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Analgesia and functional outcome after total knee arthroplasty: periarticular infiltration *vs* continuous femoral nerve block

F. Carli[1]*, A. Clemente[1], J. F. Asenjo[1], D. J. Kim[1], G. Mistraletti[3], M. Gomarasca[3], A. Morabito[4] and M. Tanzer[2]

[1] Department of Anesthesia and [2] Department of Orthopedic Surgery, McGill University Health Centre, 1650, Cedar Ave, Room D10.144, Montreal, Quebec, Canada
[3] Dipartimento di Anestesiologia, Terapia Intensiva e Scienze Dermatologiche and [4] Dipartimento di Medicina, Chirurgia e Odontoiatria, Università degli Studi di Milano, Milan, Italy

* Corresponding author. E-mail: franco.carli@mcgill.ca

Key points

- Femoral block spares opioids and has better functional recovery profile.
- Preoperative walking capacity and early postoperative walking time predict short-term recovery.
- Walk tests can be reliable indicators of knee function recovery.

Background. Capacity to ambulate represents an important milestone in the recovery process after total knee arthroplasty (TKA). The purpose of this study was to determine the analgesic effect of two analgesic techniques and their impact on functional walking capacity as a measure of surgical recovery.

Methods. Forty ASA II–III subjects undergoing TKA were enrolled in a randomized, double-blind, single-centre study receiving 48 h postoperative analgesia with either periarticular infiltration of local anaesthetic (Group I) or continuous femoral nerve block (Group F). Breakthrough pain relief was achieved with patient-controlled analgesia (PCA) morphine. The main outcome was postoperative morphine consumption. Early (postoperative days 1–3) and late (6 weeks) functional walking capacity (2 and 6 min walk tests, 2MWT and 6MWT, respectively), degree of physical activity (CHAMPS), health-related quality of life (SF-12), and clinical indicators of knee function (WOMAC, Knee Society evaluation, and range of motion) were measured.

Results. Patients in Group F used the PCA less ($P=0.02$) to achieve adequate analgesia. Postoperative 2MWT was similar in both groups ($P=0.27$). Six weeks after surgery, recovery of 6MWT, physical activity, and knee function were significantly improved in Group F ($P<0.05$). Preoperative walking capacity, physical activity and early total walking time were the independent predictors of early recovery. Distance and time spent walking were the predictors of functional walking exercise capacity at 6 weeks after surgery.

Conclusions. Femoral block is associated with lower opioid consumption and a better recovery at 6 weeks than periarticular infiltration. Early postoperative activity measures (2MWT and walking time) were proved to be possible indicators of knee function recovery at 6 weeks after surgery.

Keywords: analgesia, postoperative; analgesic techniques, intra-articular; continuous peripheral nerve block; morphine consumption; pain, acute; periarticular infiltration; total knee arthroplasty

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Rehabilitation after total knee arthroplasty (TKA) routinely starts immediately after surgery on the postoperative ward and therefore requires adequate analgesia. An ideal analgesic modality for post-TKA rehabilitation should permit adequate knee flexion with minimal pain and without motor impairment, resulting in successful mobilization.[1] Continuous femoral nerve block (CFNB) with local anaesthetics has been consistently shown to provide superior analgesia and less side-effects compared with systemic opioids, thus facilitating exercises to increase the degree of knee flexion.[2–4] However, a criticism of CFNB is that it may impair quadriceps muscle strength through block of the femoral nerve, thus delaying the ability to mobilize.

An alternative to CFNB involves periarticular infiltration of the knee with high-volume local anaesthetics, providing analgesia directly into the area of surgical trauma. After

initial reports of success using periarticular infiltration of high-volume local anaesthetics in TKA,[5] recent open and randomized studies have confirmed that this technique reduces postoperative intensity of pain and consumption of rescue analgesics.[6–8] This accelerated recovery was attributed to improved walking capacity and less quadriceps impairment.

Traditionally, the degree of knee flexion has been used as an outcome measure after TKA to evaluate functional recovery and the success of the type of analgesia used.[2–9] However, with the need to accelerate hospital discharge and shorten the period of rehabilitation,[10–12] the capacity to mobilize from a chair with minimal effort and walk a sufficient distance with minimal aid represents a more realistic criterion to assess functioning and independence after TKA.

Physical activity is an important aspect of day-to-day life, and walking capacity is a measure of exercise tolerance requiring muscle strength. Walk tests measure the distance walked over a definite time period, with greater distances indicating better performance. The 6 min walk test (6MWT) and the 2 min walk test (2MWT), respectively, reflect endurance and muscle force required to walk effectively.[13 14]

Although CFNB and periarticular infiltration have both been associated with superior analgesia and favourable knee flexion compared with systemic opioids, no randomized, double-blind study has yet been performed to compare the effect of these two techniques on postoperative walking capacity and this measure of mobility is assumed to be an index of postoperative recovery. In fact, the only previous randomized study comparing CFNB with periarticular infiltration was not double blinded and did not use standardized measures of walking capacity and physical activity.[15]

This prospective, double-blind, randomized, single-centre trial was designed to compare the quality of analgesia offered by CFNB and periarticular infiltration and their impact on 6MWT and 2MWT performance in both the postoperative period and 6 weeks after surgery. The potential for preoperative and immediately postoperative functional walking capacity to predict late recovery was also assessed. In line with the current literature, it was hypothesized that periarticular infiltration of local anaesthetics would improve functional exercise capacity in both the early and the late postoperative period compared with CFNB.

Methods

A prospective, randomized, double-blind, controlled, single-centre trial was carried out at the McGill University Health Centre (MUHC). The data for this study came from persons undergoing a primary, unilateral, tricompartmental cemented TKA between February 2007 and November 2008. The study was approved by the MUHC Research Ethics Board (GEN#06-026) and all subjects signed a written informed consent form. At the time of study approval, registration in a clinical trials database was not required.

Subjects

Persons were eligible to enter the study if they were over the age of 18 and were referred for TKA secondary to osteoarthritis. Exclusion criteria were: ASA health status class IV–V, history of abnormal liver enzymes, hepatic failure, renal insufficiency, cardiac failure, organ transplant, morbid obesity (BMI$>$40 kg m^{-2}), neuropathic pain, history of stroke or major neurological deficit, sensory and motor disorders in the operated limb, previous drug dependency, chronic use of opioids, allergy to local anaesthetics, inability to walk independently, and inability to comprehend pain assessment. Patients were instructed before surgery in the use of the numerical rating scale (NRS) to assess pain.

Anaesthesia

Standard monitoring (pulse oximeter, ECG, and non-invasive arterial pressure) was applied to all patients on their arrival in the anaesthetic room. No premedication was given. After an i.v. preload with 500 ml of 0.9% NaCl, a spinal block was performed in sitting position with either a 25 or 27 G Whitacre spinal needle inserted at the L2–L3 or L3–L4 intervertebral space. After clear free flow of cerebrospinal fluid, 12.5 mg of racemic 0.5% bupivacaine was administered to achieve sensory block (to cold and pinprick) to the 10th thoracic dermatome or above. Throughout surgery, sedation, if necessary, was achieved with a continuous infusion of propofol. Intravenous normal saline (0.9% NaCl) was administered during the surgery at an hourly rate of 6–8 ml^{-1}, and intraoperative normothermia ($>$36.0°C) was maintained with warming blankets spread over the exposed part of the body. Hypotension (arterial pressure $<$80 mm Hg) was treated with i.v. bolus doses of 100 μg of phenylephrine. Oxygen therapy (30% oxygen mask) was provided to all patients during the first 24 h.

Surgical care

All surgeries were performed by a single surgeon (M.T.). One dose of 2 g of cefazolin (GlaxoSmith Kline, England) was given i.v. 30 min before surgery and then every 8 h for a total of three doses. A pneumatic tourniquet was positioned on the thigh before surgery and inflated to 250 mm Hg. The surgical technique involved approaching the knee through a midline incision with a medial parapatellar arthrotomy. All varus/valgus deformities were then corrected using appropriate soft tissue releases. The anterior cruciate ligament was resected and the posterior cruciate ligament was preserved with a bony island. An intramedullary alignment guide was used to prepare the femur, whereas the proximal tibia was cut using an extramedullary guide. The patella was not everted for exposure or preparation in any case. All patients received a NexGen cruciate retaining TKA with patellar resurfacing (Zimmer, Warsaw, IN, USA). All components were cemented in place using Simplex P cement with tobramycin (Stryker, Rutherford, NJ, USA) that had been pressurized into the cut surfaces using a cement gun.

Analgesic techniques

All patients received a femoral nerve catheter and a periarticular knee catheter.

Continuous femoral nerve catheter

All femoral nerve catheters were inserted before spinal anaesthesia by one investigator (J.F.A.). Under aseptic conditions, a stimulating catheter (Stimucath, Arrow International, Reading, PA, USA) was used in all blocks. The femoral nerve was localized 1 cm lateral to the femoral artery at the inguinal crease and identified by a quadriceps motor response and ascension of patella. The catheter was then threaded with caution to maintain at all times the desired motor response. The threshold accepted for final catheter positioning was <0.8 mA of current intensity (0.1 ms width, 2 Hz). The catheter was then tunnelled for 5–7 cm under the skin to minimize dislodgement. At the end of surgery, patients received a loading dose of 8 ml of either ropivacaine 0.2% (Group F) or saline 0.9% (Group I). This was followed by a continuous infusion of either ropivacaine 0.2% (Group F) or saline 0.9% (Group I) at a rate of 8 ml h^{-1} for 48 h.

Infiltration of the posterior capsule of the knee to cover popliteal pain

A solution containing 100 mg of ropivacaine (50 ml of ropivacaine 0.2%), 0.5 ml of ketorolac (30 mg ml^{-1}), and 0.25 ml of epinephrine (1 mg ml^{-1}) was injected into the posterior capsule of the knee. This was done after all the bony cuts and before cementing the implants. This allowed wide exposure of the posterior capsule and thereby allowing diffuse infiltration of the capsule. This solution was administered to all patients irrespective of the group, and it was done to make the two groups similar with regard to the popliteal pain which can normally occur in 15–20% of patients undergoing TKA.

Periarticular and intra-articular infiltration

A second solution containing a total volume of 100 ml of ropivacaine 0.2%, 1 ml of ketorolac (30 mg ml^{-1}), and 0.5 ml of epinephrine (1 mg ml^{-1}) was prepared to be infiltrated in Group I. An equivalent amount of saline 0.9% was also prepared to be infiltrated in Group F. These solutions were injected into the remainder of the capsule, the cut quadriceps tendon, the patellar ligament and soft tissues surrounding the joint, and the s.c. tissues after closure of the medial parapatellar arthrotomy.

At the end of surgery, an intra-articular 3.2 mm catheter tubing (Wound-Evac™, Microtek, Dominican Republic) was inserted 5 cm proximal to the incision into the distal anterior thigh, penetrating the s.c. tissues, the quadriceps muscle, and the joint capsule, with the catheter tip running along the lateral gutter of the knee joint. Through this catheter, a third solution containing either 50 ml of ropivacaine 0.5% with ketorolac (30 mg ml^{-1}) and 0.25 ml of epinephrine (1 mg ml^{-1}) or saline 0.9% was infused in Group I and Group F, respectively, over a 2 h period at 24 h after the end of operation. At the end of the infusion, the catheter was immediately removed and a pressure bandage applied.

Randomization

On the morning of surgery, patients were randomized to one of the two groups, continuous femoral nerve block (Group F) and periarticular infiltration (Group I) using computer-generated tables and sealed brown envelopes. The solutions for both femoral and periarticular infiltration were prepared under aseptic conditions. The staff involved in the clinical care (surgeons, anaesthetists, nurses, and physiotherapists) and the patients were not aware of the treatment group assignment.

Multimodal analgesia

At arrival in the post-anaesthesia care unit (PACU), all patients in both groups were connected to a patient-controlled analgesia (PCA) pump set-up to deliver incremental doses of 1 mg of morphine, with a lockout of 7 min and no background infusion. The PCA was discontinued 48 h after surgery, and all patients received slow-release oxycodone 10 mg p.o. every 12 h. For breakthrough pain with NRS >3, oxycodone 5–10 mg p.o. every 3 h was prescribed for 3 days. Both groups started to receive in the PACU celecoxib 100 mg every 12 h for 5 days and acetaminophen 1 g every 6 h for 5 days. Patients with postoperative nausea and vomiting (PONV) received i.v. ondansetron 2–4 mg and i.v. dymenhydrate (Gravol) 50 mg as needed.

Postoperative care

No patients were placed on a fast track rehabilitation protocol. The patients were visited by the surgical team that was responsible for postoperative care and that was unaware of the results of the clinical or objective assessments. This team recorded daily knee function (flexion, wound bleeding, infection, and pain) and also determined the readiness for discharging patients from hospital according to standard criteria (patients able to ambulate with some assistance, ability to climb stairs, tolerance of solid food, absence of infection, and NRS at rest <3 out of 10). The i.v. infusion of crystalloids was discontinued on the postoperative day (POD) 1 if no complications (PONV and bleeding) occurred. Full diet was allowed as soon as the patients arrived on the surgical ward. A urinary catheter was not inserted before surgery. Bladder volume was monitored after surgery using a bladder scanner, and if the volume of urine was above 500 ml, patients would receive an in–out bladder catheterization. If they were not able to void after one in–out catheterization, the bladder catheter would be left *in situ* for 24 h.

Physiotherapy protocol

Under physiotherapist's supervision and in a progressive manner, the following interventions and exercises were undertaken daily (between 12:00 and 15:00 h) while in hospital: body mechanics, bed mobility, out of bed transfer, assisted ambulation, stair training, deep breathing and coughing exercises, flexion and extension of non-operated knee, static quadriceps, and assisted flexion exercises for the operated leg. Maximum knee flexion and pain intensity (NRS 0–10) during knee flexion were recorded. The

physiotherapist, in consultation with the surgeon, was also in charge of organizing the discharge either to home or to a rehabilitation centre.

Outcome measures

Analgesia

The quality of postoperative pain relief was estimated by daily consumption of morphine during the first 48 h and the NRS for pain (11-point scale 0–10 where 0 means no pain and 10 extreme pain) at rest, on walking, and on knee maximal flexion for each of the first 3 days, at the time of hospital discharge, and 6 weeks after surgery. The degree of knee flexion was measured by the physiotherapist with a goniometer, and pain intensity during knee assessment was assessed during the early afternoon hours for the first three PODs. The incidence of PONV was recorded for the first 48 h.

Functional walking capacity

The 2MWT and 6MWT were used to assess functional walking capacity.[16] The 2MWT was measured before surgery and in the early afternoon (between 13:00 and 17:00 h) of the first, second, and third PODs to assess muscle strength and the obstacles to walking recovery. The 6MWT was measured before surgery and at 6 weeks after surgery to assess endurance. The distance covered was then recorded in metres. If the patient was unwilling or unable to walk, the reason was recorded for that day. Baseline-predicted 2MWT and 6MWT distance was calculated using gender-specific reference equations for the 6MWT.[17]

Physical activity

Activity while in hospital was recorded as the total time out of bed either sitting or walking during the first three PODs in a journal by all patients. Also time to first full diet and first walk was recorded. To assess the amount of physical activity before and 6 weeks after surgery, patients were asked to fill the Community Health Activities Model Program for Seniors (CHAMPS) questionnaire. This was developed to evaluate the effectiveness of interventions to increase physical activity in older adults.[18] The CHAMPS has construct validity and been used in surgical patients to assess recovery.[19]

Health-related quality of life

This was measured by the acute (week recall) SF-12 health survey.[20]

Assessment of knee function

The Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC)[21] and the Knee Society evaluation[22] were administered before and 6 weeks after surgery.

Data collection

All characteristic and clinical data related to patients' outcome measures (primary, secondary, and intermediate) during the immediate and late postoperative period were collected by a research assistant unaware of the study hypothesis. Length of hospital stay and readmission rate were also recorded, and postoperative complications up to 30 PODs were fully documented.

Power of the study

The primary outcome was morphine consumption during the first 48 postoperative hours. On the basis of the values reported in two separate studies on TKA and comparing periarticular infiltration *vs* PCA morphine and similarly femoral block *vs* PCA morphine, 36 patients would be required to detect a significant difference between Group F ($n=18$) and Group I ($n=18$) >40% in morphine consumption with a power of 80% and an α of 5%.[6 23] To allow for protocol violations or increased variability in data, 40 patients in total were recruited.

Data analysis

Statistical analysis was performed using Stata Version 9.2 software (Stata Corporation, College Station, TX, USA). The clinical data of the population studied are presented in Table 1, and normally distributed continuous variables were

Table 1 Patients characteristics and clinical data presented as mean (range) for age and mean (SD), absolute number, or median (IQR) as appropriate for other variables. ASA, American Society of Anesthesiologists

Variables	Periarticular infiltration ($n=20$)	Femoral block ($n=20$)
Age (yr)	70.8 (55–85)	71.1 (56–84)
Weight (kg)	75.8 (9.0)	74.3 (17.6)
Height (cm)	163.3 (8.1)	165.6 (10.1)
Body mass index (kg m^{-2})	28.5 (3.3)	27.0 (5.2)
Sex, M/F	5/15	6/14
ASA status I/II/III	1/14/5	1/17/2
Co-morbidities		
None	8	9
Hypertension	6	11
Coronary artery disease	2	1
Atrial fibrillation	1	0
Hypercholesterolaemia	1	4
Hypothyroidism	1	1
Asthma	0	1
Diabetes	3	2
Gastric ulcer	1	0
Side of surgery, R/L	11/9	11/9
Surgery time (min)	105 (95–110)	118 (108–127)
Tourniquet (min)	97 (90–102)	102 (89–111)
Tourniquet (mm Hg)	275 (250–275)	260 (250–275)
Intraoperative blood loss (ml)	200 (125–250)	200 (125–300)
Intraoperative fluids administered (ml)	1500 (1000–1500)	1550 (1100–2000)
Time to eating (h)	7 (4–16)	10 (4–18)
Time to walking (h)	24 (24–48)	24 (24–37)
Hospital length of stay (days)	5 (4–6)	5 (4–6)

Table 2 Rescue analgesic morphine and pain intensity presented as median (IQR). Morphine consumption values were transformed into normal distributions and analysed with repeated-measures regressions for general linear models. NRS comparisons were made by repeated-measures Poisson's regressions. NRS, numeric rating scale; POD, postoperative day

Variables	Periarticular infiltration ($n=20$)	Femoral block ($n=20$)	*P*-value between groups
Patient-controlled analgesia (morphine mg)			
POD1	26.0 (13.0–43.0)	14.5 (6.5–31.1)	0.02
POD2	22.5 (11.0–33.5)	12.0 (2.5–26.0)	
P-value within groups	<0.01		
NRS for pain at rest			
POD1	5 (2–5)	2 (1–5)	0.09
POD2	3 (0–5)	1 (0–3)	
P-value within groups	<0.01		
NRS for pain on walking			
POD1	5 (4–8)	5 (4–7)	0.69
POD2	5 (3–6)	5 (3–6)	
P-value within groups	0.15		
NRS for pain at greatest knee flexion			
POD1	7 (7–8)	7.5 (5–8.5)	0.18
POD2	8 (6–9)	7 (5.5–8)	
P-value within groups	0.78		

Table 3 Early functional outcomes reported as mean (SD) or median (IQR), according to the raw variable distribution. All non-normally distributed variables were transformed into normal distributions for analysis. All comparisons were made by repeated-measures regressions for general linear models. POD, postoperative day

Variables	Periarticular infiltration ($n=20$)	Femoral block ($n=20$)	*P*-value between groups
2 min walking test (m)			
POD1	14.7 (6.2)	11.2 (7.7)	0.27
POD2	21.8 (9.5)	19.1 (12.5)	
POD3	30.6 (12.3)	26.9 (15.6)	
P-value within groups	<0.01		
Out of bed time—sitting (min)			
POD1	22.5 (10.0–67.5)	25.0 (15.0–75.0)	0.72
POD2	60.0 (15.0–120.0)	60.0 (52.5–120.0)	
P-value within groups	<0.01		
Out of bed time—walking (min)			
POD1	2.0 (0.0–5.0)	5.0 (0.0–10.0)	0.04
POD2	10.0 (2.0–10.0)	10.0 (5.0–17.5)	
P-value within groups	<0.01		
Maximal knee flexion (°)			
POD1	70.0 (57.5–75.0)	70.0 (57.5–80.0)	0.38
POD2	80.0 (74.5–83.0)	79.5 (72.5–84.5)	
P-value within groups	<0.01		

compared using Student's *t*-test. Other data were compared using Pearson's χ^2 test or Wilcoxon's rank sum test, when appropriate. The early postoperative outcomes (Tables 2 and 3) were analysed with repeated-measures regressions for general linear models, after transformation of non-normally distributed variables into normal, or with repeated-measures Poisson's regressions for NRS pain. For the late outcomes (Table 4), Student's *t*-test or Wilcoxon's rank sum test was used with unmatched approach for the comparisons between groups and with matched approach for the comparisons within groups (preoperative *vs* 6-week measurements). We evaluated the prediction of early and late postoperative outcomes with pre- and perioperative indicators by building a *post hoc* multiple linear regression model using a stepwise approach. First, Spearman's non-parametric correlations were made for 65 preoperative variables and two functional measures of recovery: the improvement in 2MWT between POD1 and POD3 (early

Table 4 Late functional outcomes presented as mean (SD) or median (IQR). Comparisons were made by Student's *t*-test or Wilcoxon's rank sum test, when appropriate. Tests for matched data were used for within-group analysis, whereas tests for unmatched data were used between groups. CHAMPS, Community Health Activities Model Program for Seniors; SF-12, short-form health-related quality of life; PCS, physical component summary; MCS, mental component summary; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index

Variables	Periarticular infiltration ($n=20$)	Femoral block ($n=20$)	*P*-value between groups
6 min walk test (m)			
Preoperative	229.0 (89.3)	231.6 (81.3)	*0.93*
6 weeks	248.0 (87.4)	267.5 (82.3)	*0.48*
P-value within groups	0.38	0.01	
CHAMPS (kcal kg^{-1} $week^{-1}$)			
Preoperative	20.4 (4.9–49.2)	23.0 (7.9–46.1)	0.59
6 weeks	29.5 (16.3–56.9)	54.2 (13.4–89.3)	0.28
P-value within groups	0.19	0.03	
SF-12			
Preoperative PCS	30 (26–35)	32 (27–36)	0.37
6 weeks PCS	42.4 (11.1)	43.2 (8.9)	0.79
P-value within groups	0.01	0.01	
Preoperative MCS	51.6 (11.4)	51.2 (10.9)	0.92
6 weeks MCS	57 (48–61)	56 (53–58)	0.79
P-value within groups	0.33	0.11	
Knee Society evaluation			
Preoperative	92.2 (24.0)	95.3 (27.4)	0.71
6 weeks	137.7 (33.7)	156.6 (24.2)	0.05
P-value within groups	0.01	<0.01	
WOMAC			
Preoperative	53.7 (14.7)	52.0 (13.6)	0.71
6 weeks	28.0 (14.2)	19.7 (10.6)	0.04
P-value within groups	<0.01	<0.01	
Maximal knee movement (°)			
Preoperative extension	5 (0–11)	10 (0–10)	0.80
6 weeks extension	0 (0–1)	0 (0–0)	0.40
P-value within groups	0.02	0.01	
Preoperative flexion	116 (111–120)	117 (110–120)	0.94
6 weeks flexion	107 (98–114)	110 (105–118)	0.15
P-value within groups	<0.01	0.49	

recovery), and the absolute value of 6MWT at 6 weeks (late recovery). Variables significantly related to these measures of recovery in the bivariate analysis, if non-normally distributed, were then transformed to produce normal distributions. Variables that were significant on this initial analysis were entered into multiple linear regression models built with a stepwise approach. This allowed us to identify variables independently related to the two established measures of recovery (Table 5). Data are expressed as mean [standard deviation (SD)], median [inter-quartile range (IQR)], or absolute numbers, when appropriate. A value of $P<0.05$ was considered statistically significant for all comparisons.

Results

Patients and clinical care

The flow of patients through the study is shown in Figure 1. The patient characteristics and clinical data related to surgery of the two groups were comparable except for a longer duration of surgery in Group F (Table 1). Two patients, one in each group, had a haematoma in the operative knee joint; however, neither of these was sufficiently severe to require surgical drainage. A second patient in Group I had atrial fibrillation on the POD2 and was treated successfully with medical therapy. No infection occurred. There were no hospital readmissions during the first 30 PODs.

Pain relief

Patients in Group F used less morphine than Group I during the first two PODs (Table 2). There was a trend to less pain at rest in the F group, but on walking, the NRS was similar between the two groups. There were also no differences in NRS pain at greatest knee flexion between groups on the first and second PODs. The incidence of PONV was similar in both groups on day 1, but was greater in Group F on day 2 (six out of 20 in Group F *vs* one out of 20 in Group I, $P=0.037$).

Table 5 Multivariate linear regressions on recovery variables. Values are regression coefficient, 95% confidence interval, and *P*-value of multivariate linear regression. Predictive ability is showed as R^2 coefficient. 2MWT, 2 min walk test; POD, postoperative day; ASA, American Society of Anesthesiologists; 6MWT, 6 min walk test

	Coefficient	95% CI	*P*-value	R^2
2MWT recovery (ΔPOD3–POD1)				
Weight	0.27	(0.07/0.48)	0.01	69.56
ASA II	−10.58	(−20.75/−0.42)	0.04	
ASA III	−13.64	(−27.76/0.47)	0.06	
Log (preoperative 2MWT)	10.33	(3.13/17.52)	0.01	
Out of bed walking total time (POD1+2+3)	0.21	(0.05/0.38)	0.02	
Constant	−46.56	(−83.20/−9.91)	0.02	
6MWT at 6 weeks				
Log (preoperative 6MWT)	130.34	(70.57/190.10)	<0.01	53.20
Patients who performed the 2MWT at POD1	54.70	(5.33/104.06)	0.03	
√Out of bed walking time in POD2	34.90	(10.33/59.48)	0.01	
Out of bed walking total time (POD1+2+3)	−2.35	(−4.42/−0.28)	0.03	
Constant	−511.75	(−827.88/−195.61)	0.01	

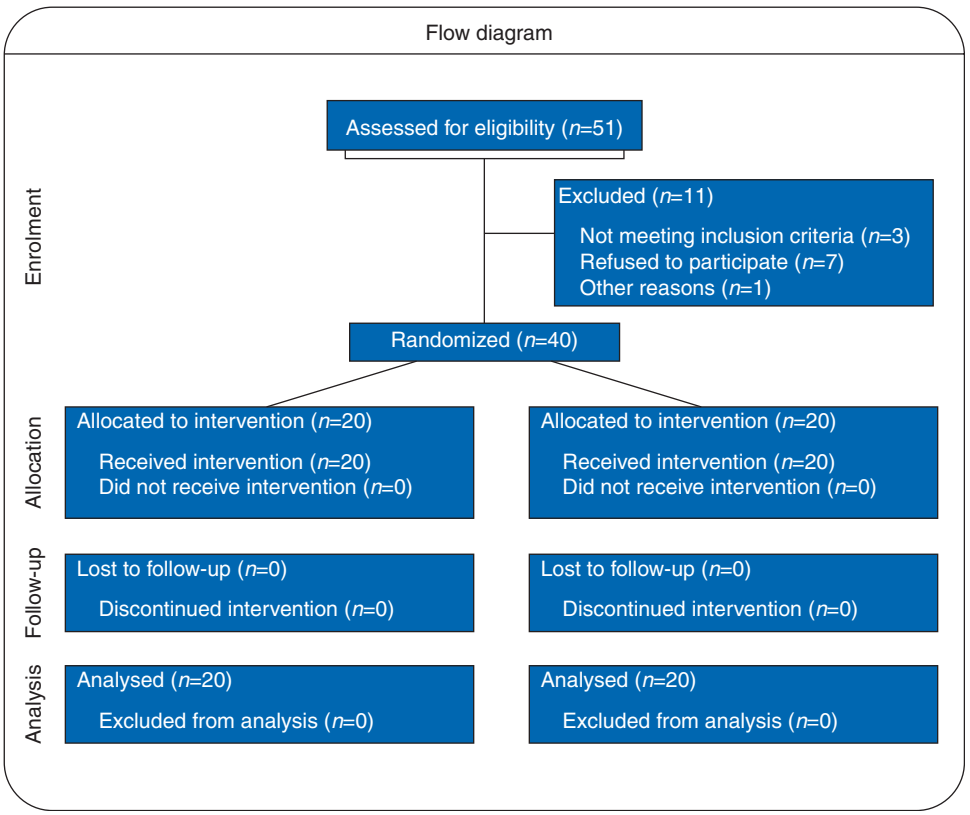

Fig 1 CONSORT diagram showing the flow of patients through the study.

Early postoperative functional outcome measures

The 2MWT decreased significantly after surgery from preoperative values in both groups (−86.7% for Group F and −83.1% for Group I) and recovered over the first 3 days 9.02 (SD 4.46) m day^{-1} for Group F and 8.37 (5.04) m day^{-1} for Group I (Table 3, Fig. 2). These changes were not different between the two groups. Seven patients in Group I (35%) and six in Group F (30%) did neither walk nor performed the

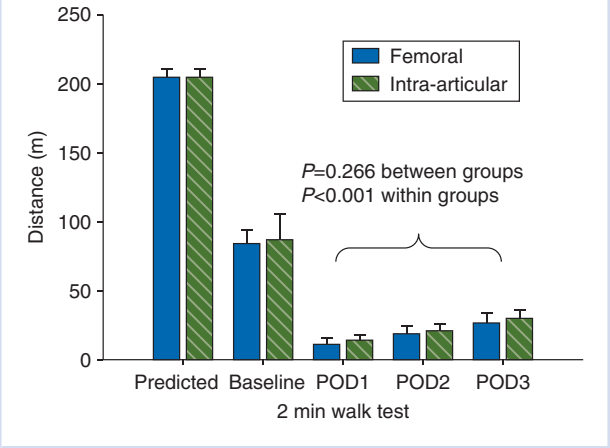

Fig 2 2MWT results. Tests were performed before surgery and on the first three PODs.

2MWT on POD1 for multiple reasons: pain (6), dizziness (5), tiredness (5), bleeding (2), and swollen knee. All patients walked on days 2 and 3. The number of patients ambulating over 30 m on day 2 in Group I were six out of 20 (30%) and in Group F three out of 20 (15%), and on day 3 were 11 (55%) in Group I and eight (40%) in Group F, with no differences between the two groups.

Time out of bed walking during the first two PODs increased significantly in both groups, with Group F spending a significantly longer time walking compared with Group I. Other functional measures (out of bed time sitting and maximal knee flexion) were not different between the two groups.

Late postoperative functional outcome

The preoperative 6MWT was similar in both groups, being approximately the 37% of age-gender appropriate predicted scores (Table 4). When repeated 6 weeks after surgery, 6MWT scores increased in Group F (+15.5%) but not significantly in Group I (+8.3%).

Reported amount of physical activity as assessed by CHAMPS showed a significant increase in Group F (+135.7%) but not significantly in Group I (+44.6%) 6 weeks after surgery compared with preoperative values.

The physical component of the SF-12 increased significantly in both groups (+35.0% for Group F and +41.3% for Group I) at 6 weeks compared with baseline. There were no changes in the mental component of the SF-12.

The Knee Society evaluation decreased significantly in both groups 6 weeks after surgery (+64.3% in Group F and +49.3% in Group I); the comparisons between measurements made 6 weeks after surgery showed absolute values significantly higher in Group F (P=0.05).

Similarly, the changes in WOMAC scores over the first 6 postoperative weeks were statistically significant in both groups (−62.1% in Group F and −47.9% in Group I), with absolute values significantly lower in Group F (P=0.04).

Maximal knee extension improved in both groups at 6 weeks with no difference between the two groups. Maximal knee flexion decreased significantly in Group I (−7.8%) but not significantly in Group F (−6.0%), with no differences between groups regarding absolute values.

Correlations between perioperative physiological variables and immediate and late post-surgical recovery indicators

Only four and three variables, respectively, for the two functional outcomes were found independently and significantly correlated with the 2MWT and the 6MWT, respectively (Table 5). Body weight, ASA, preoperative 2MWT, and total time out of bed during the first three PODs were the predictors of the immediate recovery of 2MWT. Preoperative 6MWT, ability to walk 24 h after surgery, and total time spent walking during the first three PODs were the independent predictors of the distance covered over 6 min at 6 weeks after surgery.

Discussion

In this double-blind, randomized, controlled trial, CFNB was associated with a significantly reduced postoperative consumption of morphine and a trend to better analgesia compared with periarticular infiltration. In addition, patients in the CFNB group spent more time out of bed walking during the first two PODs. Functional recovery at 6 weeks after surgery was more favourable in the CFNB group which showed a greater improvement in walking capacity, physical activity, and indices of knee function.

The initial findings from non-randomized studies reporting good quality of postoperative analgesia and opioid-sparing effect achieved with periarticular infiltration of local anaesthetics for knee arthroplasty prompted clinicians to conduct randomized, controlled studies comparing this technique with systemic opioids in the context of multimodal analgesia.[5–8] The positive findings would indicate that such a simple technique could potentially accelerate the recovery process and allow patients to be more mobile after surgery.

A recent study comparing the periarticular infiltration technique with femoral block showed the superiority of pain relief and less opioid consumption with periarticular infiltration.[15] This is in contrast with present findings where the use of femoral block was associated with less morphine consumption. Although a direct explanation for this discrepancy cannot be found, comparative analysis of results reveals that no sciatic block was used and the breakthrough administration of morphine was significantly greater than previously used.[6 7] Despite this difference, both the previous and the current studies did use similar anaesthetic regimens for both periarticular infiltration and CFNB, and used a compressed bandage as suggested to help the spread of local anaesthetic in the periarticular area.[8]

As a secondary outcome, this study aimed to determine the impact of postoperative analgesia on functional outcome. Beside knee function, we wanted to assess walking capacity and physical activity in the immediate postoperative period

and 6 weeks after surgery. The 2MWT was measured to assess muscle force in the leg exerted when walking over a short period of time.[14 24] We did not administer the 6MWT in this acute stage as it was thought that patients would not have been able to walk for such a long period of time. This is evident from the study by Ilfeld and colleagues[25] in which patients walked on average 40 m in 6 min on the second POD, whereas ours walked over 20 m in 2 min.

Functional outcome at 6 weeks after surgery

Traditionally, outcome measures assessing knee function during the postoperative period have been constructed with the intent to assess mainly the range of motions specific to the knee (WOMAC and the Knee Society)[26 27] and the pain associated with it. However, there has been an increasing interest in assessing the capacity to ambulate, as this is dependent upon muscle strength rather than range of motion, and has been shown to be a critical determinant of postoperative outcome after TKA.[28 29] Although distance has been used to determine readiness to discharge, this test has not been standardized and depends on outside influences. In contrast, the walk test is a reliable index of exercise tolerance as it assesses submaximal exercise capacity measured by a distance over a specific time using a standardized protocol. The 6MWT was originally developed to assess the disease progression in patients with chronic respiratory diseases, but more recently, it has been used and validated as a measure of recovery after surgical procedures[24 30–32] as it integrates all components of functional walking capacity such as balance, speed, and endurance in one measure. It is easy to administer, has construct validity and is sensitive to changes. Nevertheless, it can be influenced by general health status, age, gender, and BMI.

In the present study, the CFNB group had a more favourable improvement at 6 weeks not only in the outcome measures associated with mobilization and activity, 6MWT, and CHAMPS, but also with the knee function (WOMAC and the Knee Society). In the CFNB group, the walking distance increased in 6 weeks by ~35 m. This change was matched by a 136% increase in physical activity (CHAMPS, kcal kg^{-1} $week^{-1}$), with better WOMAC and the Knee Society scores.

Such findings not only confirm the positive impact of analgesia on late outcome measures specific to knee function, but also report the beneficial effects on measures of general health and recovery such as physical activity and mobilization. This is the first time that validated outcome measures of functional walking capacity have been assessed in this surgical group.

Correlation between outcome measures and prediction of functional recovery

As a *post hoc* analysis, in this paper, we also wanted to determine whether, based on the model proposed by Carli and Mayo,[33] the biological and physiological short-term changes would impact on long-term functional outcome. The functional outcome chosen was the improvement in 2MWT between POD1 and POD3 (early recovery) and the absolute value of 6MWT at 6 weeks (late recovery). These are preliminary observations and need to be confirmed in future and adequately powered studies. We found that recovery in 2MWT was positively correlated with all indices of functional activities (walk tests, CHAMPS, and the functional component of the knee society) both in the perioperative period and 6 weeks after surgery and pain intensity during walking (negative correlation). As with the 2MWT, the 6MWT was found to be well correlated at 6 weeks after surgery not only with all the preoperative indices of functional activity, but also with changes in walking time during the first 72 h after surgery. Although the population sample was small and the scope of the present investigation was not to identify those individuals with poor functional scores before surgery and predict the postoperative outcome, the findings might stimulate more research in this area and help to understand how important it is to assess clinical and patient-reported characteristics in order to identify those individuals who are at risk of postoperative poor outcome.[34] These findings would suggest that both the 2MWT and 6MWT could represent reliable indices of both functional exercise capacity and patient perception of knee function, although no correlation was found between the 2MWT and 6MWT and measures of knee function (WOMAC, range of motions, and the clinical component of the Knee Society).

There are some limitations with this study. Although care was taken to blind all techniques, we are aware that injection of ropivacaine to the back of the knee, the insertion of the catheter into the knee and the infusion of saline 0.9% into the femoral nerve are not necessarily the protocols used in the current clinical practice. Both 2MWT and 6MWT measured walking capacity at only one point in time and not throughout the day. In addition, walking represents only one type of activity and not a full range performed on a daily basis. In view of this, we administered the CHAMPS to estimate physical activity at a variety of intensities and frequency based on previous weeks. The CHAMPS before surgery and at 6 weeks were significantly correlated with walking capacity and are consistent with previous reports in surgical[18] and non-surgical populations.[35 36] Another limitation was that we did not assess the impact of the femoral block on the distance covered during 2 min and the ability to ambulate during the first three PODs. The measurement of quadriceps muscle strength would have provided an objective outcome; however, such measurement requires specialized instruments which are not easily portable to be used at the bedside.

Conclusions

Continuous femoral block provided superior analgesia over the periarticular infiltration of high volume of local anaesthetics and was associated with more favourable recovery of walking capacity, physical activity, and knee function. The 2MWT and 6MWT are meaningful outcome measures of exercise capacity and perception of knee functioning after TKA. They are safe to administer and monitor the progression of ambulation in the early postoperative period and are

possible indicators of walking ability and physical activity at 6 weeks after surgery. Further studies need to be performed to assess construct validity of these tests in this surgical model over a longer period of rehabilitation and to determine whether the preoperative measurement of walking capacity would help in identifying patients at risk of poor postoperative recovery.

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Conflict of interest

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