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Comparison of 2 Peripheral Nerve Blocks Techniques for Functional Recovery and Postoperative Pain Management After Total Knee Arthroplasty: A Prospective, Double-Blinded, Randomized Trial

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Statistical Analysis C
Data Interpretation D
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Background: Methods of pain management that have less effect on motor function after total knee arthroplasty (TKA) are needed to ensure early mobilization. We investigated whether the distal femoral triangle and distal adductor canal blocks are superior to the femoral nerve block regarding motor blockade at early postoperative hours.

Material/Methods: Patients scheduled for TKA under spinal anesthesia were blindly assigned into 2 groups. One group received the distal femoral triangle and distal adductor canal blocks and the other group received the femoral nerve block. In both groups, at 3, 6, 24, and 48 h after surgery motor blockade was evaluated with the Bromage scale. Secondary outcomes such as pain control efficacy and patient satisfaction were evaluated at 6, 24, and 48 h postoperatively using either the VAS scale or a 10-point scale.

Results: We analyzed the outcomes of 77 patients. Better motor function at 3 and 6 h after TKA was observed in the distal femoral triangle and the distal adductor canal blocks group (37.7% vs 23.4%, p=0.032 and 49.4% vs 32.5%, p=0.002, respectively). At 24 h after the surgery, patients from the femoral nerve block group consumed significantly more rescue opioid analgesics (p=0.016). We found no significant differences in pain intensity and patient satisfaction at any timepoints after the surgery.

Conclusions: The distal femoral triangle and distal adductor canal blocks resulted in significantly better motor function at the first 3 and 6 h after total knee arthroplasty. At 24 h after surgery, rescue opioid doses in the femoral nerve block group were significantly higher.

Keywords: Anesthesia and Analgesia • Arthroplasty, Replacement, Knee • Nerve Block • Pain Management

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Background

Total knee arthroplasty (TKA) is a major orthopedic surgery which is associated with severe postoperative pain [1]. Pain management after this surgery remains challenging, as every patient has a different pain threshold and perception of pain. The main goals of multimodal postoperative pain control are to ensure earlier mobilization and faster functional recovery, reduce the risk of postoperative complications such as thromboembolic complications and chronic pain, and improve patient satisfaction [2,3]. The most important part of multimodal postoperative pain control after TKA is peripheral nerve blocks, which are considered to be a safe option for postoperative pain management.

A femoral nerve block (FNB) is one of the methods for postoperative analgesia after TKA. The analgesic effect of the FNB is similar to epidural and better than intravenous patient-controlled analgesia (IV PCA) techniques, but has fewer adverse effects, such as postoperative nausea and vomiting, infections, respiratory depression, hypotension, bradycardia, and urinary retention [2, 4]. Furthermore, the FNB also provides a reduction in opioid-related adverse events such as nausea and vomiting [5,6]. However, when the FNB is performed, motor and sensory branches of the femoral nerve are blocked. As a result, the FNB reduces the strength of the quadriceps muscle, which leads to an increased risk of postoperative falls and delayed early mobilization [1,3,7,8].

Femoral triangle (FT) and adductor canal blocks (ACB) are alternatives to peripheral nerve blocks with less motor paralysis and adequate pain relief, and are considered to be a reliable option for similar postoperative pain control, together preserving quadriceps muscle strength after TKA [9]. Theoretically, the anterior region of the knee is innervated by sensory branches of the femoral nerve, and the posterior area of the knee is innervated by the popliteal plexus, which is mainly formed by the genicular branches of the tibial and posterior obturator nerves [9-11]. For adequate postoperative analgesia, the posterior and anterior surfaces of the knee must be anesthetized. The anterior surface of the knee can be anesthetized by performing distal FT block, and the posterior surface can be anesthetized by performing the distal ACB. Cadaveric studies of the distal FT and the distal ACB have been published [12,13], but to the best of our knowledge no clinical studies have evaluated the analgesic effect and motor function after TKA when distal FT block and distal ACB are performed. We hypothesized that performing distal FT block together with distal ACB could provide a better analgesic effect than ACB could provide alone, and could preserve motor function that cannot be achieved with the FNB.

The aim of this study was to investigate 2 different peripheral nerve blocks methods (FT+ACBs versus FNB) comparing their effects on functional recovery and postoperative analgesia after TKA.

Material and Methods

This prospective, double-blinded, randomized study was conducted at our institution from August 2018 to May 2019. This study was approved by the local Bioethics Committee (BEC-MF-172/2017) and registered at ClinicalTrials.gov before patient enrollment (identifier NCT03645954, August 24, 2018; principal investigator Inna Jaremko, MD). Written informed consent was obtained from all patients. Patient enrollment was started on August 28, 2018.

Study Participants

We included patients older than 18 years, who agreed to participate in this study, were admitted for elective primary unilateral TKA under spinal anesthesia, and were grade I to III according to the American Society of Anesthesiologists (ASA).

We excluded patients with coagulopathy, pre-existing lower extremity neuromuscular disorders, local infection over the medication injection site, allergy or contraindications to medications used in this study, chronic opioid use, and those who received other types of anesthesia.

Before the surgery, patients were blindly randomized into 2 groups: the femoral triangle and adductor canal blocks (FT+ACBs) group and the femoral nerve block (FNB) group. Patients were grouped using an opaque envelope method. The envelopes were prepared by a blinded outcomes assessor (1: 1 randomization ratio) and opened by the investigator only after patient enrollment. The anesthesiologist performing the block was aware of the analgesia method, but the patients and the independent outcomes assessor were not.

Standardized Anesthesia and Analgesia

During the perioperative period, all patients from both groups received the same anesthetic and analgesic. Premedication with intravenous midazolam 2.5-5 mg and dexamethasone 4 mg was given to all patients, and a slow crystalloid infusion with 1 g of tranexamic acid and 10 mg of ketamine was started 30 min before the surgery. Spinal anesthesia was performed with 15 mg of levobupivacaine at the L2/3 intervertebral space. Subsequently, the FT+ACBs or FNB (depending on the group of patients) was performed under ultrasound guidance. Patients were sedated with intravenously administered propofol during surgery. After surgery, patients were transferred to the post-anesthesia care unit (PACU).

During the postoperative period, nonsteroidal anti-inflammatory drugs (NSAIDs) for analgesia were used in both groups of patients. NSAIDs such as dexketoprofen 50 mg was administered 2 times and acetaminophen 1 g 4 times a day. Opioids

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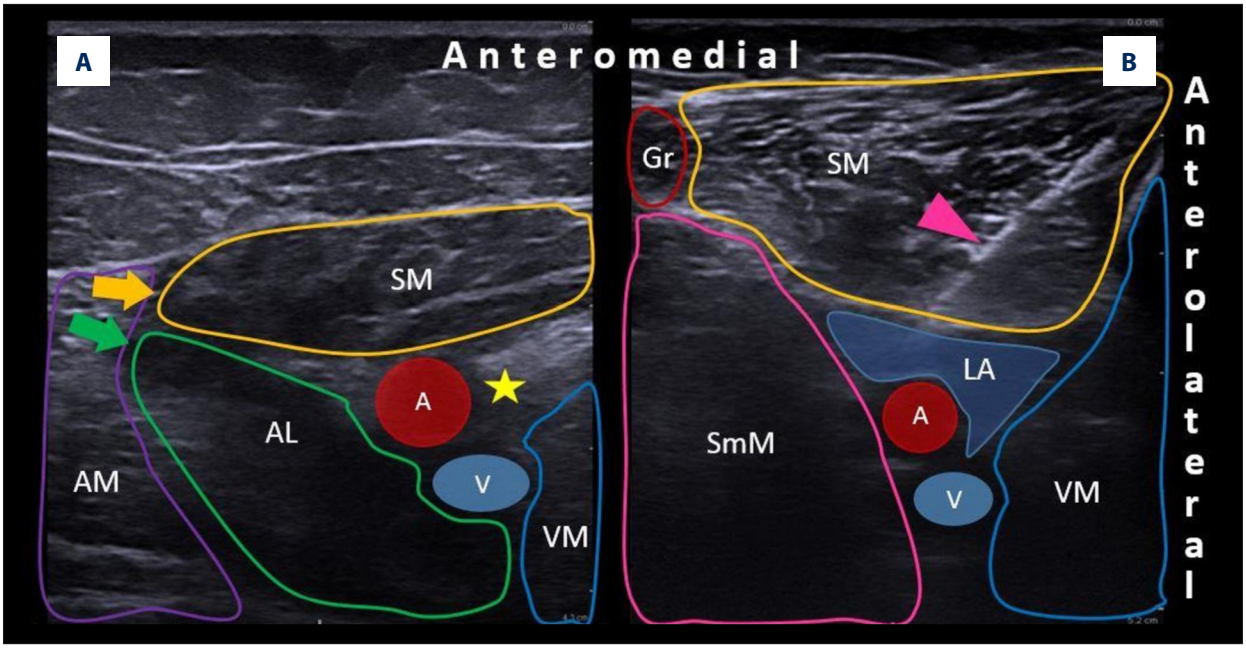

Figure 1. The ultrasonographic views: the apex of the femoral triangle (**A**) and the distal end of the adductor canal (**B**). The apex of the femoral triangle (**A**) was found at the level where the medial border of the sartorius muscle (yellow arrow) intersects the medial border of the adductor longus muscle (green arrow). Local anesthetic was injected laterally to the femoral artery (yellow star) where the saphenous nerve is located. The distal end of the adductor canal (**B**) was found at the level where the femoral artery and vein dive deeper from the sartorius muscle and become the popliteal vessels. The needle (pink arrowhead) was placed and the local anesthetic was injected above the artery. SM – sartorius muscle; AL – adductor longus muscle; VM – vastus medialis muscle; AM – adductor magnus muscle; Gr – gracilis muscle; SmM – semimembranosus muscle; A – femoral artery; V – femoral vein; LA – spread of local anesthetic after injection.

were used for patients as intramuscular boluses of pethidine 50 mg or morphine 10 mg if the subjective pain score according to visual analog scale (VAS) was more than 5.

TKA and Local Infiltration Analgesia Techniques

All arthroplasties were performed using a cemented prostheses inserted through a medial parapatellar approach without patellar resurfacing. Local infiltration analgesia (LIA) using 30 mL of 0.5% bupivacaine, 0.3 mL of 0.1% adrenaline, and 90 mL of saline was conducted for all patients. The LIA solution was injected into the tissues around the knee joint (eg, medial and lateral posterior articular capsule), deep tissues around the medial and lateral collateral ligaments, subcutaneous tissue, and wound edges.

Study Interventions

All blocks were performed by one anesthesiologist under the guidance of a linear ultrasound transducer probe (Flex Focus 400 exp, BK Medical, Denmark) using a 20-gauge 50-mm (for FNB) or 100-mm (for FT+ACBs) Ultraplex needle (B. Braun Medical, Inc., Melsungen, Germany). The FNB was performed at the proximal part of the femoral triangle by a single 20-mL injection of 0.125% bupivacaine around all the femoral nerve branches. The femoral triangle and distal adductor canal blocks were performed together. The femoral triangle block was performed at the level where the medial border of the sartorius muscle intersects the medial border of the adductor longus muscle (**Figure 1A**) with an injection of 10 mL of 0.125% bupivacaine. Local anesthetic was injected laterally to the femoral artery. The distal adductor canal block was performed at the level where the femoral artery and vein dive deeper from the sartorius muscle (**Figure 1B**) with an injection of 10 mL of 0.125% bupivacaine. Local anesthetic was injected above the femoral artery, and its spread around the artery and deeper in the popliteal fossa was observed [12].

Assessment of Outcomes

All data after surgery were collected and analyzed by the independent outcomes assessor. The extent of motor blockade was evaluated at 3, 6, 24, and 48 h after the surgery. The movement of the operated knee joint was assessed using the Bromage scale grades: Grade I, free movement of legs and feet; Grade II, just able to flex knees with free movement of feet; Grade III, unable to flex knees, but with free movement of feet; and Grade IV, unable to move legs or feet.

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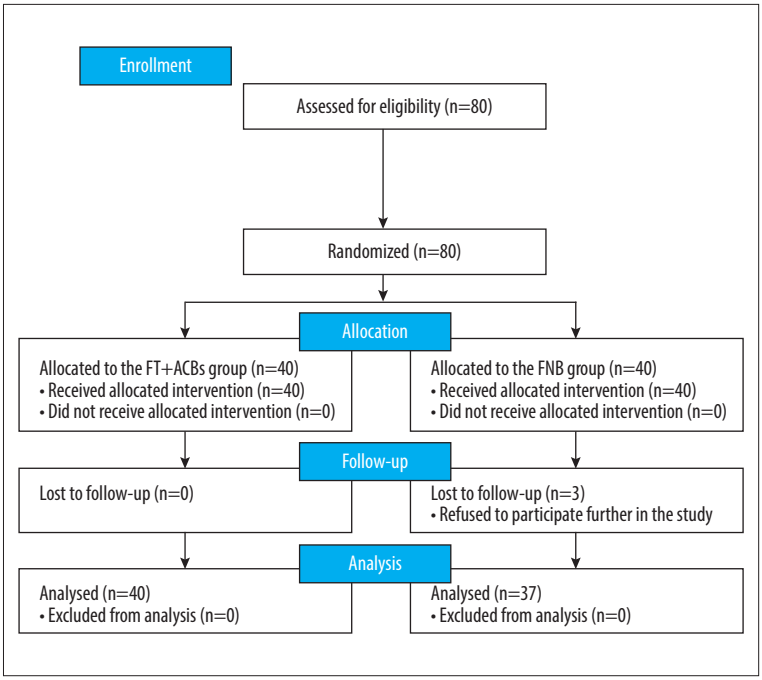

Figure 2. A Consolidated Standards of Reporting Trials (CONSORT) flow diagram of patients' randomization, allocation, and analysis. FT+ACBs – distal femoral triangle and distal adductor canal blocks; FNB – femoral nerve block.

The efficacy of pain control was evaluated at 3, 6, 24, and 48 h after the surgery using the visual analog scale (VAS) at rest and during active and passive 45-degree knee flexion. Moderate pain was defined by a VAS score from 4 to 6 and severe was defined as equal to 7 or greater. The consumption of rescue opioid analgesics for pain management at 6, 24, and 48 h was recorded. For statistical analysis, the doses of additional opioids were converted to morphine mg equivalents.

Patient satisfaction was evaluated using a 10-point scale from 0 (completely unsatisfied) to 10 (totally satisfied) at 6, 24, and 48 h after surgery.

Data Collection and Statistical Analysis

The following characteristics of patients were collected: age, sex, body mass index (BMI), and ASA status.

The primary effect variable used for power calculation analysis (G*Power, version 3.1, Dusseldorf, Germany) was the difference in motor blockade according to the Bromage scale between the 2 groups. Assuming that the difference in motor blockade of 40% between the groups would be clinically important and, aiming to detect differences for a power of 80% and a 2-tailed α error of 0.05, a sample size of 69 patients would be required. To allow for possible dropouts, 80 patients (40 patients in each group) were included in the study.

The statistical analysis was performed using IBM SPSS, version 25.0 (IBM Corporation, Armonk, NY) statistical software. The Shapiro-Wilk test was applied to assess the normality of the data distribution. Numerical variables (age, BMI, VAS score of pain) were normally distributed, and the *t* test was used to compare means between 2 groups. Also, a Levene test was conducted to verify the homogeneity of variance. Normally distributed numerical variables were presented as means with standard deviations (M (SD)). Numerical variables (patient satisfaction, opioid consumption) were not normally distributed and the Mann-Whitney U test was used to compare the 2 groups. These data were presented as median with interquartile range (IQR, 25^{th}-75^{th} percentile). Categorical variables (sex, ASA status, Bromage scale of motor blockade) between the groups were compared using the Pearson χ^2 test and were presented as number of subjects and proportion (n (%)). A p value <0.05 was considered statistically significant.

Results

Eighty patients who were scheduled for elective primary unilateral total knee arthroplasty were assessed for eligibility for this study. Three patients were excluded after randomization, leaving 77 patients in this prospective study (**Figure 2**). Patients' related data are presented in **Table 1**. The 2 groups did not differ significantly in age, sex, ASA grade, or BMI.

Comparing motor activity (the primary outcome), according to the Bromage scale, at 3, 6, 24, and 48 h, we observed that patients in the FT+ACBs group had statistically significantly better motor function at 3 and 6 h after the surgery than the FNB group (**Table 2**). However, no difference in pain level was observed when comparing these groups at the same time points

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Table 1. Characteristics of the patient groups.

		FT+ACBs n=40 (51.9%)	FNB n=37 (48.1%)	*p* value
Age,	M (SD), years	68.5 (9.8)	69.1 (9.3)	0.783*
Sex:	Male (n, %)	11 (27.5)	13 (35.1)	0.47**
	Female (n,%)	29 (72.5)	24 (64.9)	
ASA status:	I (n,%)	2 (5.0)	2 (5.4)	0.993**
	II (n,%)	36 (90.0)	33 (89.2)	
	III (n,%)	2 (5.0)	2 (5.4)	
BMI,	M (SD), kg/m^2	31.2 (5.7)	31.9 (5.5)	0.596*

Data are expressed as mean±SD or n (%), as appropriate. FT+ACBs – distal femoral triangle and distal adductor canal blocks; FNB – femoral nerve block; M – mean; SD – standard deviation; n – number of subjects; BMI – body mass index. * *t* test; ** χ^2 test.

Table 2. The extent of motor blockade at different time points after TKA.

Time	No motor paralysis (Bromage I*)		With motor paralysis (Bromage II, III, IV*)		*p* value
	FT+ACBs	FNB	FT+ACBs	FNB	
3 hours	29 (37.7)	18 (23.4)	11 (14.3)	19 (24.6)	0.032**
6 hours	38 (49.4)	25 (32.5)	2 (2.6)	12 (15.5)	0.002**
24 hours	35 (45.5)	31 (40.3)	5 (6.5)	6 (7.7)	0.642**
48 hours	34 (44.2)	29 (37.7)	6 (7.8)	8 (10.3)	0.452**

Data are presented as n (%). FT+ACBs – distal femoral triangle and distal adductor canal blocks; FNB, femoral nerve block. * Bromage scale grades: I – free movement of legs and feet; II ,– just able to flex knees with free movement of feet; III – unable to flex knees with free movement of feet; IV – unable to move legs and feet. ** χ^2 test.

as motor activity was measured. The mean pain level of all patients, according to VAS, was below 5, which is considered adequate pain control after TKA (**Figure 3**).

Comparing the requirement for additional opioids between the groups, we observed that 24 h after TKA, opioid consumption was statistically significantly higher in the FNB group of patients (**Table 3**). There were no statistically significant differences in rescue opioid consumption at 6 and 48 h after TKA.

Comparing the occurrence of adverse effects between the groups, we found that 6 patients from the FT+ACBs group and 7 from the FNB group had nausea, and 1 patient in each group experienced vomiting; however, all these adverse events were related to opioid use seeking better pain control.

Discussion

We found that the FT+ACBs at 3 and 6 h after TKA resulted in significantly lower motor blockade and more active leg movements compared to the FNB group. Compared with other studies, similar findings were observed by Kirandeep et al [14], who evaluated the motor blockade of 50 patients after TKA and reported that at 4 h after surgery, patients from the ACB group had better motor recovery compared to the FNB group, according to the Bromage scale.

In recent years a number of studies comparing the ACB with the FNB effects after TKA were performed [1,15,16], and based on recent meta-analyses [17,18] a consensus on the equivalent postoperative pain-relieving effect of these 2 peripheral nerve blocks was reached. Systematic reviews evaluating the difference in quadriceps muscle strength and ability of early mobilization found both were better with the ACB [18-20] or were not different [21]. This difference in quadriceps muscle strength can be explained by the fact that ACB (compared to FNB) primarily provides sensory blockade and is associated with less impairment of quadriceps muscle strength [18,22]. While performing the FNB, the sensory and motor branches of the femoral nerve are blocked, which results in a more restricted motor function and an increased risk of falls [17,18,22,25]. However, in most meta-analyses a wide heterogeneity among the included studies was present. For example, studies with healthy volunteers [22,23], different types of anesthesia [1,15], and peripheral nerve blocks techniques (continuous vs single-shot)

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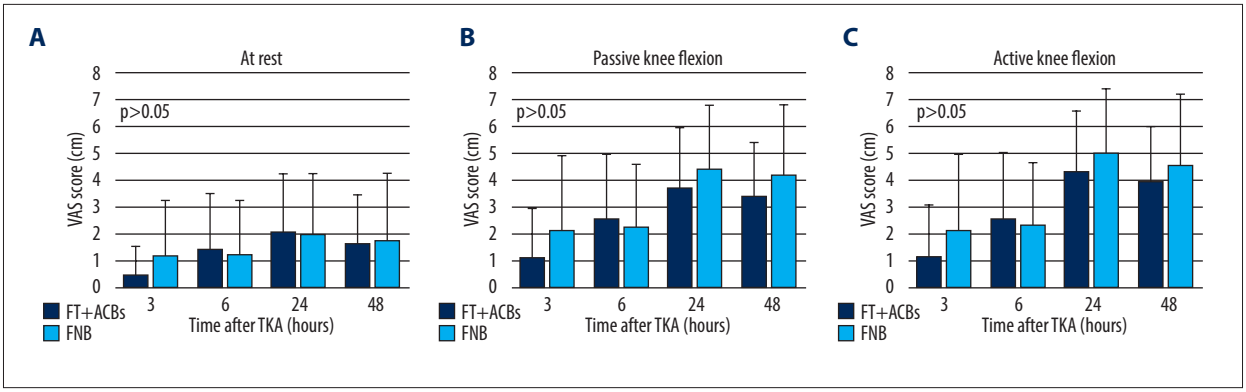

Figure 3. Pain intensity according to the VAS scores at rest (**A**), during passive (**B**), and active (**C**) 45-degree knee flexions at different timepoints after TKA. FT+ACBs – distal femoral triangle and distal adductor canal blocks; FNB – femoral nerve block; VAS – visual analog scale; cm, centimeters. Values are presented as mean and standard deviation. The *t* test was used to compare means.

Table 3. The opioid analgesics consumption and the rate of patient satisfaction at different timepoints after TKA.

	Opioid consumption			Satisfaction scores		
	FT+ACBs	FNB	*p* value	FT+ACBs	FNB	*p* value
6 hours	0.0 (0-6.7)	0.0 (0-6.7)	0.527*	10 (8-10)	9 (7.5-10)	0.107*
24 hours	6.7 (0-6.7)	6.7 (0-13.3)	**0.016***	8 (8-10)	8 (7-10)	0.46*
48 hours	6.7 (0-6.7)	6.7 (0-6.7)	0.14*	9 (8-10)	9 (7-9.5)	0.315*

Data expressed as median mg (IQR, 25th-75th percentiles). FT+ACBs – distal femoral triangle and distal adductor canal blocks; FNB – femoral nerve block; IQR, 25% to 75% interquartile range. * Mann-Whitney U test.

[24]; or methodology, for example, inconsistent locations of local anesthetic injections while performing the ACB and confusing terminology (naming the block as the ACB when it is performed more proximal to the anatomic adductor canal at the level of the femoral triangle) [25]. Therefore, the conclusions of some meta-analyses may be inaccurate, limited, and cannot be compared. Unfortunately, we found no studies comparing the FT+ACBs with the FNB effects on the motor function and analgesic efficacy after TKA, but our results suggest that the FT+ACBs has a similar pain control effect as the FNB, but has better motor function at 3 and 6 h after surgery, allowing early mobilization of the patient. It is still unclear if any difference in pain control and motor function could be observed comparing the ACBs with the FT+ACBs; thus, further studies are needed to answer this research question.

We found no significant differences in postoperative pain comparing these 2 peripheral nerve block methods at rest or during active and passive knee flexion after TKA at any timepoint. Similar findings were observed by Kim et al [15], who investigated pain control at 6-8, 24, and 48 h after TKA in patients from ACB and FNB groups, and reported no significant difference in pain relief effect between the groups.

We observed that 24 h after TKA, patients from the FNB group had statistically significantly greater consumption of rescue opioid analgesics. However, we were unable to demonstrate significant differences between the FT+ACBs and FNB groups of patients in the need for opioid analgesics and their consumption at 6 and 48 h after surgery. Furthermore, the incidence of adverse effects related to opioid use was very low and did not significantly differ between the 2 groups. Thus, it can be assumed that both methods of peripheral nerve block provide sufficient postoperative analgesia at the early postoperative hours, but when their effect is gone, the requirement for additional opioids increases.

Aiming to provide sufficient postoperative analgesia, both anterior and posterior areas of the knee have to be anesthetized. Therefore, we performed the distal FT block to take away the anterior knee pain. However, as the posterior surface of the knee is not affected by this block, pain control may be insufficient. Therefore, together with the distal FT block, we performed the distal ACB block, with the intention to block the popliteal plexus [9,12,13] and anesthetize the posterior surface of the knee. Consequently, to provide an adequate postoperative analgesia, 2 peripheral nerve blocks are needed.

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On one hand, the infiltration between the popliteal artery and capsule of the knee (IPACK block) could be an alternative method to the distal ACB to provide analgesia for the posterior aspect of the operated knee, because it affects sensory structures and preserves motor function [3,25]. On the other hand, the IPACK block requires changing the position of the leg. This block can be performed to patients in supine position; however, the leg has to be slightly elevated to put the ultrasound transducer probe on the popliteal site. No additional leg movements are needed when the distal ACB is performed.

There are some limitations of the study. We were analyzing 2 groups of patients (FT+ACBs vs FNB) and did not investigate patients who received the FT block only. Such a comparison could determine whether adding the distal ACB block to the FT block would give a significant clinical effect in terms of early patient mobilization. However, our observation of better motor function at 3 and 6 h after surgery in the FT+ACBs group suggests that this type of anesthesia has more advantages compared to the FNB only, but also indicates the need of further studies to compare their effectiveness with the FT block.

We did not investigate the knee pain location. Therefore, further studies are needed to evaluate the clinical significance of the posterior knee pain management when the distal ACB is performed (for example, distal FT+ACBs and distal FT block alone).

Conclusions

In conclusion, the FT+ACBs are superior to the FNB in motor function recovery after TKA, as at the first 3 and 6 postoperative hours they cause significantly lower motor blockade. At 24 h after total knee arthroplasty, rescue opioid doses in the femoral nerve block group were significantly higher, with no difference in pain control.

Department and Institution Where Work Was Done

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Conflicts of Interest

None.

Declaration of Figure Authenticity

All figures submitted have been created by the authors, who confirm that the images are original with no duplication and have not been previously published in whole or in part.

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