimulating catheters.³⁴ In our study, the outcome of postoperative analgesia and early functional recovery did not differ between the two groups, which may be explained by the multimodal analgesic effect or by the limited number of patients. A recent study³¹ showed that catheters stimulated at 1 mA or less provided more effective blocks than did those at greater than 1 mA, resulting in lower VAS scores, fewer boluses of ropivacaine, and less morphine. Stimulating catheters may still be valuable for continuous femoral blocks for post-TKA analgesia.

A limitation of our study is that it was not possible to blind the operator and the observer during the implementation of the block. Because the needle and probe are in the middle of the procedure field, it is impossible to eliminate bias in such studies that compare ultrasound with other techniques.

In conclusion, ultrasound-assisted placement of stimulating catheters for femoral nerve blocks decreases the duration of the time required to perform the block compared with the use of the nerve-stimulating technique alone. In addition, more complete blockade is achieved using the ultrasound-assisted technique.

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