

# The Effect of Single-Injection Femoral Nerve Block Versus Continuous Femoral Nerve Block After Total Knee Arthroplasty on Hospital Length of Stay and Long-Term Functional Recovery Within an Established Clinical Pathway

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Total knee arthroplasty (TKA) may result in severe pain, and single-injection femoral nerve blocks (SFNB) have been demonstrated to have a limited duration of analgesia. Continuous femoral nerve blocks (CFNB) can prolong the analgesic duration of SFNB. We prospectively randomized 36 patients undergoing TKA to CFNB versus SFNB and evaluated the effect on hospital length of stay (LOS) as the primary outcome within a standardized clinical pathway. Secondary outcomes included visual analog scale (VAS) pain scores, opioid consumption, and long-term functional recovery at 12 wk. Mean VAS resting scores were significantly lower among patients who received CFNB versus SFNB: first day (1.7 vs 3.3 [ $P = 0.002$ ]) and second day (0.9 vs 3.2 [ $P < 0.0001$ ]) after surgery. Mean maximal VAS scores during physical therapy were significantly lower

among patients who received CFNB versus SFNB: first day (4.7 vs 6.3 [ $P = 0.01$ ]) and second day (3.9 vs 6.1 [ $P = 0.0005$ ]) after surgery. Mean oxycodone consumption was significantly lower among patients who received CFNB versus SFNB: 15 mg versus 40 mg ( $P = < 0.0001$ ) on the first day after surgery; 20 mg versus 43 mg ( $P = 0.0004$ ) on the second day after surgery. There was no difference in hospital LOS (3.8 vs 3.9 days) or long-term functional recovery (117° versus 113° knee flexion at 12 wk) between the two groups. The lack of effect provided by increased duration of analgesia (from CFNB) after TKA may now have minimal impact on hospital LOS and long-term functional recovery in the contemporary healthcare environment within the United States.

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**P**ain after total knee arthroplasty (TKA) is often severe and may hinder participation in early intensive physical therapy, considered one of the most important factors for optimal postoperative knee rehabilitation (1–3). Single-injection femoral nerve blocks (SFNB) have been shown to significantly improve postoperative analgesia compared with systemic opioid therapy and may even reduce hospital length of stay (LOS) after TKA (3–5). Placement of a femoral nerve catheter allows prolonged site-specific regional analgesia. This may be beneficial, because

previous studies have shown that duration of analgesic effect from a SFNB is typically 12 to 24 h (4,6) but may be as long as 48 h (5), whereas severe pain after TKA, especially during physical therapy, may persist through the second day after surgery (postoperative day [POD] 2) (5,7).

Two previous randomized, controlled trials reported that continuous femoral nerve blocks (CFNB) provide superior analgesia compared with IV patient-controlled analgesia (IV-PCA), analgesia comparable with that of continuous lumbar epidural analgesia, accelerated recovery of physical function, and reduced hospital LOS (1,2). One prospective, randomized study failed to demonstrate improvements in analgesia by CFNB compared with SFNB. However, this study failed to provide an adequately powered analysis (8). Thus, it remains unclear whether CFNB provides additional benefits compared with SFNB, especially in light of the additional time, cost and skill required to place and manage continuous femoral catheters. The primary objective of this study was to

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compare the effects of our current standard of care (SFNB) versus CFNB on hospital LOS within an established clinical pathway for postoperative recovery after TKA. Clinical pathways are protocols that aim to standardize management through a systematic approach so that postoperative care may be provided in a timely and cost-effective manner. Secondary objectives were analgesic efficacy, systemic opioid analgesic consumption, treatment-related side effects and complications, and functional recovery (knee flexion) 12 wk after surgery.

## Methods

After local IRB approval and written, informed patient consent, 36 ASA physical status I–III patients scheduled for unilateral primary TKA under spinal anesthesia were included in this prospective, randomized study. Exclusion criteria included age <18 yr or >85 yr; body mass index more than 45; renal insufficiency; contraindications (localized infection, sepsis, pre-existing lower extremity neurological abnormality) or patient refusal of either spinal anesthesia or femoral nerve block; allergy to local anesthetics, morphine, or oxycodone; chronic opioid use; and difficulties in comprehending visual analog scale (VAS) pain scores or use of an IV-PCA device.

Patients were recruited for the study in the preoperative clinic at least 1 day before scheduled surgery, at which time the VAS pain scale assessment (which ranged from 0 = no pain to 10 = worst pain) used within the TKA clinical pathway and the randomization process were explained. Patients were randomized into two postoperative analgesic groups using computer-generated random numbers and a sealed envelope design. Group SFNB patients would receive a femoral nerve block in the postanesthesia care unit (PACU) upon resolution of the spinal anesthetic to the T12 dermatome. Group CFNB patients would have a continuous femoral stimulating catheter placed in the PACU (upon resolution of the spinal anesthetic to the T12 dermatome) and would receive a femoral nerve block via the catheter, followed by a continuous infusion of local anesthetic until 8:00 AM on the morning of the second day after surgery (POD2). Before entering the operating room, the sealed envelope was opened revealing the group assignment. All patients in the study were scheduled to complete surgery before 10:00 AM on the morning of surgery.

Per the clinical pathway, all patients took warfarin 5 mg the night before surgery, and then 5–10 mg each evening during their hospitalization for perioperative venous thromboembolism prophylaxis. After placement of standard ASA monitors and supplemental oxygen, all patients had a standardized spinal anesthetic (12.5 mg of hyperbaric bupivacaine plus 20  $\mu$ g

of fentanyl with the operative extremity dependent) performed by the primary anesthesiology team. Pre-medication for placement of the spinal anesthetic was limited to IV midazolam (up to 30  $\mu$ g/kg) and IV fentanyl (up to 1.5  $\mu$ g/kg). Intraoperative sedation consisted only of an IV propofol infusion titrated at the discretion of the primary anesthesiology team. TKA was performed by one of three surgeons using the same surgical technique and implants.

Upon resolution of the spinal anesthetic (to pinprick) in the PACU, the femoral nerve blocks (SFNB group) and femoral nerve catheters (CFNB group) were all placed by one investigator (FVS) with significant experience in both techniques. For either technique, the initial stimulating needle placement was located 1–1.5 cm lateral to the femoral artery pulsation just below the inguinal crease (9,10). After sterile preparation and draping, the femoral nerve was localized by eliciting quadriceps contractions (as evidenced by either visible or palpable cephalad movement of the patellar area of the knee at  $\leq 0.5$  mA current output) with the peripheral nerve stimulator (B-Braun, Bethlehem, PA) settings at 2 Hz and pulse width of 0.1 s.

In patients randomized to SFNB, 30 mL of ropivacaine 0.375% with epinephrine 2.5  $\mu$ g/mL was incrementally injected via the 50-mm, 22-gauge insulated Stimuplex needle (B-Braun), followed by placement of a sterile dressing over the injection site. In patients randomized to CFNB, a 90-mm, 17-gauge insulated stimulating Tuohy needle (Arrow International, Reading, PA) was used to initially localize the femoral nerve as described for the single-injection technique. After localization of the femoral nerve, a 19-gauge stimulating catheter (connected to the nerve stimulator) was advanced 4–5 cm past the needle tip via the catheter while quadriceps contractions were still being elicited. If quadriceps contractions decreased in intensity or disappeared, the stimulating catheter was carefully withdrawn back into the needle and the stimulating needle was slightly adjusted (either rotating the bevel, changing the angle to the skin, or advancing/withdrawing the needle). After the stimulating needle adjustment, the stimulating catheter was again advanced. The final position of the femoral catheter was acceptable only when quadriceps contractions were still elicited at  $\leq 0.5$  mA via the catheter. The femoral catheters were tunneled 8 cm subcutaneously just below and parallel to the inguinal crease, after which a clear sterile dressing was placed over the catheter insertion site and femoral catheter. Thirty milliliters of ropivacaine 0.375% with epinephrine 2.5  $\mu$ g/mL was incrementally injected via the catheter. The block was maintained by a continuous infusion of ropivacaine 0.2% at 10 mL/h via the catheter started 6 hours after the initial femoral nerve block.

Initial femoral block in both groups was confirmed in the PACU by loss of pinprick sensation over both

**Table 1.** Discharge Criteria Within the Total Knee Arthroplasty Clinical Pathway

Medically stable.
Ability to safely transfer to and from a supine and sitting position to standing.
Ability to safely ambulate level ground with a wheeled walker.
Ability to safely navigate up and down stairs (when required by home environment).
Understanding of both rehabilitation goals and safety precautions.

the mid-anterior thigh (anterior division of femoral nerve) and the medial aspect of the calf above the medial malleolus (posterior division of the femoral nerve). Members of the anesthesia pain service not involved in the study, and who were not blinded to the method of analgesia, conducted subsequent evaluations for the presence or absence of a femoral nerve block each morning and afternoon until the patients were discharged.

In accordance with the clinical pathway protocol, a morphine IV-PCA, programmed to deliver a 1-mg bolus with a 5-minute lockout, was available to all patients, who were instructed to titrate their VAS pain scores to  $\leq 3$  of 10 until the morning of the day after surgery (POD1). On POD 1, the morphine IV-PCA was discontinued and breakthrough pain (defined as  $\geq 4/10$ ) was treated on demand with oral oxycodone (5 mg) tablets until discharge. During the hospital stay, all patients received oral ibuprofen 600 mg three times a day, beginning in the afternoon on the day of surgery. The femoral catheter sites were inspected daily for signs of localized infection and were removed at 8:00 AM on the morning of POD 2.

The rehabilitation aspect of the TKA clinical pathway involved twice-daily intensive physical therapy consisting of passive and active knee range of motion and progressive ambulation with a wheeled walker, as tolerated by the patient, and continuously supervised by a member of the inpatient physical therapy staff. Continuous passive range of motion devices were not part of this standardized clinical pathway. Patients were discharged from the hospital when they were medically stable and met predetermined discharge criteria (Table 1). Achievement of discharge criteria within the clinical TKA pathway was determined only by the primary physical therapist in conjunction with the primary orthopedic surgeon, neither of whom was blinded to the method of postoperative regional analgesia.

The intensity of postoperative pain at rest was assessed using the VAS pain scale twice daily by the anesthesia pain service. In addition, maximal VAS pain scores were assessed and recorded by the primary physical therapist during each physical therapy

**Table 2.** Patient Characteristics

	SFNB	CFNB
Patients (n)	18	18
Sex (M/F)	7/11	11/7
Age	67 (9)	68 (6)
Height (cm)	171 (10)	172 (10)
Weight (kg)	91 (14)	92 (18)
Body Mass Index (kg/m <sup>2</sup> )	32 (5)	31 (5)

Values are mean ( $\pm$  SD). There were no significant differences between groups. SFNB = single injection femoral nerve block; CFNB = continuous femoral nerve block.

session. Data on cumulative IV morphine consumption through POD 1, oral oxycodone consumption through the morning of POD 3, total number of medication requirements for nausea or vomiting, and achievement of objective intermediate (6-wk knee range of motion) and long-term (12-wk range of motion and functional independence without mechanical assistance) goals were recorded.

Based on previous studies, we considered a 25% reduction (1 day) in hospital LOS to be clinically relevant. Review of institutional data over the last 2 years indicated that our average LOS was 4 days (with the patients discharged on the morning of the third day after surgery), with a standard deviation of 1 day. Thus, a power analysis indicated that a minimum of 16 patients per group would provide an 80% power for detecting a 25% difference (1 day) in hospital LOS at an  $\alpha$  level of 0.05. Patient characteristics, resting and peak pain scores (during physical therapy), cumulative morphine and oral oxycodone consumption, number of antiemetic requests for nausea or vomiting, differences in hospital LOS, 6-wk, and 12-wk functional outcome were compared with unpaired and paired Student's *t*-test, and repeated measures analysis of variance. Results are expressed as mean  $\pm$  SD, except for postoperative antiemetic therapy, which is reported as median, with  $P < 0.05$  considered statistically significant.

## Results

During the study period, 42 patients were recruited in the preoperative clinic. Of these patients, five elected to undergo surgery under general anesthesia, and one patient refused a femoral nerve block. Eighteen patients received a CFNB and 18 patients received a SFNB. Patient demographics (Table 2) were comparable between the two analgesic groups. The initial femoral nerve block (ropivacaine 0.375% with epinephrine 2.5  $\mu$ g/mL) was successful in all 36 patients.

By the morning of POD 1, only 2 of 18 patients in the SFNB group still had sensory evidence of a femoral nerve block, and by the evening of POD 1, no patient in the SFNB group had sensory evidence of a femoral



**Table 3.** Resting VAS Pain Scores and Peak VAS Pain Scores in SFNB and CFNB Groups

	SFNB	CFNB	P Value
VAS <sub>R</sub>			
4 h	2.6 (1.6)	2.1 (1.6)	NS
8 h	2.8 (1.4)	2.7 (1.3)	NS
12 h	2.4 (1.2)	2.4 (1.2)	NS
POD 1 <sub>AM</sub>	3.3 (1.6)	1.7 (1.4)	0.002*
POD 1 <sub>PM</sub>	3.8 (1.5)	1.7 (1.5)	0.0001*
POD 2 <sub>AM</sub>	3.2 (1.1)	0.9 (1.3)	<0.0001*
POD 2 <sub>PM</sub>	3.3 (1.8)	1.3 (1.4)	0.0004*
POD 3 <sub>AM</sub>	2.6 (1.4)	1.7 (1.5)	0.06
VAS <sub>PT</sub>			
POD 1	6.3 (1.9)	4.7 (1.7)	0.01*
POD 2	6.1 (1.5)	3.9 (1.9)	0.0005*

Values are mean ( $\pm$  sd).\*  $P < 0.05$  significant.

CFNB = continuous femoral nerve block; SFNB = single-injection femoral nerve block; VAS<sub>R</sub> = visual analog scale score at rest (0 = no pain, 10 = worst pain); VAS<sub>PT</sub> = peak visual analog scale score during physical therapy sessions (0 = no pain, 10 = worst pain). 4 h–12 h = number of hours after initial femoral nerve block; POD 1 = first day after surgery; POD 2 = second day after surgery; POD 3 = third day after surgery.

nerve block. In contrast, a femoral nerve block in both the anterior and posterior division of the femoral nerve was present in 18 of 18 patients in the CFNB group through the afternoon of POD 2.

The resting VAS scores and peak scores during physical therapy sessions are presented in Table 3. There were no significant differences in the resting pain scores for the first 12 hours between the two groups. Beginning on POD 1 through the morning of POD 3, the resting VAS scores and peak pain scores during physical activity were significantly lower in the CFNB group compared with the SFNB group. The overall pain scores were significantly lower in the CFNB group compared with the SFNB,  $P < 0.0001$ . On POD 1 and POD 2, the peak pain scores during physical therapy sessions were consistently 3 cm higher compared with the resting pain scores in both groups,  $P < 0.0001$ .

Systemic analgesic requirements are presented in Table 4. Cumulative morphine IV-PCA requirements through the morning of POD 1 were less in the CFNB group compared with the SFNB group. Moreover, the cumulative oral oxycodone consumption during the hospitalization was significantly less in the CFNB group compared with the SFNB group,  $P < 0.0001$ . There was no significant difference in the number of antiemetic requests (median number of requests = 1, 0–2 for 25th–75th percentile, and a range of 0–4) during the hospitalization between the two groups.

There were no differences in hospital LOS, 6-wk knee flexion, and 12-wk knee flexion between the SFNB group and the CFNB group (Table 5). All patients were considered to be functionally independent at 12 wk postoperatively by their primary orthopedic surgeon.

**Table 4.** Systemic Analgesic Requirements Through the Morning of POD 3

	SFNB	CFNB	P value
Morphine IV-PCA (mg)	25 (12)	16 (10)	0.02*
Oxycodone (mg)			
POD 1	40 (14)	15 (12)	<0.0001*
POD 2	43 (22)	20 (12)	0.0004*
POD 3	26 (19)	10 (6)	0.002*
Total	109 (39)	45 (20)	<0.0001*

Values are mean ( $\pm$  sd).\*  $P < 0.05$  significant.

CFNB = continuous femoral nerve block; SFNB = single-injection femoral nerve block; IV-PCA = IV patient-controlled analgesia; POD 1 = first day after surgery; POD 2 = second day after surgery; POD 3 = third day after surgery.

**Table 5.** Hospital Length of Stay, Intermediate and Long-Term Functional Outcome

	SFNB	CFNB
Hospital LOS (days)	3.9 (0.6)	3.8 (0.3)
6-wk Knee Flexion	102° (12)	108° (11)
12-wk Knee Flexion	113° (10)	117° (10)

Values are mean ( $\pm$  sd). There were no significant differences between the two groups CFNB = continuous femoral nerve block; SFNB = single-injection femoral nerve block; LOS = length of stay in days including day of surgery, with discharge on the third day after surgery equivalent to a LOS of 4 days.

## Discussion

There has been a dramatic increase in the number of total joint arthroplasty procedures over the past few decades (11–13). The latest data in the United States indicate that more than 326,000 TKAs were performed in 2001 (14), and from 1979 to 2002, the rate of TKAs in those aged  $>65$  increased nearly eightfold (15). Thus, interventions that can accelerate recovery of physical function, decrease length of hospital LOS, and improve postoperative analgesia may have tremendous impact on health economics and quality of life.

Previous studies have reported that improved analgesia after TKA can improve recovery of physical function and reduce hospital LOS (1–3). In our study, use of CFNB resulted in lower pain scores than SFNB beginning on POD 1, despite a significantly larger opioid consumption (Table 4) in the SFNB group. The  $\geq 2$ -cm difference (Table 3) on the VAS scale between the CFNB group compared with the SFNB group (both at rest and with physical therapy) were probably clinically significant, as previous studies indicate that such a reduction results in clinically appreciable improvement in analgesia (16). However, the improved analgesia did not improve long-term functional outcome or decrease hospital LOS over SFNB in the context of our study. This finding is in contrast to previous studies that observed both decreased hospital LOS and decreased time to achieve predetermined functional outcome goals with better analgesia from CFNB

compared with IV PCA after TKA (1,2). In these studies, the CFNB groups had faster recovery of range of motion in the knee and were discharged 4–13 days sooner from the hospital. However, there are critical differences between our study and these previous trials. Our study used a structured inpatient clinical pathway to standardize postoperative physical rehabilitation and recovery. These pathways in themselves are effective means to accelerate postoperative recovery and reduce hospital LOS (17). A review on effectiveness of clinical pathways specifically for total joint arthroplasty concluded that data were limited in methodology but supported the ability of clinical pathways to reduce costs and decrease hospital LOS (18). Thus, the common clinical practice of incorporating a clinical pathway may have overshadowed any functional or economic effects from the improved analgesia in the CFNB group.

The previous studies reporting functional benefit from CFNB were performed several years ago and in a different clinical and economic environment. Thus, their institutional (hospital and inpatient rehabilitation) LOS after TKA was quite long (21–50 days compared with 4 days in both our analgesic groups). Our outcomes are more typical of the current clinical environment, in that data from the United States Hip and Knee Registry indicate that average hospital LOS after TKA in 2001 was 3.7 days regardless of type of postoperative analgesia (19). This LOS is similar to the range (5–11 days after TKA) currently reported from Australia (20) and Europe (21). A large part of this discrepancy may be that the previous (1,2) studies performed complete physical rehabilitation in the hospital, whereas only 28%–36% of patients in the United States are discharged to a rehabilitation unit after TKA (19). The ability to efficiently discharge patients to outpatient physical rehabilitation after TKA has been previously identified as an important means to reduce inpatient hospital LOS and reduce cost (20,22). Thus, it is likely that our experience reflects the current efficiencies of medical practice and demonstrates the difficulties in extracting any further improvement in postoperative recovery with a single intervention. The lack of effect of improved analgesia from CFNB versus SFNB suggests that quality of postoperative analgesia after TKA may now have minimal impact on functional recovery and hospital LOS in the United States. Improved analgesia may reduce LOS in other countries that currently report longer LOS after TKA.

Use of CFNB provides prolonged duration of superior analgesia compared with traditional systemic opioid-based therapy that is not subject to the concern of spinal hematoma from continuous epidural analgesia in the recommended practice of anticoagulation after TKA. Not only does CFNB provide a similarly high quality of analgesia compared with continuous epidural analgesia but also motor block is less because

of the unilateral nature of CFNB (1,2). Nonetheless, CFNB will not block the entire operative limb and should be considered part of a multimodal technique.

Use of CFNB may also pose risk and complications that we did not assess. Placement of femoral nerve catheters requires additional skill, time, and postoperative management. All of our CFNB catheters were successfully placed, but we did not compare time required for CFNB versus SFNB. Finally, placement of catheters poses the potential for infection, especially distressing for TKA, and nerve injury. We observed no catheter-related infections or nerve injury (during hospitalization or at 12-wk follow-up) but our sample size was small. A previous study examining 211 femoral nerve catheters also observed no serious nerve injury or catheter-related infections but did note a 57% rate of bacterial colonization of the extracted catheters (23). Because of these potential complications, we did not perform a double-blind study with placebo femoral catheters. The lack of blinding as a result of ethical concerns raised by our local IRB is a limitation of our study. During the recruitment process, the patients were specifically informed that SFNB was the current standard of care within our institution and that CFNB was a newer modality of postoperative analgesia that might or might not increase their duration of analgesia. Thus, it was unlikely that patients and medical providers had a preconceived bias that CFNB would provide superior analgesia.

In summary, we observed improved analgesia after TKA with CFNB versus SFNB. In contrast to previous studies (1,2), there was not an associated reduction in hospital LOS. Our findings suggest that current use of clinical pathways, multimodal analgesia, and other practices may overshadow the ability of improvements in quality and duration of postoperative analgesia to affect recovery from TKA. However, for patients undergoing TKA, postoperative pain, length of recovery, and functional independence are of equal concern (24,25). Despite the additional time, effort, and cost to place and manage continuous femoral nerve catheters, CFNB after TKA provides anesthesiologists the opportunity to play a central role in optimizing postoperative analgesia, because provision of CFNB addresses that concern more effectively than SFNB.

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