A Comparison of Epidural Analgesia With Combined Continuous Femoral-Sciatic Nerve Blocks After Total Knee Replacement

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Epidural analgesia remains the "gold standard" of pain relief after total knee replacement. However, peripheral nerve block is gaining popularity because the incidence of side effects may be reduced. Our study tests this postulate. Sixty patients were prospectively randomized to receive either epidural infusion or combined continuous femoral and sciatic nerve blocks. Ropivacaine 2 mg/mL plus sufentanil 1 μg/mL was given either epidurally or through the femoral nerve catheter, and ropivacaine 0.5 mg/mL was given through the sciatic nerve catheter using elastomeric infusers (delivering 5 mL/h for 55 h). The primary outcome measure was the total incidence of side effects (urinary retention and moderate to severe degrees of dizziness, pruritus, sedation, and nausea/vomiting on the first postoperative day). Intensity of motor blockade, pain at rest and on mobilization, and rehabilitation indices were also registered for 72 h. One or more side effects were present in 87% of patients in the epidural group whereas only 35% of patients in the femoral and sciatic block groups were affected on the first postoperative day ($P = 0.0002$). Motor blockade was more intense in the operated limb on the day of surgery and the first postoperative day in the peripheral nerve block group ($P = 0.001$), whereas the non-operated limb was more blocked in the epidural group on the day of surgery ($P = 0.0003$). Pain on mobilization was well controlled in both groups and there were no differences in the length of hospital stay. Rehabilitation indices were similar. The results demonstrate a reduced incidence of side effects in the femoral/sciatic nerve block group than in the epidural group on the first postoperative day.

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Epidural infusion of a local anesthetic with an opiate is a well established analgesia regimen after total knee replacement (TKR) (1,2), providing better pain control than patient-controlled analgesia (PCA) with morphine (3). There are, however, frequent side effects such as urinary retention, dizziness, sedation, pruritus, nausea, vomiting, catheter displacement, or the spread of analgesia to the non-operated limb (4,5). Lorenzini et al. (4) report that 68% of patients receiving a combination of ropivacaine 2 mg/mL and sufentanil 1 μg/mL had nausea/vomiting, 66% had urinary retention, and 58% had pruritus after 24 h of epidural infusion. Thus, the optimal analgesic technique that does not hinder mobilization and delay rehabilitation after TKR remains undetermined.

An alternative to epidural analgesia is the peripheral nerve block technique (6,7). Improvements in methods of neural localization have made this method both more reliable and increased its use (8,9). Peripheral nerve block has been shown to give better analgesia than PCA with morphine (6), and superior analgesia with less morphine consumption than spinal anesthesia (7,10). Singelyn et al. (11) compared 3 different pain relief regimes after TKR: PCA with IV morphine, continuous epidural infusion, and continuous femoral nerve block, using bupivacaine 1.25 mg/mL, sufentanil and clonidine for both infusions. Both regional anesthetic regimes were better than PCA with morphine. The frequency of side effects (nausea, vomiting, hypotension, urinary retention, unilateral blockade of the non-operated limb, and catheter problems) was less in the femoral nerve block group than in the epidural. Several subsequent investigations have confirmed these findings (12,13); others did not (14).

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In this prospective, randomized study, we compared continuous epidural infusion with combined continuous femoral and sciatic nerve blocks. The primary outcome was the incidence of side effects, and secondary outcomes were pain relief, motor blockade, morphine consumption, and rehabilitation indices.

Methods

Sixty ASA physical status I–III TKR patients were randomly allocated to one of two postoperative analgesia groups: those receiving conventional continuous epidural analgesia (EPI) and those receiving continuous femoral and sciatic nerve blocks (PNB). All patients were administered general anesthesia. Exclusion criteria were morphine intolerance, neurological diseases, coagulation disturbances, and patients with chronic pain and rheumatoid arthritis.

The Local Ethics Committee approved the study protocol. Written informed consent was obtained at a preoperative interview, and the participants were instructed in the use of the visual analog pain scale (VAS) and the PCA infuser.

Patients were premedicated with midazolam 3.75 or 7.5 mg per os 1 h before surgery. Computerized random number tables and sealed opaque envelopes were used to randomize the patients to the EPI group or the PNB group. Patients were sedated with midazolam 1 mg and/or alfentanil 0.5 mg IV. In patients randomized to the EPI group, a lumbar epidural catheter was placed at the L3-4 level using loss-of-resistance procedure (Braun, 18-gauge Tuohy needle and 20-gauge catheter). Three mL lidocaine 20 mg/mL with adrenaline (1:200 000) was given to test for intravascular or intrathecal placement. Thereafter ropivacaine 7.5 mg/mL was given in 5-mL aliquots to attain a level of analgesia at Th 10.

In PNB group patients, the femoral and sciatic nerves were located using a nerve stimulator (Stimuplex HNS 11, B. Braun, Melsungen, Germany). The femoral nerve was identified under the inguinal ligament (6) with a 5-cm Contiplex cannula (B. Braun). When the movement of the patella was still apparent at a current setting of 0.3 mA, 30 mL of ropivacaine 7.5 mg/mL was injected as a bolus and a 20-gauge catheter was inserted 5 cm past the cannula. The sciatic nerve was identified using an anterior approach (15) with an 11-cm Contiplex cannula (B. Braun). When plantar or dorsal flexion of the ankle was maintained with a current of 0.3 mA, 30 mL of ropivacaine 7.5 mg/mL was administered and a 20-gauge catheter was inserted 5 cm through the cannula. Catheters were secured to the skin with catheter clamps (Lockit, SIMS, Portex, Hythe, UK), and covered with a transparent dressing (Smith & Nephew, Hull, UK). Onset of peripheral nerve blocks was verified using the pinprick method.

General anesthesia was induced with propofol 2–2.5 mg/kg and maintained with continuous infusion of propofol 5–10 $mg \cdot kg^{-1} \cdot h^{-1}$ and remifentanil 0.5–1 $\mu g \cdot kg^{-1} \cdot min^{-1}$. A laryngeal mask airway was inserted, and patients' lungs were ventilated. Infusion rates were adjusted in accord with the patient reaction to surgical stimuli, arterial blood pressure, heart rate, and bispectral index monitor readings (40–50 U were planned during surgery). Surgery was performed with a tourniquet inflated to 350 mm Hg. The infusions were stopped after tourniquet deflation at the end of the operation. Urinary catheters were not used routinely. Bladder ultrasonography was undertaken at regular intervals in the postoperative care unit (PACU) and at the ward. Single catheterization was performed when bladder volume was more than 400 mL and if the patient was unable to void spontaneously. Patients were monitored and given normal saline infusions and ephedrine as required in accord with standard procedure.

In the PACU, the epidural catheter (for patients in the EPI group) was connected to an elastomeric infuser (Baxter LV5, Deerfield, IL) containing ropivacaine 2 mg/mL and sufentanil 1 μg/mL. The patients in the PNB group had 2 infusers (Baxter LV5), the first containing ropivacaine 2 mg/mL and sufentanil 1 μg/mL, was connected to the femoral nerve catheter. The second containing ropivacaine 0.5 mg/mL was connected to the sciatic nerve catheter. Infuser volume was 275 mL, and the infusion rate was 5 mL/h. All patients had access to an IV morphine PCA infuser (AP II; Baxter A/S Allerød, Denmark) set to allow a bolus of 2 mL = 2 mg with a lockout period of 6 min and maximum dose 20 mg/h. The patients were also given paracetamol 1 g 4 times daily. If the patients had a VAS > 3 at rest, 5 mL ropivacaine 7.5 mg/mL bolus was given through the catheters. If the pain score was >5, 5 mL of lidocaine 20 mg/mL bolus was given by the acute pain nurse specialist (BC). Infusions were continued for 55 h. Thereafter, patients received a standard oral analgesia with rofecoxib (Vioxx; Merck, Whitehouse Station, NJ) 25 mg in the morning, sustained release morphine (Contalgin) 20 mg (10 mg for patients older than 70 yr) twice daily and morphine 10 mg as required. Thromboprophylaxis, low molecular weight heparin (LMWH) tinzaparin 3 500 I.E. subcutaneously was administered daily from the day of surgery (after induction of general anesthesia) until discharge. All neural catheters were removed on the evening of the second postoperative day at least 10 h after LMWH was given. Patients with nausea and vomiting were given ondansetron 4 mg as required, as were droperidol 0.625 mg IV and dexamethasone 8 mg IV if symptoms persisted.

The blinding of the groups was not attempted because it is difficult to hide which regime the patient followed; those in EPI group had bilateral motor

blockade whereas those in PNB group had unilateral motor blockade.

The acute pain nurse made twice-daily visits at 2 and 4 h postoperatively and at 11 AM and 14.30 PM on the first, second, and in the morning of the third postoperative days. The following variables were registered:

1. Side effects: The patients were asked to grade their experience of dizziness, sedation, nausea/vomiting (PONV), and pruritus on a 4-point scale (none, mild, moderate and severe). Urinary retention: bladder volume was measured by ultrasonography and if the volume was more than 400 mL and if the patient was unable to void spontaneously, single catheterization was performed. An indwelling bladder catheter was used if repeated (>6) catheterizations were necessary or if the patient was incontinent.
2. Pain according to VAS scale (0 = no pain, 10 = worst conceivable pain) at rest and on mobilization.
3. PCA morphine consumption.
4. Motor blockade was estimated using a modified Bromage scale (0 = no blockade: extended limb lift off the bed; 1 = flexion/extension at knee and ankle joint; 2 = no flexion/extension at knee or ankle joint; and 3 = complete blockade).
5. Rehabilitation indices: The mobilization was started on the first postoperative day and continuous passive motion was introduced on the second postoperative day. Physiotherapists completed an evaluation form giving points for each stage in the mobilization program the patient was able to follow. On the first postoperative day the patients were expected at least to be able to sit at the bedside and stand beside the bed with help. On the second postoperative day they were expected to stand without help, use the walker with help, and transfer to a chair with help. On the third postoperative day transfer to a chair and walker mobilization without help as well as walking with crutches was expected. Number of degrees of active knee flexion was also registered.
6. Duration of admission was noted. Patients underwent inpatient rehabilitation and were discharged directly home. Discharge criteria were as follows: able to walk independently, able to manage the stairs, and active knee flexion of at least 70 degrees.

The patients were thus followed for 72 h. They were also visited on the seventh postoperative day by the surgeon and the acute pain nurse to exclude late onset complications (e.g., wound infection, sensory or motor nerve disturbances). The surgeon examined the patients 6 wk later, again asking about any adverse experience while the pain nurse prospectively registered the results.

Table 1. Demographic Data

	Epidural group (n = 23)	PNB group (n = 26)
Gender (F/M)	11/12	15/11
ASA physical status (I/II/III)	3/20	4/17/5
Age (yr)	67 ± 6	66 ± 7
Weight (kg)	82 ± 13	83 ± 18
Height (cm)	172 ± 10	168 ± 9
Duration of surgery (incision to closure in min)	92 ± 24	88 ± 24

The values are expressed as number of patients or mean ± SD. PNB = peripheral nerve block

Data were collected and analyzed using SPSS 11 statistical package (SPSS; Inc., Chicago, IL) for Windows. From earlier data collection, we knew that the highest frequency of dizziness, sedation, and PONV was experienced on the first postoperative day. Eighty-eight percent of patients with epidural analgesia after TKR experienced one or more of the following side effects: urinary retention, dizziness, pruritus, sedation, PONV, or catheter problems. If this incidence of 88% was reduced by 30% in a PNB group, 30 patients in each group would suffice to demonstrate a significant difference with a probability of type I error of 0.05 and power of 80%. Results are expressed as mean ± SD for the continuous variables, and analysis of variance was used for the statistical analyses. Ordinal and non-normally distributed variables are expressed as median (range) and the Mann-Whitney *U*-test was used for the statistical analyses. Nominal variables were analyzed by χ^2 and Fisher's exact test where appropriate. A P value <0.05 was considered statistically significant.

Results

Patient characteristics are displayed in Table 1. In 6 EPI group patients and 4 PNB group patients analgesia was insufficient although the onset of epidural and peripheral nerve blockade was ascertained before induction of general anesthesia. The reason for insufficiency of epidural analgesia was either lateralization to the wrong side or cranial rather than caudal spread of analgesia that was first discovered when the effect of ropivacaine bolus disappeared and maintenance infusion was started. As for PNB patients, 4 demonstrated incomplete femoral nerve block or lack of obturator nerve block. Supplementary nerve blocks were given, and these patients were excluded. Another EPI patient suffered an acute myocardial infarction after surgery and was transferred to another hospital for

Table 2. Incidence of Side Effects

		Day of surgery			POD 1			POD 2		
Side effects	VRS:	EPI	PNB	*P* value	EPI	PNB	*P* value	EPI	PNB	*P* value
Dizziness	None/mild	19	24		20	26		19	24	
	Moderate/severe	4	2	0.4	3	0	0.09	4	2	0.4
Pruritus	None/mild	21	26		22	24		21	26	
	Moderate/severe	2	0	0.22	1	2	1.0	2	0	0.22
Sedation	None/mild	23	25		21	25		23	25	
	Moderate/severe	0	1	1.0	2	1	0.59	0	1	1.0
PONV	None/mild	19	24		20	24		19	24	
	Moderate/severe	4	2	0.4	3	2	0.66	4	2	0.4
Urine retention	None	6	20		9	23		18	22	
	Catheterization	16	6		13	3		3	4	
	KAD	0	1	0.002	1	0	0.001	2	0	0.3

POD = postoperative day; VRS = verbal rating scale; PONV = postoperative nausea and vomiting; KAD = indwelling urinary catheter; EPI = epidural; PNB = peripheral nerve block.

acute coronary bypass operation. Recovery was uneventful and he was discharged on the 30th postoperative day. Thus, 23 patients in the EPI group and 26 patients in the PNB group were included in the analysis. No patient exhibited clinical signs of local anesthetic toxicity, even though large-dose ropivacaine boluses were given.

The incidence of each side effect for the 3 days is shown in Table 2. The frequency of dizziness, pruritus, sedation, and nausea/vomiting was not different for the two groups when viewed separately. Urinary retention was more pronounced in the EPI group on the day of surgery ($P = 0.002$) and the first postoperative day ($P = 0.001$). The combined frequency of moderate and severe degrees of dizziness, pruritus, sedation, PONV, and urinary retention was higher in the EPI group on the first postoperative day (87% of patients had experienced one or more of these side effects as compared with the patients in the PNB group, where only 35% experienced side effects; $P = 0.0002$) (Table 3).

Four hours after the conclusion of surgery both groups, controlled in PACU, had median VAS scores of zero (Table 4). Mean time lapse from the end of surgery to pain debut was 18–19 h in both groups. PNB patients had more intense motor blockade of the operated limb than EPI patients ($P = 0.001$) whereas blockade of the non-operated limb was more pronounced in the EPI group ($P = 0.0003$).

On the first postoperative day (Table 5), motor blockade in the operated limb in the PNB patients was still more pronounced than in the EPI patients ($P = 0.01$), whereas the contralateral block in the EPI patients had resolved. VAS scores at rest and on mobilization were low and comparable. Supplementary analgesia with lidocaine and ropivacaine was necessary in both groups with larger consumption of lidocaine in the PNB group ($P = 0.01$). PCA morphine usage was the same.

On the second postoperative day (Table 5) the difference in motor blockade between the groups had resolved. The need for supplementation with ropivacaine was still present with no difference between the groups. Morphine consumption was unchanged from the previous day. Pain scores had low values and were similar in the two groups.

There was no significant difference in fulfillment of the mobilization program and in the degrees of active knee flexion as evaluated by physiotherapists (Table 6). The greatest difference between the groups was found on the third postoperative day, when 73% of PNB patients and 91% of EPI patients accomplished physiotherapy goals. Duration of admission was similar: 7 days (6,16) in the EPI group and 8 (6,10) in the PNB group ($P = 0.6$).

One cardiovascular complication occurred in the EPI group; the patient developed atrial fibrillation, underwent successful DC conversion, and was able to continue the standard postoperative training. No other complications were reported at the 6-wk follow-up.

Discussion

There are two different approaches to the analysis of the frequency of side effects after TKR in the literature: to analyze each side effect for each day of the infusion (4) or to form an overview of presence or absence of side effects for each individual patient throughout the observation period (11,12). When all grades of side effects were considered for each day, there were no differences between the EPI and PNB patients, as shown in Table 2. However, when the presence or absence of side effects for each patient was noted, less side effects occurred in patients with combined continuous femoral and sciatic nerve blocks. Side effects were not serious or long lasting; all patients were fully recovered at 7-day follow-up. Our findings are comparable to those of Singelyn et al., Capdevila et al., and

Table 3. Total Incidence of Side Effects

	Day of surgery			POD 1			POD 2		
	EPI	PNB	*P* value	EPI	PNB	*P* value	EPI	PNB	*P* value
One or more side effects	17 (74)	7 (27)		20 (87)	9 (35)		12 (52)	9 (35)	
No side effects	6 (26)	19 (73)	0.001	3 (13)	17 (65)	0.0002	11 (48)	17 (65)	0.22

Values are expressed as number of patients and (%). EPI = epidural; PNB = peripheral nerve block.

Table 4. On the Day of Surgery

	EPI (n = 23)	PNB (n = 27)	*P* value
No of patients in need of alfentanil IV on arrival at PACU	3	7	0.43
Bromage score in the operated limb 4 h after surgery	1 (0, 3)	3 (0, 3)	0.001
Bromage score in the non-operated limb 4 h after surgery	0 (0, 3)	0 (0, 0)	0.0003
VAS score 2 h after surgery	0 (0, 6.5)	0 (0, 6.5)	0.07
VAS score 4 h after surgery	0 (0, 5.2)	0 (0, 4.3)	0.14
Lidocaine 20 mg/mL in the catheter/s at the ward	3	5	0.18
Ropivacaine 7.5 mg/mL in the catheter/s at the ward	12	3	0.01
Time from operation end to pain debut (h)	19.6 ± 11	18 ± 9.5	0.62

N = 23 in epidural (EPI) and 27 in peripheral nerve block (PNB) group as a result of exclusion of patients with insufficient blockade and one patient with acute myocardial infarction in EPI group. Values are expressed as median (range) and in number of patients. PACU = postoperative care unit; VAS = visual analog scale. Modified Bromage score where grade 0 = no motor blockade and grade 3 = complete blockade.

Table 5. First and Second Postoperative Days

	POD 1			POD 2		
	EPI	PNB	EPI	PNB	EPI	PNB
Bromage score in the operated limb	1 (0 1)	1 (0, 2)	0.01	1 (0, 1)	1 (0, 1)	0.07
Bromage score in the nonoperated limb	0 (0, 0)	0 (0, 0)	1.0	0 (0, 0)	0 (0, 0)	1.0
VAS score at rest	2 (0, 9)	3.2 (0, 9)	0.2	0.8 (0, 5)	1.1 (0, 5.6)	0.39
VAS score during motion	2.7 (0, 7.5)	4 (0, 8)	0.25	4 (0, 10)	3.7 (0, 9.3)	0.53
Patients with need for ropivacaine supplement	16	19	0.78	11	13	0.2
Patients with need for lidocaine supplement	8	19	0.01	0	0	
PCA morphine consumption (mg)	32.6 ± 26	31 ± 26	0.83	30.2 ± 26.3	32.3 ± 25.7	0.78

The values are expressed as median (range), number of patients and as mean ± SD. Modified Bromage scale with 0 grade for no blockade and grade 3 = complete blockade. VAS = visual analog scale from 0 = no pain to 10 (worst pain); PCA = patient-controlled analgesia; EPI = epidural; PNB = peripheral nerve block.

Table 6. Rehabilitation Indices

	Physiotherapy goals		
	EPI (n = 23)	PNB (n = 26)	*P* value
Patients with accomplished goals			
POD 1	20 (87%)	24 (92%)	0.66
POD 2	21 (91%)	23 (88%)	1.0
POD 3	21 (91%)	19 (73%)	0.15
Degrees of active flexion of knee joint			
POD 1	45 (20–75)	42.5 (30–90)	0.65
POD 2	60 (25–90)	55 (35–90)	0.35
POD 3	70 (30–95)	65 (45–105)	0.36
Before discharge	90 (70–105)	87.5 (70–100)	0.4

The values are expressed as number of patients (%) and median (range). POD = postoperative day; EPI = epidural; PNB = peripheral nerve block.

Chelly et al. (11–13). Davies et al. (14) found no significant difference between the two methods but did not include urinary retention in the list of side effects. Chelly et al. (13) found a number of advantages of PNB: better recovery and 90% decrease in serious complications, but the patients in this study were not randomized, which is known to exaggerate the advantages of new methods.

Motor blockade in our study was significantly different in the two groups: only the operated limb was blocked in PNB patients whereas both limbs were affected in EPI patients until the first postoperative day. The intensity of motor blockade was more pronounced in the PNB group and could have influenced the patients' ability to mobilize. However, the effect was not so profound that it significantly influenced the patients' performance as evaluated by physiotherapists. More patients would be necessary to confirm or disprove this tendency. The efficacy of analgesia and duration of hospitalization were comparable in both groups.

Severe neurological complications (spinal hematoma, cauda equine syndrome) after central neural blockade are rare events (16) but should be considered when choosing a safe method for postoperative analgesia. Peripheral nerve damage can occur after peripheral nerve block but the consequences are not as grave (17). A clear advantage of the peripheral nerve block method is that it can be applied even if patients have received LMWH as thrombosis prophylaxis. In 6 of our EPI patients with inadequate analgesia, conversion was made to peripheral nerve block. It has an important role whenever epidural catheterization is contraindicated and it is effective backup when epidural analgesia fails.

Singelyn et al. (11) and Capdevila et al. (12) used only continuous femoral nerve block for analgesia after TKR. We came to the same conclusion as Ben-David et al. (18) that addition of continuous sciatic block to a continuous femoral block regimen is necessary for adequate analgesia after TKR. We chose ropivacaine 2 mg/mL at the rate of 5 mL/h and not a smaller concentration for epidural infusion because we prefer a ready-made preparation and because the analgesic effect is dependant on the total dose rather than on the concentration (19). With this dose we found that epidural motor blockade was not profound and did not hinder mobilization.

The ideal concentration, infusion rate, and nature of the local anesthetic for peripheral nerve block are not established. Infusion rates in published studies vary from 6 mL/h (20,21) to 12 mL/h (13). We chose 5 mL/h, the rate given by simple elastomeric infusers. They can be strapped around the patient's waist, are light, and are no hindrance to mobilization. We had the services of the pain nurse who performed the function of PCA refinement of more elaborate mechanical pump systems. An alternative and less labor-intensive method would be to use mechanical infusers with PCA function. The choice of a small concentration of ropivacaine (0.5 mg/mL) for continuous sciatic block was the result of trial and error with different concentrations. No significant difference in effect or duration of action has been found in comparative studies of bupivacaine and ropivacaine for peripheral nerve block (6,10).

The incidence of side effects on the first postoperative day was reduced from 87% to 35% in the PNB group compared with the EPI group. All side effects were of temporary nature and disappeared before discharge. The two methods had similar analgesic efficacy and rehabilitation indices and duration of hospital stay were comparable.

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References

1. Mahoney OM, Noble PC, Davidson J, Tullos HS. The effect of continuous epidural analgesia on postoperative pain, rehabilitation and duration of hospitalization in total knee arthroplasty. Clin Orthop Relat Res 1990;260:30–7.
2. Pettine KA, Wedel DJ, Cabanela ME, Weeks JL. The use of epidural bupivacaine following total knee arthroplasty. Orthopaedic Review 1989;18:894–901.
3. Raj PP, Knarr DC, Vigdorth E, et al. Comparison of continuous epidural infusion of a local anesthetic and administration of systemic narcotics in the management of pain after total knee replacement. Anesth Analg 1987;66:401–6.
4. Lorenzini C, Moreira LB, Ferreira MBC. Efficacy of ropivacaine compared with ropivacaine plus sufentanil for postoperative analgesia after major knee surgery. Anaesthesia 2002;57:424–8.
5. Forster JG, Rosenberg PH. Small dose of clonidine mixed with low-dose ropivacaine and fentanyl for epidural analgesia after total knee arthroplasty. Br J Anaesth 2004;93:670–7.
6. Ng HP, Cheong KF, Lim A, et al. Intraoperative single-shot '3-in-1' femoral nerve block with ropivacaine 0.25%, ropivacaine 0.5% or bupivacaine 0.25% provides comparable 48-hr analgesia after unilateral total knee replacement. Can J Anaesth 2001;48:1102–8.
7. Allen JG, Denny NM, Oakman N. Postoperative analgesia following total knee arthroplasty. Reg Anesth Pain Med 1998;23:142–6.
8. Koscielniak-Nielsen ZJ, Pedersen HS, Lippert FK. Readiness for surgery after axillary block: single or multiple injection techniques. Eur J Anaesthesiol 1997;14:164–71.
9. Chelly JE. History. In: Chelly JE, Casati A, Fanelli G, eds. Continuous peripheral nerve block techniques. St. Louis: Mosby International Limited 2001;1:3–10.
10. McNamee DA, Convery PN, Milligan KR. Total knee replacement: a comparison of ropivacaine and bupivacaine in combined femoral and sciatic block. Acta Anaesthesiol Scand 2001;45:477–81.
11. Singelyn FJ, Deyaert M, Joris D, et al. Effects of intravenous patient-controlled analgesia with morphine, continuous epidural analgesia, and continuous three-in-one block on postoperative pain and knee rehabilitation after unilateral total knee arthroplasty. Anesth Analg 1998;87:88–92.
12. Capdevila X, Barthelet Y, Biboulet P, et al. Effects of perioperative analgesic technique on the surgical outcome and duration of rehabilitation after major knee surgery. Anesthesiology 1999;91:8–15.
13. Chelly JE, Greger J, Gebhard R, et al. Continuous femoral blocks improve recovery and outcome of patients undergoing total knee arthroplasty. J Arthroplasty 2001;16:436–44.
14. Davies AF, Segar EP, Murdoch J, et al. Epidural infusion or combined femoral and sciatic nerve blocks as perioperative analgesia for knee arthroplasty. Br J Anaesthesia 2004;93:368–74.
15. Chelly JE, Delaunay L. A new anterior approach to the sciatic nerve block. Anesthesiology 1999;91:1655–60.

16. Moen V, Dahlgren Nirestedt L. Severe neurological complications after central neuraxial blockades in Sweden 1990–1999. Anesthesiology 2004;101:950–9.
17. Fanelli G, Casati A, Garancini P, Torri G. Nerve stimulator and multiple injection technique for upper and lower limb blockade: failure rate, patients acceptance, and neurologic complications. Anesth Analg 1999;88:847–52.
18. Ben-David B, Schmalenberger K, Chelly JE. Analgesia after total knee arthroplasty: is continuous sciatic blockade needed in addition to continuous femoral blockade? Anesth Analg 2004;98:747–9.
19. Dernedde M, Stadler M, Bardiau F, Boogaerts JG. Continuous epidural infusion of large concentration/small volume versus small concentration/large volume of levobupivacaine for postoperative analgesia. Anesth Analg 2003;96:796–801.
20. Hirst GC, Lang SA, Dust WN, et al. Femoral nerve block: single injection versus continuous infusion for total knee arthroplasty. Reg Anesth 1996;21:292–7.
21. Edwards ND, Wright EM. Continuous low-dose 3-in-1 nerve blockade for postoperative pain relief after total knee replacement. Anesth Analg 1992;75:265–7.