Continuous Femoral Nerve Analgesia After Unilateral Total Knee Arthroplasty: Stimulating Versus Nonstimulating Catheters

Salim M. Hayek, MD, PhD*†‡§
R. Michael Ritchey, MD*‖
Daniel Sessler, MD†‡§
Robert Helfand, MD‖
Samuel Samuel, MD*
Meng Xu, MS¶
Michael Beven, BA*
Demetrios Bourdakos, MD‖
Wael Barsoum, MD#
Peter Brooks, MD#

BACKGROUND: Continuous femoral analgesia provides extended pain relief and improved functional recovery for total knee arthroplasty (TKA). Stimulating catheters may allow more accurate placement of catheters.
METHODS: We performed a randomized prospective study to investigate the use of stimulating catheters versus nonstimulating catheters in 41 patients undergoing TKA. All patients received IV patient-controlled anesthesia for supplementary pain relief. The principal aim of the trial was to examine whether a stimulating catheter allowed the use of lesser amounts of local anesthetics than a nonstimulating catheter. The additional variables we examined included postoperative pain scores, opioid use, side effects, and acute functional orthopedic outcomes.
RESULTS: Analgesia was satisfactory in both groups, but there were no statistically significant differences in the amount of ropivacaine administered; the median amount of ropivacaine given to patients in the stimulating catheter group was 8.2 mL/h vs 8.8 mL/h for patients with nonstimulating catheters, $P = 0.26$ (median difference −0.6; 95% confidence interval, −2.3 to 0.6). No significant differences between the treatment groups were noted for the amount of fentanyl dispensed by the IV patient-controlled anesthesia, numeric pain rating scale scores, acute functional orthopedic outcomes, side effects, or amounts of oral opioids consumed.
CONCLUSION: The use of stimulating catheters in continuous femoral nerve blocks for TKA does not offer significant benefits over traditional nonstimulating catheters.
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Total knee arthroplasty (TKA) causes considerable postoperative pain. It can prolong hospitalization, impair rehabilitation and early mobilization (1,2), and may worsen functional outcome (3). Compared with IV patient-controlled analgesia (IVPCA), both epidural analgesia and continuous femoral analgesia provide better pain relief and rehabilitation in patients undergoing TKA. However, continuous femoral analgesia is superior to epidural analgesia because it causes fewer side effects (4–8).

From the Departments of *Pain Management, †Outcomes Research, ‖General Anesthesiology, ¶Quantitative Health Sciences, and #Orthopaedic Surgery, The Cleveland Clinic, Cleveland, Ohio; ‡Outcomes Research Institute; and §Department of Anesthesiology, University of Louisville, Louisville, Kentucky.

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Address correspondence and reprint requests to Salim Michel Hayek, MD, PhD, Division of Pain Medicine, Department of Anesthesiology, University Hospitals Case Medical Center, 11100 Euclid Ave., Cleveland, OH 44106. Address e-mail to salim.hayek@uhhospitals.org

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The potential limitations of femoral nerve blocks include block failure and local anesthetic toxicity. When performing a continuous femoral nerve catheter block, the operator locates the nerve with the help of a nerve stimulator and then advances the catheter through the needle and into the femoral "sheath." However, injection of local anesthetic through the catheter occasionally fails to produce an adequate nerve block. Failure may occur because the catheter tip is insufficiently close to the nerve (9). Furthermore, the reported rates for "secondary failure" after successful block with an initial bolus of local anesthetic are roughly 10% (10,11). Recently, stimulating catheters have become available. After nerve localization with an insulated needle and a nerve stimulator, the catheter can then be advanced past the needle tip, and the effects of stimulation can be monitored continuously during and after the positioning of the catheter.

Stimulating catheters allow clinicians to position the tip of a catheter close to the target nerve (12), and may thus reduce the amount of local anesthetic needed for a successful block (13). The use of stimulating catheters was reported to increase the success rate of catheter placement in observational studies (14). Furthermore, a study in volunteers demonstrated that stimulating catheters produced significantly better femoral sensory and motor blocks than nonstimulating catheters (12). We therefore tested the hypothesis that less local anesthetic would be required for successful femoral nerve blocks with stimulating than nonstimulating catheters in patients undergoing TKA under spinal anesthesia.

METHODS

With approval of the Cleveland Clinic's IRB, informed consent was obtained from patients aged 40–84 yr scheduled for unilateral TKA. Exclusion criteria included history of dementia, Alzheimer's disease, or cerebrovascular accident that might impair operating an IVPCA pump or participating in active physical therapy, history of ipsilateral TKA, history of vascular surgery involving the femoral vessels on the operative side, contraindications to regional anesthesia such as coagulopathy or local infection, history of drug dependence or abuse, history of chronic pain unrelated to the knee requiring treatment with long-acting opioids, patients undergoing bilateral TKA, history of hepatic or renal insufficiency, or history of arrhythmias or seizures.

Protocol

Patients undergoing unilateral TKA were randomly allocated to 1) continuous femoral nerve block using a nonstimulating catheter (Contiplex®, B. Braun, Spangenberg, Germany); or 2) continuous femoral nerve block using a stimulating catheter (StimuCath®, Arrow International, Reading, PA). Patients were randomly assigned to stimulating or nonstimulating catheters with a computer-generated randomization process. Physicians were blinded to the randomization until just before catheter insertion. Patients in both groups were also given fentanyl IVPCA with 20 μg bolus and no basal rate with 6 min lockout interval.

Femoral catheters were inserted under the supervision of anesthesiologists skilled in regional anesthesia techniques. Residents in training were allowed one attempt at placement of the femoral catheters; if unsuccessful, the catheter was inserted by the attending anesthesiologist. If catheter placement was unsuccessful after 30 min, the procedure was aborted, and the patient was excluded from the study. Femoral sheath catheters were inserted preoperatively using a nerve stimulator. A Contiplex system (18-gauge, 2-in. insulated needle and 20-gauge catheter) was used in patients assigned to the nonstimulating catheter group. A StimuCath continuous nerve block set (17-gauge, 3.5-in. needle and 19-gauge catheter) was used in patients assigned to the stimulating catheter group.

After sterile preparation and draping of the femoral area on the operative side, stimulation at 2 Hz and 2 mA was applied after the needle was felt to have gone through two fascial planes, 1 cm lateral to the femoral artery. When quadriceps contraction was detected, the current was decreased and needle position was optimized for evident contraction at a current output of 0.2–0.6 mA. The Contiplex catheter was advanced to a depth of 5 cm past the needle tip in patients allocated to the nonstimulating catheter group. In those patients allocated to the stimulating catheter group, the StimuCath catheter was attached to the nerve stimulator, and the catheter advanced slowly to a depth of 4–5 cm past the needle tip while maintaining quadriceps contraction at a current $\leq$0.9 mA at all times.

Given appropriate catheter placement in both groups (5 cm past the needle tip), the needle was withdrawn and the catheter secured in place by tunneling it 5–7 cm subcutaneously laterally. A test dose consisting of 5 mL of 1.5% lidocaine with epinephrine 1:200,000 was then injected, and patients were monitored for signs and symptoms of intravascular injection such as increased heart rate or metallic taste. Given a negative test dose, the patients were then transferred to the operating room for induction of spinal anesthesia and surgery.

Intraoperatively, patients were administered a spinal anesthetic with 10–15 mg bupivacaine, 25 μg fentanyl, and 0.2 mg epinephrine injected intrathecally at the second to the fourth lumbar level. No anesthetics were injected through the femoral catheter during surgery.

In the recovery room, patients were assessed for return of sensory and motor function. Once spinal anesthesia had regressed to the L1 dermatome level or patients started to experience mild knee discomfort, patients were administered a 25 mL bolus of ropivacaine 0.2% injected through the femoral sheath catheter. The femoral catheter was then infused with ropivacaine 0.2% at 6 mL/h. An IVPCA with fentanyl 20 μg bolus, no basal rate, and a 6-min lockout interval was provided to all patients. Patients were assessed in the postoperative period for proximal thigh (above the dressing) numbness by an investigator who was unaware of the designated catheter type. Success of the femoral block was assessed using an alcohol pad over the anterior proximal thigh on the operative side and compared with the nonoperative side.

Measurements

Pain level was assessed every 4 h by ward nurses using a Likert 11-point verbal numeric pain rating scale (NRS), with 0 signifying no pain and 10 the worst possible pain. Patients with a NRS score >4 were given a 10-mL bolus of ropivacaine 0.2% through the femoral catheter, and the infusion rate was increased to 9 mL/h. Four hours later, if pain scores still exceeded 4, another 10-mL bolus was administered through the femoral catheter, and the infusion rate was increased to 12 mL/h. No further increases in the infusion rate or femoral catheter boluses were allowed. The IV PCA was discontinued 36–48 h after surgery, and the femoral catheters were removed 24–48 h after surgery. An oral combination of acetaminophen 325 mg and oxycodone 5 mg (1–2 tablets) was then given every 4–6 h on an as-needed basis. Immediately after surgery, all patients started identical physical therapy regimens.

Ropivacaine use, pain scores, amount of IVPCA fentanyl used, amount of oxycodone used, maximal

Table 1. Relationship of Catheter Type to Selected Variables

Factor	Stimulating catheter ($N = 19$)[a]	Nonstimulating catheter ($N = 22$)[b]	Difference in median	95% CI
Age (yr)	70 (63, 74)	72 (64, 76)	−2	−8, 4
Current of needle (mA)	0.5 (0.4, 0.5)	0.5 (0.4, 0.5)	0	−0.5, 0.08
No. of attempts for needle	1.0 (1.0, 2.0)	1.0 (1.0, 2.0)	0	−1, 0
No. of attempts for catheter*	1.0 (1.0, 2.0)	1.0 (1.0, 1.0)	0	0, 1
Ropivacaine (cc/h)	8.2 (6.7, 10.4)	8.8 (7.2, 10.8)	−0.6	−2.3, 0.6
Fentanyl (mcg/h)				
At 12 h	87.5 (71.7, 109.8)	94.2 (59.6, 112.5)	−6.7	−20.8, 21.8
At 24 h	67.9 (63.0, 81.0)	65.8 (56.0, 90.8)	2.1	−15.6, 21
Total fentanyl	47.5 (37.0, 76.0)	59.0 (41.0, 91.0)	−11.5	−32, 11

Data are presented as medians; values within parentheses indicate interquartile ranges.

[a] Except for fentanyl at 24 h and total fentanyl, for which $N = 18$.

[b] Except for fentanyl at 24 h, for which $N = 21$.

* $P = 0.016$ (Wilcoxon's rank sum test).

knee flexion, distance walked during physical therapy 48 h after surgery, incidence of deep vein thrombosis during the first 3 postoperative days, incidence of nausea and vomiting (assessed 4–6 times daily), and the amount of medication used to treat nausea and pruritus were assessed.

Statistical Analysis

Our primary end point was the volume of local anesthetic needed to achieve adequate analgesia (pain score <5 on the visual analog scale); other end points were considered secondary. A 20% difference in analgesic requirements in the first 72 h was considered clinically important.

On the basis of previous work (15) and our experience, we expected ropivacaine analgesic requirements for the two groups to be 330 and 264 mg/24 h with a standard deviation of 40 in each group. With a mean difference of 66 and a standard deviation of 40 mg/24 h, 20 patients (10 per group) provided a 90% power at an α level of 0.05. Twenty patients (10 per group) offered more than 80% power to detect a 2 point difference in mean NRS (0–10 scale, 0 = no pain, 10 = worse possible pain), assuming a within-group standard deviation of 1.5 point, or a 3.5 point difference with a within-group standard deviation of 2.5 point. We therefore chose to enroll 20 patients/group.

Analgesic requirements and functional variables in the two groups were compared with a Wilcoxon's ranked sum test. Results are presented as medians (with interquartile ranges). Fisher's exact test and the Pearson χ^2 test were used to compare complications between the two study groups.

RESULTS

A total of 25 patients were recruited in each group. However, three patients in the nonstimulating catheter group and six patients in the stimulating catheter group were excluded from data analysis. The reasons for exclusion included recruitment error (use of long-acting opioids preoperatively in one patient), failure to record data (current needed to simulate the femoral nerve in three patients), and intolerance of fentanyl IVPCA and having to switch to another IV opioid in five patients. A total of 41 patients undergoing unilateral total knee arthroplasty completed the study; 26 were women and 15 were men. Patients' ages ranged between 46 and 84 yr and body mass indexes between 22 and 47 kg/m^2. There were no signs of intravascular injection in response to any of the preoperative test doses. Among the 41 patients enrolled, 19 were randomized to receive stimulating catheters (StimuCath), and 22 patients were assigned to the nonstimulating catheter (Contiplex).

Table 2. Frequency of Adjustment of Local Anesthetic Infusion Rate

LA infusion rate adjustments*	Total	Stimulating catheter N	Stimulating catheter %	Nonstimulating catheter N	Nonstimulating catheter %
0 (6 mL/h)	8	4	20.0	4	18.2
1 (9 mL/h)	14	7	35.0	7	31.8
2 (12 mL/h)	20	9	45.0	11	50.0

* $P = 0.99$; Fisher's exact test. No significant differences were noted between groups.

There were no significant differences in the currents required to elicit quadriceps contraction with the stimulating needle with either of the devices. There was also no difference in the number of attempts for needle placement in close proximity to the femoral nerves. As might be expected, there were significantly more attempts for catheter placement for the stimulating catheter group when compared with the nonstimulating catheter group (Table 1). At the time of placement, the mean current for the stimulating catheters was 0.5 ± 0.2 mA; the median current was 0.4. Postoperative clinical examination, after resolution of the spinal anesthesia revealed decreased cold and touch sensation on the proximal anterior thigh ipsilateral to the operative site when compared with the contralateral side in all patients, suggesting successful block of the femoral nerve.

There were no statistically significant differences in the amount of ropivacaine administered or in the

Table 3. Functional Variables Recorded on Postoperative Day 2 After Total Knee Arthroplasty

Effect	Stimulating catheter		Nonstimulating catheter		Difference in median	95% CI	P value*
	N	Median	N	Median			
Maximum knee flexion	13	58.0 (54.0, 69.0)[a]	20	60.0 (42.5, 70.5)	−2	−8, 18	0.63
Distance walked (feet)	15	20.0 (14.0, 25.0)	18	15.5 (10.0, 30.0)	4.5	−6, 10	0.45

[a] Values within parentheses indicate 25th and 75th quartiles.

* Using Wilcoxon's rank sum test; no significant differences were noted between patients receiving stimulating femoral nerve catheters and those receiving nonstimulating catheters.

Table 4. Relationship of Catheter Type to Complications and Oral Medication Use

Factor	Total	Stimulating catheters		Nonstimulating catheters	
		N	%	N	%
Nausea					
No	21	9	47.4	12	54.6
Yes	20	10	52.6	10	45.5
Urinary retention					
No	40	19	100	21	100
Pruritus					
No	35	18	94.7	17	81.0
Yes	5	1	5.3	4	19.1
DVT					
No	40	19	100	21	95.5
Yes	1	0	0.0	1	4.6
Total oxycodone 24 h[a]		19	0.0 (0.0, 0.0)	22	0.0 (0.0, 0.0)
Total oxycodone 48 h		19	2.0 (0.0, 6.0)	21	2.0 (0.0, 4.0)
Total oxycodone 72 h		18	2.0 (1.0, 6.0)	20	2.0 (0.0, 4.0)
Total dolasetron		19	0.0 (0.0, 12.5)	21	0.0 (0.0, 12.5)
Total diphenhydramine		19	0.0 (0.0, 0.0)	22	0.0 (0.0, 0.0)

[a]Data in this row and all subsequent rows are presented as medians; values within parentheses indicate interquartile ranges.

No significant differences were noted between groups.

amount of fentanyl dispensed by the IVPCA in patients assigned to stimulating and nonstimulating catheters (Table 1). The median amount of ropivacaine given to patients in the stimulating catheter group was 8.2 mL/h vs 8.8 mL/h for patients with nonstimulating catheters, $P = 0.26$. From the collected data, *post hoc* calculations reveal 82% power to detect the 20% difference in the volume of local anesthetic used between the two groups.

The corresponding average amounts for fentanyl per hour dispensed via IVPCA were 55.5 μg/h and 55.0 μg/h, respectively (Table 1). There were also no significant differences between the two treatment groups in NRS scores. In addition, there was no difference between the two groups in the fraction of patients who needed no adjustment in the local anesthetic infusion rate or in the total number of local anesthetic infusion rate adjustments (Table 2). There was also no difference between the two groups in the number of patients who never achieved satisfactory analgesia, defined as a NRS of <5, between 8 and 24 h postoperatively.

There were no functional differences in terms of maximal degree of knee flexion or distance walked 48 h after surgery during physical therapy (Table 3). Similarly, no significant differences were noted between the catheter types in terms of oxycodone consumption once the IVPCA was discontinued. And finally, there were no significant differences in the incidence of nausea, vomiting and itching, or in the amounts of dolasetron or diphenhydramine used to treat nausea and pruritus (Table 4); no patient developed urinary retention, and only one patient displayed evidence of deep-vein thrombosis within the first 72 postoperative hours.

DISCUSSION

The amount of local anesthetic required for successful femoral nerve blocks after unilateral TKA was similar in patients assigned to stimulating and nonstimulating catheters. Furthermore, secondary outcomes including postoperative pain and IV opioid requirements were also comparable in patients given stimulating or nonstimulating femoral nerve catheters. Our findings are consistent with those reported by Morin et al. (16) in patients undergoing major knee surgeries under general anesthesia. Our findings are also consistent with a retrospective study by Jack et al. (17), in which there were no statistically significant differences in pain scores or morphine consumption in patients receiving stimulating and nonstimulating femoral nerve catheters. Morau et al. (18) also reported that equivalent visual analog scores and morphine consumption occurred in patients undergoing painful knee surgeries, regardless of whether a nerve stimulator was used to place a femoral nerve catheter or a fascia iliaca compartment catheter was placed without a nerve stimulator.

Although advantageous from a theoretical standpoint and in experimental designs (12), stimulating catheters have not been more beneficial than the nonstimulating catheters in clinical TKA studies. Besides limitations of clinical trial design, other factors may explain this discrepancy. The presumption that nerve stimulation magnitude may reliably quantify proximity of the needle or catheter to the nerve may not be entirely precise (13,19).

A limitation of our study design is that it did not allow patients total control over the amount of local anesthetic used, and therefore, the amount consumed did not necessarily parallel the intensity of pain. This design was implemented to avoid patient confusion with having to operate two PCA devices (IV and femoral nerve analgesia). An alternative design that would have involved nurse-administered IV opioid analgesia and patient-controlled femoral nerve analgesia may have resulted in a more accurate reflection of local anesthetic requirements with either catheter type. Significantly lower consumption of ropivacaine has been shown with patient-controlled femoral analgesia with boluses-only techniques when compared with techniques that only include a basal infusion in patients undergoing painful knee surgeries (20).

The knee is innervated by the lumbar plexus (femoral and obturator nerve) anterolaterally and the sacral plexus posteriorly (sciatic nerve) (21,22). In patients undergoing TKA under general anesthesia, the combination of a single preoperative sciatic nerve block with continuous femoral nerve block achieved good pain control in an observational study by Mansour and Bennetts (23). However, in a double-blind randomized study in patients undergoing TKA under spinal anesthesia, Allen et al. (24) did not find added benefit when sciatic nerve block was combined with femoral nerve block. Other investigators, however, noted better pain control (25) and reduced opioid requirements in patients receiving sciatic nerve blocks in addition to femoral nerve blockade (26). Yet, it is clear that continuous femoral nerve blockade after TKA does not provide total analgesia.

Some of the postoperative opioid consumption may have compensated for incomplete femoral nerve blockade or for pain transmitted from nonfemoral innervated areas. Because all major joints in the lower extremities are innervated by nerve branches from both plexuses, it would be difficult to perform comparative studies between stimulating and nonstimulating catheters in lower extremity surgeries.

Though offering significant promise, it appears that in our clinical setting of TKA, use of the newer stimulating catheters is not advantageous. The increased cost and need for additional catheter adjustments during placement with the stimulating catheter thus appears unnecessary, at least in the context of TKA. Whether simulating catheters increase block reliability and permit the use of lower amounts of local anesthetics for other types of continuous peripheral nerve blocks or under different clinical settings remains to be determined.

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