Postoperative Analgesia and Functional Recovery After Total-Knee Replacement: Comparison of a Continuous Posterior Lumbar Plexus (Psoas Compartment) Block, a Continuous Femoral Nerve Block, and the Combination of a Continuous Femoral and Sciatic Nerve Block

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Background and Objectives: Continuous femoral nerve block is a well-accepted technique for regional analgesia after total-knee replacement. However, many patients still experience considerable pain at the popliteal space and at the medial aspect of the knee. The goal of this study is to evaluate whether a psoas compartment catheter provides better postoperative analgesia than a femoral nerve catheter does and whether it is as effective as the combination of a femoral and a sciatic nerve catheter and, thus, improves functional outcome.

Methods: Ninety patients who underwent total-knee replacement under standardized general anesthesia participated in this prospective randomized study. Group FEM received a continuous femoral nerve block, group FEM/SCI received a combination of a femoral and a sciatic continuous nerve block, and group PSOAS received a continuous psoas compartment block. Patient-controlled analgesia with piritramide was available for 48 hours. Maximal bending and extending of the knee and walking distance was assessed during the first 7 days. A standardized telephone survey was conducted after 9 to12 months to evaluate residual pain and functional outcome.

Results: Postoperative opioid consumption during 48 hours was significantly less in the FEM/SCI group (median: 18 mg; 25th/75th percentile: 6/40) compared with the FEM group (49 mg; 25/66) and the PSOAS group (44 mg; 30/62) (P =.002). Postoperative pain scores were not different, and no differences occurred with respect to short-term or long-term functional outcome.

Conclusion: The FEM/SCI catheter is superior to FEM and PSOAS catheter with respect to reduced analgesic requirements after total-knee replacement, but functional outcome does not differ with those 3 continuous regional analgesia techniques. *Reg Anesth Pain Med 2005;30:434-445.*

Key Words: Femoral nerve block, Sciatic nerve block, Lumbar plexus block, Psoas compartment block, Continuous peripheral nerve block, Total-knee replacement.

Postoperative pain after total-knee replacement (TKR) is a major concern. It is severe in 60% of patients and moderate in 30%.[1] Pain is known to impair early intensive physiotherapy and rehabilitation and is probably the most important factor for good postoperative knee rehabilitation.[1] Continuous peripheral nerve blocks offer the potential benefit of extended postoperative analgesia with few side effects and allow faster rehabilitation compared with intravenous patient-controlled analgesia (PCA), as measured by the maximal degree of knee flexion and walking distance obtained in the early postoperative days, length of hospitalization, and total length of rehabilitation.[1-3] A well-accepted and commonly used technique for regional analgesia after TKR is the anterior femoral approach to the lumbar plexus ("3-in-1 block," or the femoral nerve block [FEM]),[1-3] which is simple and has minimal

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risk of major complications. Although this technique reduces opioid consumption, some patients may experience considerable pain. Reports of satisfactory analgesia with FEM block alone[1,2] are countered by studies that found it to be inadequate.[4,5] However, data are inconsistent to whether the addition of sciatic nerve (SCI) block to FEM block improves postoperative analgesia in TKR. Allen et al.[6] found that the addition of a single-injection SCI block to an FEM block did not provide a beneficial effect, whereas Weber et al.[5] reported that 67% of patients who had a preoperative FEM block required the addition of a postoperative SCI block. Furthermore, local anesthetic spread to the obturator nerve is almost never achieved with the FEM block.[7,8] A recent study demonstrated improved postoperative analgesia after TKR, with the addition of an obturator nerve block to a combined FEM/SCI block.[9] With a posterior lumbar plexus block (psoas compartment [PSOAS]), the three major nerves of the lumbar plexus (femoral, obturator, and lateral femoral cutaneous nerve) can be reached with a single injection.[8-10] Thus, it may be superior to an FEM block for postoperative analgesia.[8,11] Moreover, most cephalad parts of the sciatic nerve can possibly be reached with the PSOAS approach as well.[10]

The aim of this study was to evaluate the efficacy of continuous FEM, continuous PSOAS, and a combination of continuous FEM/SCI block for postoperative analgesia and functional outcome after TKR. Furthermore, the onset and quality of sensory and motor block were evaluated.

Methods

Patient Selection and Study Design

After approval by the ethical review board, we studied 90 patients undergoing TKR. All patients had given their written informed consent to participate in this prospective randomized study. Patients were allocated randomly, by use of sealed envelopes, to 1 of 3 study groups (30 patients each) immediately before the block was performed. Group FEM received a continuous femoral nerve block, Group FEM/SCI received a combination of continuous femoral and continuous sciatic nerve block, and Group PSOAS received a continuous psoas compartment block. Exclusion criteria were infection near the insertion site, coagulation disorders, preexisting neurologic disorders, known allergies to local anesthetics, prior vascular surgery near the insertion site, ASA classification IV or V, age younger than 18 years, inability to understand the PCA device, and pregnancy or lactation period.

Regional Anesthetic Techniques

Regional blocks were performed in the preoperative holding area on conscious and cooperating patients by 1 of 4 anesthesiologists (AMM, CDK, GD, or GG), all with considerable experience in performing these blocks. For all patients, a stimulating catheter (the Arrow StimuCath continuous nerve block set with a 17-gauge Tuohy needle 9 or 15 cm in length and a 19-gauge stimulating catheter [Arrow, Germany]) was used. The nerve stimulator current was initially set at 1 mA, with 2 Hz and 0.3 ms (Stimuplex HNS 11, Braun, Germany). After skin disinfection with alcohol, and covering of the puncture site with a sterile drape, an intradermal local anesthesia with mepivacaine 1% was performed. In the FEM group, the femoral nerve was identified by the inguinal paravascular approach, as described by Winnie et al.,[10] which elicited quadriceps contractions (patellar elevation), with a current setting at 0.3 mA or less. The SCI catheter was inserted via the anterior approach described by Beck,[12] about 5 cm distal of the insertion site of the FEM catheter. This approach was chosen for practical reasons because the patient could stay in the supine position, and a second disinfection and sterile draping was not necessary. The SCI nerve was identified by eliciting either the common peroneal or the tibial nerve (dorsiflexion or plantar flexion of the foot) with a stimulation of 0.3 mA or less. In the PSOAS group, the lumbar plexus was identified with the patient in the lateral position and the operative side up, as described by Chayen et al[13]: the fourth or fifth lumbar spine was identified, and the insertion point 3 cm caudal and 5 cm lateral was marked. Quadriceps muscle twitches were sought. All catheters were advanced 5 cm beyond the needle tip. Nerve stimulation via the catheter was used in all occasions during advancement to verify correct placement of the catheter, and acceptable amperage was no more than 1 mA. Catheters were sewn to the skin to avoid catheter dislodgement and were covered with a sterile dressing. After a negative aspiration test for blood, the initial bolus of the local anesthetic solution (prilocaine 1% mixed with ropivacaine 0.75%) was injected. Patients with only 1 catheter (FEM or PSOAS) received 300 mg of prilocaine 1% (30 mL) and 150 mg of ropivacaine 0.75% (20 mL), and patients with 2 catheters (FEM/SCI) received 200 mg prilocaine 1% (20 mL) and 75 mg ropivacaine 0.75% (10 mL) through each catheter.

Preoperative Assessment

The time interval from the first penetration of the skin with the stimulating needle until correct cath-

eter placement was defined as catheter placement time. Patients were asked to rate the procedure of catheter placement on a visual analog scale (VAS = 0 for not bad at all and well tolerable to VAS = 10 for very painful and beyond endurance). The patient's cooperation during catheter placement was rated by the anesthesiologists on a 4-point scale (1 = very good, 2 = rather good, 3 = rather bad, and 4 = very bad), as well as the ease of catheter placement (1 = very easy, 2 = rather easy, 3 = rather difficult, 4 = very difficult).

After administration of the local anesthetic, the onset of sensory and motor block was evaluated repeatedly during a period of 30 minutes at 3 defined areas of the skin for all 3 study groups (anterior, medial, and lateral aspect of the thigh above the patella) and at 2 more areas in the FEM/SCI and the PSOAS groups (lateral portion of the calf and lateral aspect of the foot) to compare block of the SCI nerve. Sensory block was defined as a decreased perception of cold sensation from a piece of cotton dunked in alcohol. Evidence of motor block was tested by extension of the knee and abduction and adduction of the hip with knee flexed in all patients and furthermore by dorsiflexion and plantar flexion of the foot in the FEM/SCI and the PSOAS groups. Motor block was then defined as onset of weakness, which means a partial, detectable weakness of grade II or higher according to the modified Bromage scale (grade I = no weakness, grade II = partial weakness, grade III = almost complete weakness, and grade IV = complete weakness).[14] Sensory and motor testing was performed every 2 to 3 minutes until the presence of sensory and motor block, but no longer than 30 minutes.

In case of failure (nerve stimulation via the stimulating needle not possible within 15 minutes), the intended procedure was switched to another procedure (a failed PSOAS block and a failed FEM/SCI block would be switched to a FEM block; a failed FEM block would be switched to a PSOAS block), and the patient was included in a per-protocol analysis.

Perioperative Management

Patients received oral premedication with 20 mg of clorazepate 1 hour before the procedure. After placement of the catheters and after completion of the 30-minute testing phase, standardized general anesthesia was performed in all patients with intravenous propofol until loss of consciousness and 4 to 8 μg/kg of intravenous fentanyl for induction and desflurane in N_2O for maintenance, according to clinical needs. Patients were intubated after administration of 0.5 mg/kg of intravenous rocuronium, and controlled ventilation was started. All patients received a 100-mg diclofenac suppository after induction of anesthesia and 2.5 g of metamizole intravenously before the end of surgery.

Postoperative Assessment

Postoperative care was standardized during the first 48 hours. A ropivacaine 0.2% infusion with 14 mL/h for the FEM group and the PSOAS group or 2 × 7 mL/h for the FEM/SCI group was started after the 30-minute testing period and was maintained during surgery and for at least 48 hours. No bolus application of a local anesthetic was allowed during this period. All patients received a daily oral dose of 3 × 50 mg of diclofenac. Intravenous PCA was provided with piritramide (10 mg morphine is approximately equivalent to 15 mg piritramide) in a bolus of 2 mg or more as needed and a lockout interval of 10 minutes for 48 hours.

All patients had identical physical therapy regimens. From the day after surgery until discharge, active and assisted knee flexion and extension exercises were performed twice daily. In addition, a continuous motorized motion machine was applied 2 to 3 times daily for 30-minute duration, with the range of motion set at the level well tolerated by the patient. Maximal bending and extending and maximum walking distance were assessed daily by a physical therapist for 7 days.

The patients were visited at least twice a day by two specially trained observers (EH and NA), who assessed piritramide consumption and pain scores at rest and during physiotherapy by use of VAS scoring (VAS = 0 for no pain to VAS = 10 for maximal pain), and who evaluated the correct position of the catheter by neurologic examination. The higher of 2 VAS scores was used as daily VAS score for analysis (separate evaluation of pain at rest and during physiotherapy). Catheters were left in place even after the study period of 48 hours, as long as deemed necessary or until local infectious signs occurred, but intravenous PCA with piritramid was discontinued in all patients after 48 hours.

After 9 to 12 months, a standardized telephone interview was performed with all patients to determine general state of health, knee function, pain at the knee joint, and consumption of pain medication compared with the time before surgery. Table 1 shows the questionnaire. Questions 1, 2, and 3 were taken from the SF 36 (http://www.sf36.org), an instrument to measure quality of life. Questions 4 and 5 were developed for this study. Patients were called 5 times with at least 5 days between each attempt, but then no further efforts were made to reach the patient. All data were collected by 2 observers (EH and

NA) who were *not* blinded to the technique used. The results of the study were reported according to the requirements of the CONSORT statement (www.consort.org).

Statistical Analysis

On the basis of data from Singelyn et al.,[1] a prospective power analysis revealed that 90 patients provided a 90% chance (power) to detect a reduction of total mean piritramide consumption within the first 48 hours by one third (e.g., from 60 mg in the FEM group to 40 mg in the FEM/SCI and the PSOAS groups) during the first 48 hours after surgery, with a type I error of 0.05 by an *F*-test, when the standard deviation was not greater than 50% of the means and correction for nonnormal distribution of the values was assumed. Sample-size calculation was performed by NCSS Trial (Number Cruncher Statistical System, Kaysville, Utah). This main outcome variable was analyzed by use of one-way analysis of variance (ANOVA). Furthermore, continuous data that were repeatedly recorded (piritramide consumption, VAS pain ratings, bending and extending of the knee, and walking distance) were analyzed by use of a two-factorial analysis of variance. Analyses of single measurements were performed by use of the Kruskal-Wallis test, and in case of significance the Mann-Whitney *U*-test was used as a post hoc test. Repeated measurements of dichotomous data (onset of sensory and motor block) were subjected to a Kaplan-Meier survival statistics by use of the nonparametric log-rank (Mantel-Cox) test. This test was also used for post hoc testing in case of significance. The χ^2-test (with correction for continuity) or Fisher's exact test, if appropriate, was used for any other nominal data. Statistical significance was assumed if $P < .05$ without adjustment of the level of significance. All statistical calculations were performed by StatView version 4.57 for Windows (SAS Institute Inc. Cary, NC).

Results

During the study period, 129 patients presented for elective total-knee replacement. Of these patients, 9 patients elected to undergo surgery under spinal anesthesia and 7 patients refused a peripheral nerve block. Of the remaining 113 patients eligible for the study, 15 patients were not included for organizational reasons (e.g., none of the 4 anesthesiologists or the 2 observers was available), and 6 patients refused to participate in the study. Informed consent was obtained from 92 patients. Of these patients, 2 patients were not randomized because surgery was postponed. Thus, 90 patients were randomized as planned, 30 for each group.

One subsequent dropout from the PSOAS group was not included in the final analysis because of incomplete recordings. Finally, 89 patients were included in the analysis, 30 patients in the FEM group, 30 patients in the FEM/SCI group, and 29 patients in the PSOAS group. Four patients from the FEM/SCI group received only a FEM catheter because nerve stimulation of the SCI nerve via the stimulating needle was not successful even after a

Table 1. Telephone Survey Questionnaire 9 to 12 Months After Total-Knee Replacement

How would you judge your state of health in general?	Excellent (1) Very good (2) Good (3) Less good (4) Bad (5)
Compared with last year, how would you describe your state of health?	At the moment much better than last year (1) At the moment a little better than last year (2) Comparable to last year (3) At the moment slightly worse than last year (4) At the moment much worse than last year (5)
How strong has your pain at the knee joint been during the past 4 weeks?	I did not have pain (1) Very light (2) Light (3) Moderate (4) Strong (5) Very strong (6)
How is your need for pain medication compared with the time before TKR?	No medication (1) Noticeable less (2) Slightly less (3) A little more (4) Noticeable more (5)
I achieved nonconstraining mobility with my new knee joint.	This statement applies completely (1) This statement applies largely (2) This statement applies in part (3) This statement applies to a lesser extent (4) This statement does not apply at all (5)

15-minute effort. Two more patients randomized to receive a PSOAS catheter received a FEM catheter for the same reason. Thus, 36 instead of 30 patients finally received a FEM catheter, 26 instead of 30 received a FEM/SCI catheter, and 27 instead of 29 received a PSOAS catheter. With this degree of group crossover, we decided to perform a per-protocol analysis. The patients were transferred to the group with the technique they actually received with respect to onset time of sensory and motor block, postoperative VAS pain scores and supplemental opioid requirements, and early and late functional outcome. An intention-to-treat analysis would lead to artificially better results for the group with a high failure rate. However, patients remained in their intended group and were submitted to an intention-to-treat analysis for the issues of demographic data, catheter placement time, patient's rating of procedure of catheter placement, patient's cooperation during catheter placement, and the ease of catheter placement. Demographic data are presented in Table 2. No relevant differences could be observed.

Preoperative Assessment

Catheter placement time was 3 to 4 times longer in the FEM/SCI group compared with the groups with 1 catheter only, but no difference in time occurred between the FEM and PSOAS groups (Table 2). Patients judged the procedure of catheter placement as quite tolerable in all groups (Table 2). The anesthetists who performed the blocks for this study rated patients' cooperation comparable but catheter placement most difficult in the FEM/SCI group (Table 2).

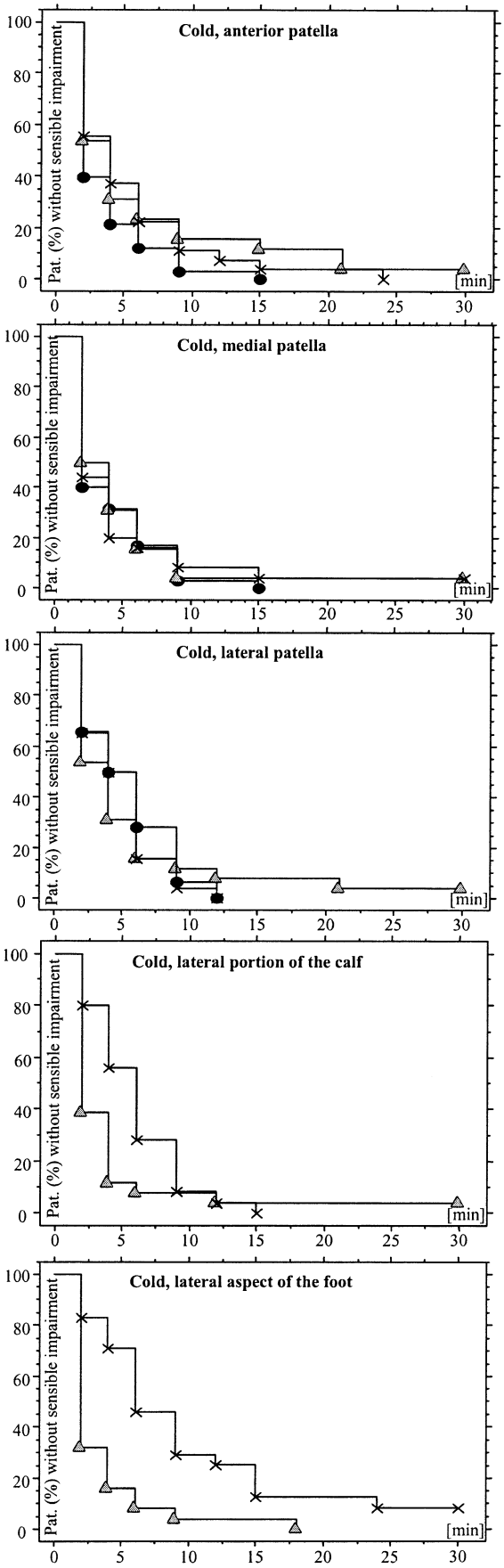
The current required to elicit a motor response *after* catheter placement was equal in all groups in median, but 2 catheters in the FEM group and 1 catheter in the PSOAS group were not stimulable at 5 mA, although needle current had been below 0.3 mA (Table 2). However, these catheters were left in place.

The onset time and quality of sensory (Fig 1) and motor block (Fig 2) after injection of the bolus dose differed in some of the tested areas and muscle groups. At the knee (anterior, medial, and lateral aspect of the thigh above the patella), sensory block was equally fast and profound in all groups, but at the lateral portion of the calf and the lateral aspect of the foot as representative areas for the SCI nerve, the FEM/SCI group showed a faster onset time of sensory block compared with the PSOAS group ($P = .02$ for the lateral portion of the calf; $P = .0002$ for the lateral aspect of the foot). Concerning the onset time and quality of motor block for extending the knee, no group differences occurred, whereas in abduction and adduction of the hip, the FEM group revealed the slowest onset time (hip abduction: FEM *v* FEM/SCI, $P = .028$; FEM *v* PSOAS, $P = .0013$; FEM/SCI *v* PSOAS, $P = .2$; hip adduction:

Table 2. Demographic Data and Characteristics of Catheter Placement

	FEM (n = 30)	FEM/SCI (n = 30)	PSOAS (n = 29)	*P* Values
Age (y)	68 (62/74)	71 (63/74)	65 (53/73)	.45
Sex ratio (male/female)	15 (50%)/15 (50%)	9 (30%)/21 (70%)	12 (41.4%)/17 (58.6%)	.29
Body mass index (kg/m^2)	29 (27.4/32.3)	31 (26.9/34.9)	27.2 (24.3/29.4)	.006*
Duration of surgery (min)	80 (65/90)	75 (65/86)	75 (64/95)	.83
Catheter placement time (min)	4.5 (3/7)	FEM: 4 (2/5) FEM + SCI: 16.5 (14/22)	5 (4/12)	<.0001* FEM *v* FEM/SCI: .0001* FEM *v* PSOAS: .17 FEM/SCI *v* PSOAS: .0005*
Catheter current during advancement (mA)	0.3 (0.1/0.8) (2 catheters not stimulable with 5 mA)	FEM: 0.4 (0.2/0.5) (max. value 1.5 mA) SCI: 0.4 (0.2/0.7) (max. value 1.6 mA)	0.4 (0.2/0.5) (1 catheter not stimulable with 5 mA)	.38
Patient satisfaction with catheter placement (VAS 0–10)	3 (2/4)	3 (1.5/5)	2 (1/4)	.59
Patient's cooperation (n)				.20
very good	23 (77%)	17 (57%)	22 (76%)	
rather good	3 (10%)	8 (27%)	5 (17%)	
rather bad	2 (7%)	5 (17%)	2 (7%)	
very bad	2 (7%)	0	0	
Anesthesiologist's evaluation of difficulty of catheter placement (n)				.0024* FEM *v* FEM/SCI: .001* FEM *v* PSOAS: .14 FEM/SCI *v* PSOAS: .024*
	15 (50%)	4 (13%)	8 (28%)	
Very easy	9 (30%)	9 (30%)	13 (45%)	
Rather easy	3 (10%)	9 (30%)	5 (17%)	
Rather difficult	3 (10%)	8 (27%)	3 (10%)	
Very difficult				
Catheter duration (days)	3 (2/4)	3 (2/3)	3 (2/4)	.45

NOTE. Values are expressed as median (25/75 percentile) or n = (%). Analyzed on an intention-to-treat basis.
*Statistically significant.



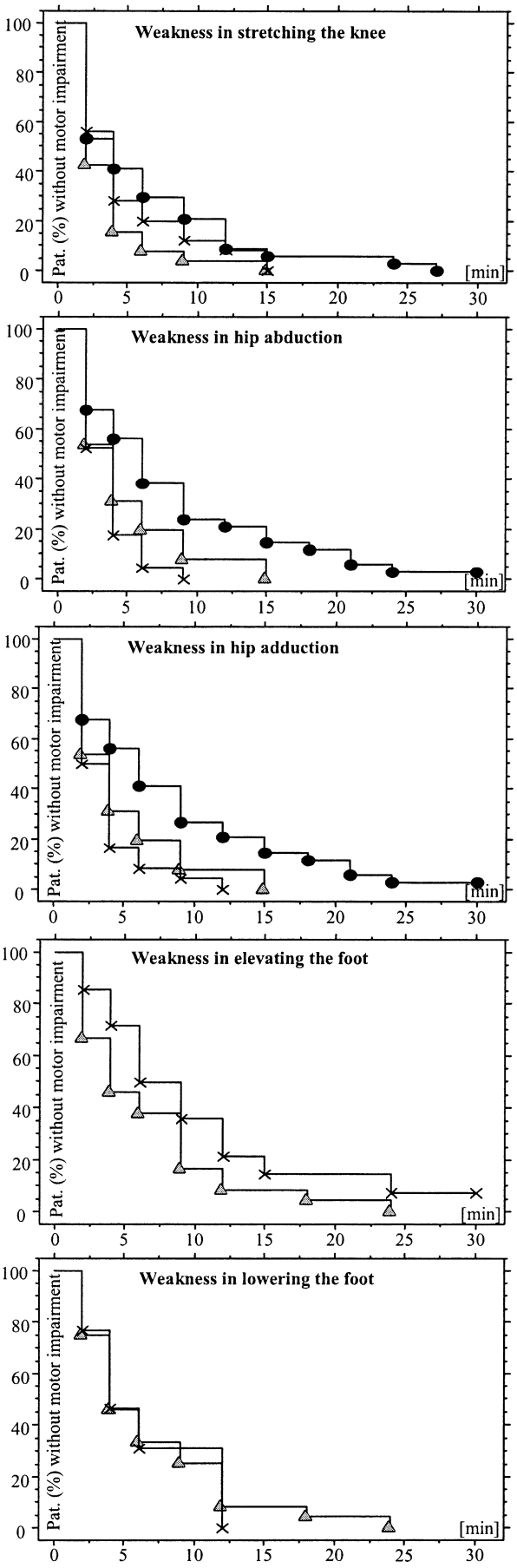
FEM *v* FEM/SCI, $P = .023$; FEM *v* PSOAS, $P = .0017$; FEM/SCI *v* PSOAS, $P = .3$). Onset time and quality of dorsiflexion and plantar flexion of the foot were similar in the FEM/SCI and in the PSOAS group. Besides an epidural spread in 2 patients in the PSOAS group that was no longer detectable 2 to 3 hours after surgery, no immediate adverse effects were observed.

Postoperative Assessment

The main outcome parameter of this trial, the postoperative opioid consumption via PCA during the first 48 hours differed significantly between the study groups (Table 3). A difference could be observed between the FEM and the FEM/SCI groups ($P = .001$) as well as between the FEM/SCI and the PSOAS groups ($P = .0048$). No difference was observed between the FEM and the PSOAS groups. Pain values at rest and during physiotherapy exercise did not differ between the groups within the 7 days after surgery (Fig 3). Statistically significant better values over time in all groups could be detected, although not clearly visible in the Figure 3.

The ability to bend and extend the knee or to walk did not show any group differences but marked intragroup improvement over the 7 postoperative observation days (Fig 4). Physiotherapists reported that active exercise was more difficult to perform and walking were more insecure with patients who had the combined FEM/SCI catheter because of more pronounced motor weakness, but exercise and walking was still possible in all patients. Motor weakness was in no case a reason for reduction of infusion rate or discontinuation of the catheters. However, in 1 case of the FEM/SCI group, surgeons asked to discontinue the ropivacaine infusion through the SCI nerve catheter immediately after surgery until block was completely

Fig 1. The onset time and quality of sensory block at the 5 tested areas and their failure rates after the initial local anesthetic dose (analyzed on the per-protocol basis). Patients with still-maintained sensibility are indicated in percent every 2 to 3 minutes. This observation means, for example, that at the lateral aspect of the foot, all patients of the FEM/SCI group show a loss of cold sensation after 18 minutes, whereas 10% of the PSOAS group still has cold sensation after 30 minutes. For anterior aspect of the thigh above the patella, $P = .16$. For medial aspect of the thigh above the patella, $P = .94$. For lateral aspect of the thigh above the patella, $P = .82$. For lateral portion of the calf, $P = .02$*. For the lateral aspect of the foot, $P = .0002$*. Dark circles indicate FEM group. Gray triangles indicate FEM/SCI group. Cross marks indicate PSOAS group. Asterisk in legend denotes statistical significance.



resolved, to make an evaluation of SCI nerve function in case of perioperative nerve injury. Ropivacaine infusion was resumed 8 hours after surgery. The intravenous PCA with piritramide was discontinued in all patients after 48 hours.

Catheters were left in place 3 days (median) in all groups (Table 2), as long as clinically indicated, depending on a daily evaluation of the intensity of pain and the evaluation of the insertion site. No catheter required removal because of secondary block failure or local infection. No signs of nerve irritation or neurologic complication were observed. No bleeding complication could be observed either, although all patients got 40 mg of enoxaparin once a day beginning on the day before surgery. High-risk patients for thromboembolic complications got 60 mg of enoxaparin daily, and those who usually had coumadin medication got 40 mg of enoxaparin twice a day.

The telephone interview 9 to 12 months after surgery could be performed in 72 (81%) of the patients (23 of the FEM group, 24 of the FEM/SCI group, and 25 of the PSOAS group; n.s.). No group differences were present in any of the 5 questions (Table 4).

Discussion

Analgesia after total-knee replacement is a main factor for rehabilitative success.[1] Poorly managed pain may inhibit the early ability to mobilize the knee joint, which, in turn, may result in capsular contracture that risks the success of surgery.[1,2] Systemic analgesic medication alone is often not sufficient in this setting. Therefore, regional anesthetic techniques are now routinely employed for perioperative analgesia. Peripheral neural blocks are at least equal to central neuroaxial techniques and may have fewer complications and side effects.[1-3,15] The optimal kind of peripheral nerve block remains unknown. Multiple studies have demonstrated that

Fig 2. The onset time and quality of motor block and their failure rates after the initial local anesthetic dose (analyzed on the per-protocol basis). Patients with still-maintained motor function are indicated in percent every 2 to 3 minutes. For weakness in extending the knee, $P = .12$. For weakness in hip abduction, $P = .027$* (FEM *v* FEM/SCI, $P = .028$*; FEM *v* PSOAS, $P = .0013$*; FEM/SCI *v* PSOAS, $P = .2$). For weakness in hip adduction, $P = .0027$* (FEM *v* FEM/SCI, .023*; FEM *v* PSOAS, .0017*; FEM/SCI *v* PSOAS, $P = .3$). For elevating the foot, $P = .14$. For lowering the foot, $P = .89$. Dark circles indicate FEM group. Gray triangles indicate FEM/SCI group. Cross marks indicate PSOAS group. Asterisk in legend denotes statistical significance.

Table 3. Postoperative Opioid Requirements

	FEM (n = 30)	FEM/SCI (n = 30)	PSOAS (n = 29)	*P* Values
Cumulative piritramide consumption 0-3 h (mg)	0 (0/11)	0 (0/0)	0 (0/5)	.0058* FEM *v* FEM/SCI: .0012* FEM *v* PSOAS: .47 FEM/SCI *v* PSOAS: .0059*
Cumulative piritramide consumption 0-24 h (mg)	36 (20/54)	10 (2/16)	25 (16/42)	<.0001* FEM *v* FEM/SCI: <.0001* FEM *v* PSOAS: 0.25 FEM/SCI *v* PSOAS: .0015*
Cumulative piritramide consumption 24-48 h (mg)	8 (1/22)	7 (2/10)	10 (5/22)	.46
Cumulative piritramide consumption 0-48 h (mg)	49 (25/66)	18 (6/40)	44 (30/62)	.0020* FEM *v* FEM/SCI: .001* FEM *v* PSOAS: .86 FEM/SCI *v* PSOAS: 0.0048*

NOTE. Values are expressed as median (25/75 percentile). Analyzed on the per-protocol basis.
*Statistically significant.

a FEM catheter can significantly reduce opioid consumption with a PCA system after major knee operations.[1-3] A recurring problem, though, is despite the use of an FEM catheter, a large number of patients experience pain in the posterior or medial aspect of the knee.[3-5,10] Thus, block of the obturator and the SCI nerve in addition to the FEM nerve could possibly decrease the need for opioid analgesia. Recently, McNamee et al.[9] investigated the effect of an additional block of the obturator nerve combined with FEM and SCI nerve blocks (all single shot) in patients undergoing TKR, and detected a significant increase in time until first request for analgesia and a significant reduction in total requirements for morphine throughout the 48 hours after surgery. These results could be confirmed by Macalou et al.,[16] who compared a "placebo" FEM block with an FEM block and a combined FEM and obturator nerve block (all single shot). During the investigational period of 6 hours, analgesia was best in the group who received a combined FEM and obturator nerve block. Neither study investigated functional outcome.

However, the 3 principal nerves of the lumbar plexus may be easier to block with 1 single injection by use of the PSOAS technique. Kaloul et al.[17] found that the PSOAS block provides a more consistent block of the obturator nerve than does the FEM block, but morphine consumption and pain scores did not differ between groups in patients after TKR. Our own results are in accordance with those of Kaloul et al.[17] Although we could observe a marked and significant difference in onset time of weakness in hip adduction in the PSOAS group (Fig 2), which revealed better obturator nerve block, postoperative opioid consumption during the 48 hours after surgery was not significantly different (Table 3). These results support the hypothesis that the obturator nerve does not contribute significantly to development of pain after TKR.

We found a significant slower onset time for the induction of motor weakness of hip abduction in the FEM group compared with the FEM/SCI and PSOAS groups. This difference is explained by innervation of the muscles responsible for hip abduction. Four muscles (gluteus medius, gluteus minimus, tensor fasciae lata, and piriformis) are innervated by cranial fibers of the sacral plexus (nervus gluteus superior from L4-S1), and only 1 (sartorius) is innervated by the FEM nerve. Another interesting finding is that on the one hand, the SCI nerve, which is exclusively responsible for dorsiflexion and plantar flexion of the foot, is equally impaired by both FEM/SCI and PSOAS block, but on the other hand, sensory innervation of the lateral portion of the calf and the lateral aspect of the foot is significantly faster impaired by the FEM/SCI group compared with the PSOAS group. The insertion point we used was relatively low (3 cm distal and 5 cm lateral from the fourth or fifth lumbar spine) and may, therefore, be responsible for the finding of a comparatively high incidence of sciatic nerve block. These findings suggest that the PSOAS block can reach cranial parts of the sacral plexus as already discussed before,[10] but this hypothesis has not been supported by other authors.[8,18] In this trial, an obvious discrepancy occurs between sensory and motor block in the PSOAS group in areas exclusively innervated by the SCI nerve on the one hand and postoperative opioid requirements on the other hand. The latter was significantly higher in the PSOAS group than in the FEM/SCI group, which indicates that block of the SCI nerve by the PSOAS approach is not sufficient to obtain adequate analgesia. As we did not expect to find sensory and motor impairment in the FEM group in

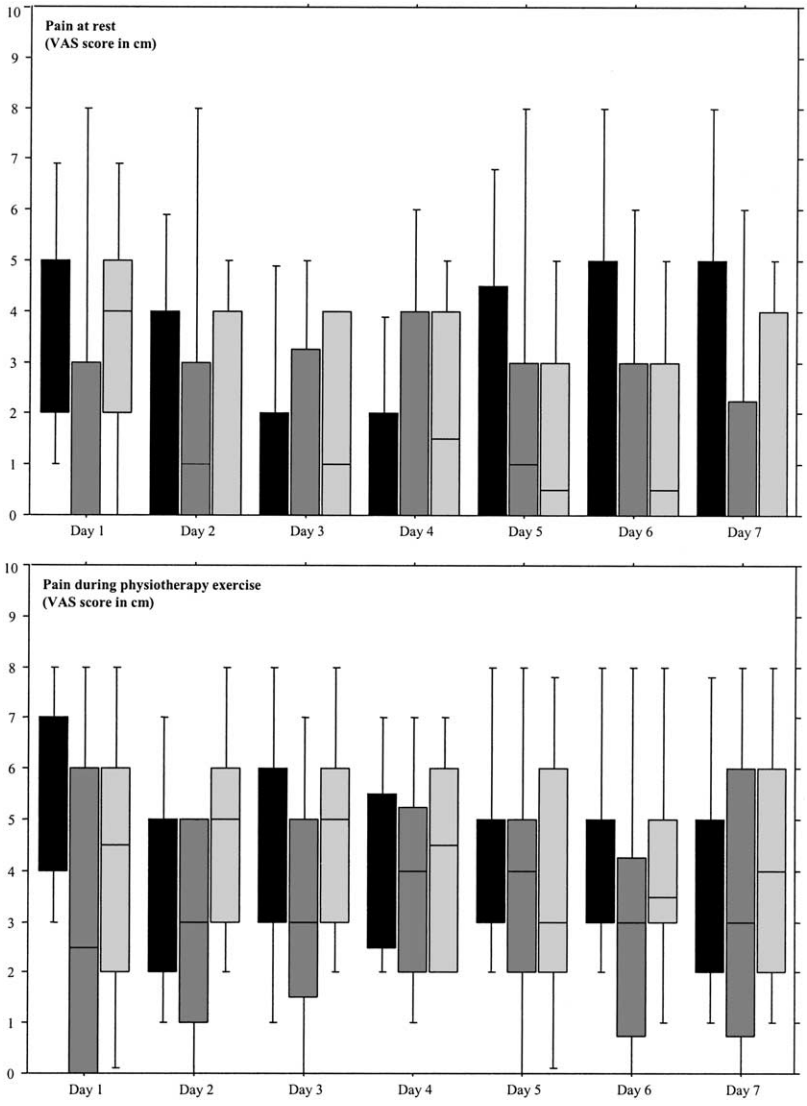


Fig 3. Pain values at rest and during physiotherapy exercise during the 7 observational days. Statistical analysis using a two-factorial analysis of variance did not show any significant difference between the groups at rest ($P = .44$) and during physiotherapy exercise ($P = .19$). Over time, VAS values decreased significantly only at rest ($P < .0001$) but not during movement ($P = .20$). No statistically significant interactions occurred between time and the type of catheter placement (analyzed on the per-protocol basis).

the areas known to be exclusively innervated by the SCI nerve, we did not test them in the FEM group. One can criticize this decision, as the FEM group could have served as a perfect control group.

Our results go along with those of most other authors who claim that in most cases, adequate analgesia after TKR cannot be achieved with continuous femoral nerve block alone, and that the addition of SCI nerve block renders a significant improvement in analgesia.[3,5,6,19-21] In this trial, patients from the FEM/SCI group needed less than half of the demand opioid compared with those from the PSOAS group and about one third of those from the FEM group during the 48 hours after surgery (Table 3). VAS scores at rest and during exercise did not differ between groups, probably because we instructed our patients repeatedly to use as much piritramid as needed to obtain a level of pain that was well tolerable (Fig. 3). Because no differences occurred between the current needed to obtain adequate motor response via the stimulating catheter (Table 2), we can rule out different block quality caused by more exact catheter placement in any of the 3 groups.

The routine use of a continuous SCI nerve block might obscure diagnosis of early compartment syndrome or perioperative nerve injury. Therefore, some surgeons ask to wait until initial block is re-

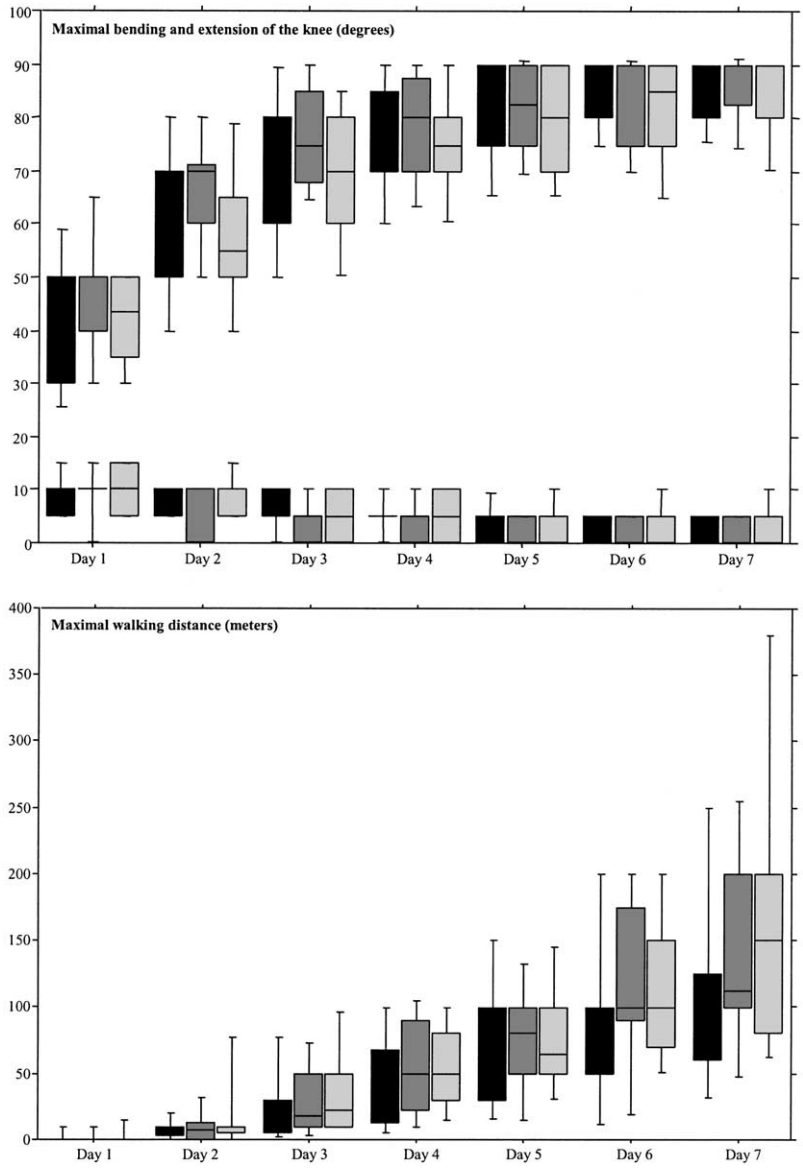


Fig 4. Maximal bending and extending of the knee and maximal daily walking distance under physiotherapy on the 7 observational days. No significant differences occurred between the groups over time for bending ($P = .19$), extending ($P = .17$), or walking distance ($P = .70$). However, bending, extending, and walking distance significantly improved during the first 7 postoperative days in all groups ($P < .0001$). No statistically significant interactions occurred between time and the type of catheter placement (analyzed on the per-protocol basis).

solved before the continuous infusion via the SCI nerve catheter is initiated. In our trial, this situation occurred once. We waited 8 hours until we were sure that no residual paresis was present and no nerve injury had occurred. Ben David et al.[21] also reported that in their institution, they had to change their routine use of both continuous FEM and SCI nerve block because of concerns that SCI block, and its motor consequences in particular, might obscure diagnosis of perioperative SCI nerve injury. The revised protocol included placing single-shot blocks and perineural catheters at both sites but infusing local anesthetic postoperatively only in the FEM catheter. In a sample group, 10 of 12 patients required continuous infusion via the SCI nerve catheter after resolution of the initial bolus dose.[21] The authors used the posterior subgluteal approach and did not describe the high failure rate that we observed. Our anterior approach has the advantage of the patient remaining in the same position as for FEM nerve block. However, this technique is not widely used for several reasons: it is a difficult approach, patients complain of pain after needle contact with periosteum of the femur,

Table 4. Results of the Telephone Interview Nine to Twelve Months after Total-Knee Replacement

	FEM (n = 30)	FEM/SCI (n = 30)	PSOAS (n = 29)	*P* Values
Actual state of health	3 (3/4)	3 (2/4)	3 (2/3)	.14
State of health compared with the time before surgery	2 (1/3)	1 (1/2)	2 (1/2)	.18
Pain at the knee joint during the past 4 weeks	2.5 (1/4)	2 (1/4)	2 (1/4)	.44
Need for pain medication compared with the time before surgery	1 (1/3)	1 (1/1.5)	1 (1/2)	.44
Nonconstraining mobility with the new knee joint	2 (1/3)	2 (1/3)	1 (1/3)	.24

NOTE. Values are expressed as median (25/75 percentile) (analyzed on the per-protocol basis).

and the posterior femoral cutaneous nerve is not constantly blocked.[22]

No significant differences concerning functional outcome (bending and extending of the knee and walking distance) (Fig. 4) could be demonstrated between the study groups during the immediate postoperative period of 7 days. The telephone survey conducted 9 to 12 months later did not show any group differences in knee mobility in daily use either. This finding is not surprising and confirms the results of other authors who did not find differences in outcome, even in comparison of a regional anesthetic technique with an epidural catheter and an intravenous PCA.[1,2] Furthermore, quality of life as assessed using questions of the SF36 questionnaire did not show any differences among the 3 groups. This survey also revealed that 25% of all patients still suffered strong or very strong pain 9 to 12 months after surgery. This finding may indicate that optimized analgesia could be expanded to later times in rehabilitation with great patient benefit.

Conclusion

The combination of continuous FEM and SCI block is associated with a marked reduction in supplementary analgesic requirements after TKR during the first 48 hours after surgery, compared with a continuous FEM block alone or a continuous PSOAS block. However, catheter placement time and failure rate of the anterior SCI nerve block were comparatively high, which indicates that another approach to the SCI nerve could possibly lead to even better results. The PSOAS block shows a significantly faster onset time of obturator nerve block compared with the FEM group and, furthermore, reaches SCI nerve territories, but this finding is not reflected in a better analgesic outcome.

Because no differences occurred between groups with respect to the immediate (within 7 days) and long-term (9 to 12 months) postoperative functional outcome, recommendations simply rely on the postoperative opioid requirements. Combined FEM/SCI catheter is the technique of choice if avoidance of opioids is the first aim. Otherwise, the FEM block is equally effective and faster to perform than the PSOAS block.

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