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The analgesic efficacy of anterior femoral cutaneous nerve block in combination with femoral triangle block in total knee arthroplasty: a randomized controlled trial

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Background: Ultrasound-guided femoral triangle block (FTB) can provide motor-sparing anterior knee analgesia. However, it may not completely anesthetize the anterior femoral cutaneous nerve (AFCN). We hypothesized that an AFCN block (AFCNB) in combination with an FTB would decrease pain during movement in the immediate 12 h postoperative period compared with an FTB alone.

Methods: Eighty patients scheduled to undergo total knee arthroplasty were randomized to receive either FTB alone (FTB group) or AFCNB with FTB (AFCNB + FTB group) as part of the multimodal analgesic regimen. The primary outcome was pain during movement at 12 h postoperatively. Secondary outcomes included numeric rating scale (NRS) pain scores, incidence of surgical incision site pain, intravenous morphine consumption, immediate functional performance, patient satisfaction, and length of hospital stay.

Results: The NRS pain scores on movement 12 h postoperatively were significantly lower in the AFCNB + FTB group than in the FTB group (mean difference: –2.02, 95% CI: –3.14, –0.89, P < 0.001). The incidence of pain at the surgical incision site at 24 h postoperatively and morphine consumption within 48 h postoperatively were significantly lower (P < 0.001), and quadriceps muscle strength at 0° immediately after surgery was significantly greater in the AFCNB + FTB group (P = 0.04).

Conclusions: The addition of ultrasound-guided AFCNB to FTB provided more effective analgesia and decreased opioid requirement compared to FTB alone after total knee arthroplasty and may enhance immediate functional performance on the day of surgery.

Keywords: Arthroplasty; Knee; Nerve block; Peripheral nerves; Postoperative pain; Ultrasonography.

Introduction

Motor-sparing anterior knee analgesia as part of a multimodal protocol for total knee arthroplasty (TKA) is popular and preferred because it enhances patient recovery and satisfaction and reduces the length of hospital stay [1,2]. Adductor canal block (ACB) is an essential component of motor-sparing anterior knee analgesia, as it provides sensory

blockade with minimal effect on quadriceps muscle strength compared with a traditional femoral nerve block [3,4]. Moreover, supplemental infiltration of the space between the popliteal artery and posterior capsule of the knee (IPACK block) is effective in achieving motor-sparing posterior knee analgesia [5,6].

Manickam et al. [7] first described the ultrasound-guided ACB, in which local anesthetic was injected into the distal adductor canal to block the saphenous nerve. Since then, several approaches to anterior knee analgesia have been developed. The operator relies on the position of the sartorius muscle (SM) and subsartorial or superficial femoral artery (SFA), which courses from the apex of the femoral triangle along the adductor canal to the adductor hiatus in an ultrasound image, and new terminologies have been developed to define each injection point [8–10]. A needle injection point at the position where the SFA lies inferior or medial to the SM in the ultrasound image (femoral triangle block [FTB] or proximal ACB) is the most common [10–12]. Analgesia following FTB or proximal ACB is superior to that of other approaches, as the corresponding site is closer to the apex of the femoral triangle and can involve other branches of the femoral nerve, such as the vastus medialis nerve and infrapatellar branch of the saphenous nerve, and possibly the medial cutaneous nerve of the thigh, comprising the majority of nerve supply to the anteromedial knee joint [11,13].

The most commonly used surgical approach for TKA is the medial parapatellar approach, which exposes most structures in the anteromedial aspect of the knee. Therefore, the additional analgesic effect due to the blockade of the lateral femoral cutaneous nerve is minimized, as it mainly innervates the skin in the anterolateral part of the thigh and knee [14]. The anteromedial cutaneous regions of the distal thigh and knee are innervated by the anterior division of the sensory branch of the femoral nerve, called the anterior femoral cutaneous nerve (AFCN), which consists of the intermediate and medial cutaneous nerves of the thigh (ICNT and MCNT) [12,15]. The FTB may not completely anesthetize these nerves. The AFCN block (AFCNB) is used for postoperative pain relief after TKA [16,17]. However, the analgesic efficacy of combined AFCNB and FTB has not been compared with that of FTB alone.

Hence, the purpose of this study was to compare the postoperative analgesic effect of AFCNB combined with FTB with that of FTB alone in patients undergoing TKA as part of a multimodal analgesic regimen including continuous ACB (CACB) and IPACK block. We hypothesized that AFCNB + FTB would significantly lower pain scores during movement in the immediate 12 h postoperative period when compared with FTB alone.

Materials and Methods

This study was approved by the Institutional Review Board of Chulalongkorn University (Ref no. 781/62), and written informed consent was obtained from all participants. The trial was registered prior to patient enrollment at clinicaltrials.in.th (TCTR2019 1209004, Principal investigator: W. K., date of registration: December 9, 2019). This clinical research was done following the ethical principles for medical research involving human subjects in accordance with the Helsinki Declaration 2013 and this manuscript adheres to the applicable Consolidated Standards of Reporting Trials guidelines.

Owing to the variable courses and patterns of the ICNT and MCNT, as demonstrated in previous cadaveric studies [18–20], we first selected five soft embalmed cadavers donated for scientific research at the Department of Anatomy, Chulalongkorn University, to explore the anatomical structure of the AFCN (ICNT and MCNT) and to determine the needle injection point in ultrasound-guided AFCNB (Figs. 1A and 1B). We found that the ICNT pierces the SM and fascia lata distal to the inguinal crease or courses between the SM and fascia lata before perforating the fascia lata at the level of the femoral triangle and reaching the subcutaneous fat with descending branches along the forepart of the thigh. The MCNT has a variable course and pattern and medially overlays the course of the ICNT [19,20]. We found several branches that descended anteromedially to the femoral artery in the area of the femoral triangle and reached superficial layers of the SM by coursing distally and medially to the medial border of the SM or penetrating the medial border of the SM at the apex of the femoral triangle. Therefore, the site of the SFA beneath the medial border of the SM was determined as the needle injection point for ultrasound-guided AFCNB.

Thereafter, this prospective, double-blind, randomized controlled trial was conducted from January 2020 to August 2020. Adult patients (aged ≤ 80 years) with American Society of Anesthesiologists classification status I to III and body mass index between 18 and 40 kg/m^2 scheduled for elective primary TKA due to osteoarthritis were considered for enrollment in the study. The exclusion criteria included a varus-valgus deformity > 20°, knee flexion deformity > 30°, receiving any type of intraoperative periarticular infiltration (PAI) of local anesthetic by the surgeons, known allergy to study drugs, contraindication to neuraxial or regional anesthesia, chronic opioid use (daily or almost daily use of opioids for ≥ 3 months or morphine use ≥ 60 mg/day for ≥ 1 month), and inability to cooperate or unwillingness to provide informed consent. All eligible patients were interviewed and provided with information on the day of the preoperative admission.
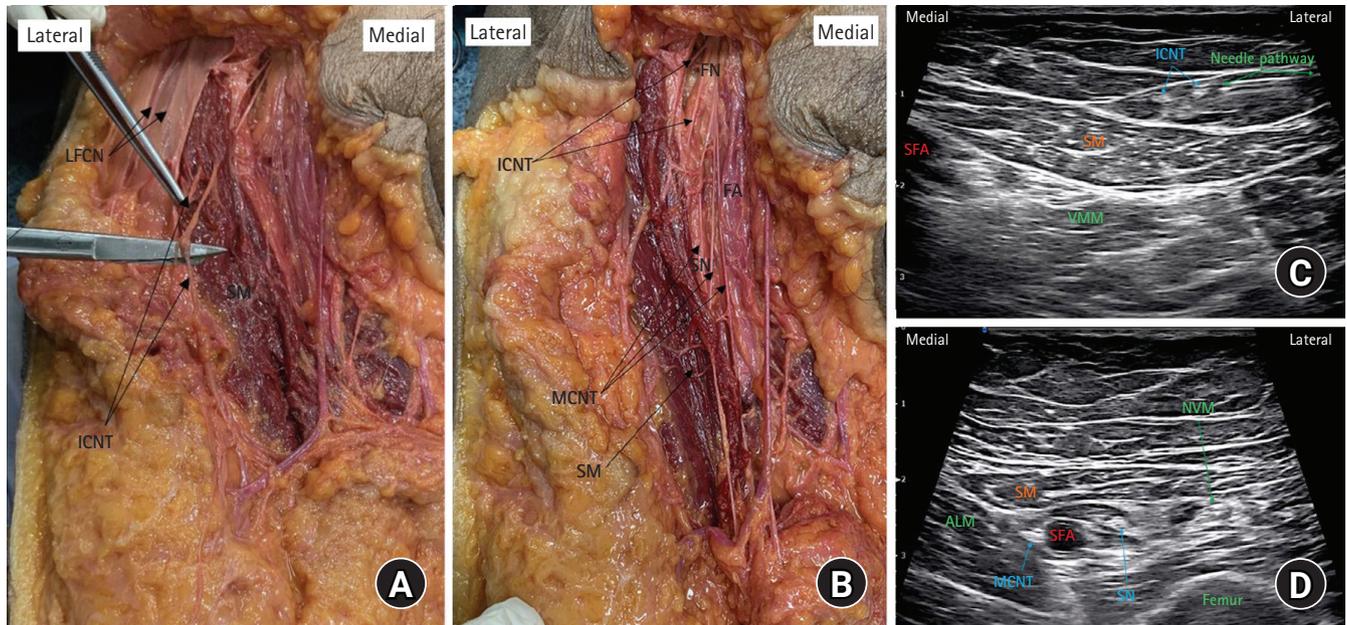
Fig. 1. A and B: Illustrations of anatomical dissection delineating the trajectories of the anterior femoral cutaneous nerve and its branches (the ICNT and MCNT). (A) The ICNT pierces the fascia lata just below the inguinal crease and descends anterior to the fascia lata along the forepart of the thigh. (B) The MCNT branches descend along the medial border of the SM. C and D: Illustrations of ultrasound views for the anterior femoral cutaneous nerve block. (C) Ultrasound image of the path traced by the needle while injecting the local anesthetic mixture anterior to the FL that covers the SM and the ICNT as seen after hydrodissection. (D) Ultrasound image of the branch of the MCNT around the SFA and the SN lateral to the SFA after injection of the local anesthetic mixture. ALM: adductor longus muscle, FA: femoral artery, FL: fascia lata, FN: femoral nerve, ICNT: intermediate cutaneous nerve of the thigh, LFCN: lateral femoral cutaneous nerve, MCNT: medial cutaneous nerve of the thigh, NVM: nerve to vastus medialis, SFA: superficial femoral artery, SM: sartorius muscle, SN: saphenous nerve, VMM: vastus medialis muscle.

Demographic data, preoperative pain scores, and functional performance results (timed up and go [TUG] test, five times sit-to-stand test [FTSST], quadriceps muscle strength [QMS], and knee range of motion [ROM]) were obtained on the day before the surgery by a blinded research assistant. All patients were provided with instructions to assess pain intensity using the numeric rating scale (NRS) for the area where the TKA would be performed.

Treatment allocation and blinding

After providing informed consent, all patients were randomly assigned to either the FTB alone group (FTB group; n = 40) or the AFCNB and FTB combination group (AFCNB + FTB group; n = 40) using computer-generated block randomization in a 1 : 1 ratio (blocks of 4 and 6) by a statistician not involved in the study. Treatment allocation was concealed using consecutively numbered, sealed, opaque envelopes that were opened by the nurse anesthetist before the patient's arrival in the room where the nerve blocks were performed. All nerve blocks were performed by a single, experienced, regional anesthesiologist (W.K.) with a nurse anesthetist; both were uninvolved in any other study phases, thus eliminating performance bias. All surgeons, research assistants, and operating room and floor nurses, patients, and statisticians were blinded to group allocation.

Preoperative and block procedures

All patients received multimodal analgesia, including oral acetaminophen (650 mg) 30 min before surgery. After standard non-invasive monitoring was initiated, peripheral intravenous (IV) catheters were applied, the patient was placed in a supine position with the legs slightly abducted, and the procedural area was cleaned. A high-frequency linear-array transducer (L11-3, Sonimage® HS1, Konica Minolta, Japan) used for ultrasonography was also disinfected. A titrated anxiolytic 1–2 mg IV dose of midazolam was administered to the patient. Sterile mixtures of local anesthetic solution consisted of 100 mg levobupivacaine (20 ml of 0.5% levobupivacaine) with 0.2 mg epinephrine and 30 mg ketorolac in 20 ml normal saline (total 40 ml divided by 2; syringes of 20 ml each) and 20 ml normal saline for the sham AFCNB in the FTB group, and 150 mg levobupivacaine (30 ml of 0.5% levobupivacaine) with 0.3 mg epinephrine and 30 mg ketorolac in 30 ml normal saline (total 60 ml divided by 3; syringes of 20 ml each) in the AFCNB + FTB group.

Under sterile conditions, ultrasound-guided AFCNB was performed by placing the transducer along the upper to middle third of the thigh. After identifying the position of the SFA beneath the SM in the ultrasound image, the transducer was moved slightly cephalad to identify the optimal position of the SFA beneath the medial border of the SM in the ultrasound image [11]. After administration of 1–2 ml of 1% lidocaine to anesthetize the skin, a 21-gauge 10-cm stimulating needle (Stimuplex® A100; B. Braun Medical, Inc., USA) was inserted from the lateral-to-medial direction using an "in-plane technique" and was advanced until the needle tip was superficial to the fascia lata at the junction of the sartorius and rectus femoris muscles [16,17]. Thereafter, 10 ml of the local anesthetic mixture was slowly injected with aspiration, while the needle was advanced superficial to the fascia lata covering the SM until it reached the medial border of the SM to block the ICNT (Fig. 1C). The needle was then redirected to pierce the fascia lata [12], and another 10 ml of anesthetic mixture was slowly injected between the fascia lata and SM until the tip of the needle reached the medial border of the SM to block the MCNT branches and ensure adequate spread to the ICNT. In the FTB group, 20 ml of normal saline was injected.

The needle was then advanced through the SM at the same level until the tip of the needle was located beneath the SM and anterolateral to the SFA. In the FTB group, 20 ml of local anesthetic mixture was injected. In the AFCNB + FTB group, the needle was carefully advanced periarterially toward the medial side of the SFA and beneath the medial border of the SM, in order to achieve spread to the MCNT branches (Fig. 1D) [12]. Subsequently, patients in both groups were placed in 90° flexion of the knee to perform the IPACK block under sterile conditions with a 20 ml local anesthetic mixture, as described in a previous study [21].

Intraoperative protocol

All patients received spinal anesthesia with 3 to 3.2 ml of 0.5% hyperbaric bupivacaine. Antiemetic prophylaxis was administered to all patients with 10 mg IV dexamethasone and 4 mg IV ondansetron. Minimally invasive TKA was performed by two surgeons blinded to the group allocation, and the patients did not receive any intraoperative PAI of local anesthetic by the surgeons.

Postoperative protocol

CACBs were performed in the postanesthesia care unit by the regional anesthesiologist team using an 80-mm Touhy needle and Perifix® 18-gauge epidural catheter (B. Braun Medical, Inc., USA) for all patients in their operated extremities. After ultrasound

identification of the SFA under the SM and below the apex of the femoral triangle, a Touhy needle was inserted in-plane from the lateral-to-medial direction and advanced until the tip was positioned between the SM and SFA. Thereafter, 5–10 ml of normal saline was injected to confirm the optimal positioning of the catheter and to secure catheter insertion [22]. An ACB catheter was then inserted through the needle and fixed over the skin after the position of the catheter tip was confirmed by ultrasound. Subsequently, levobupivacaine 0.15% was continuously infused at 5 ml/h for 60 h via a disposable infusion pump (Coopdech Syrinjector, Daiken Medical Co., Ltd., Japan). A standardized analgesic protocol comprising two doses of IV parecoxib 20 mg every 12 h, oral acetaminophen 650 mg every 6 h, and oral pregabalin 75 mg and oral celecoxib 400 mg (starting after the last dose of parecoxib) once a day. In addition, for patients with NRS scores ≥ 4, 2 mg IV morphine was administered every 30 min. If a patient continued to exhibit an NRS score ≥ 4 for up to 1 h, patient-controlled anesthesia (PCA) was initiated using morphine (no basal rate; PCA dose, 2 mg; lockout time, 10 min) as a rescue drug. Discharge criteria [23] were assessed by the surgeons blinded to the treatment.

Outcome assessments

All data were collected by a research assistant who was blinded to the group assignment and was not involved in perioperative patient care. The primary outcome was pain score on movement as measured using an NRS (0–10; 0: no pain, 10: worst imaginable pain) in the first 12 h after surgery. The secondary outcomes included the following: pain scores at rest and during movement until 2 months after surgery; the end-of-analgesia time, defined as the time from the end of surgery to the first NRS score ≥ 4; incidence of surgical incision site pain, defined as the proportion of patients who experienced moderate-to-severe pain (NRS score ≥ 4) in the area of the surgical incision in the first 24 h after surgery; IV morphine consumption (in mg; at 12, 24, and 48 h postoperatively); immediate functional performance measures (recorded by a blinded physiotherapist from preoperative to postoperative day [POD] 2) including (i) the TUG test, with results measured in seconds, requiring the patient to stand up from an armchair, walk 3 m, turn, walk back to the chair, and sit down [24]; (ii) the FTSST, with results measured in seconds, requiring the patient to stand and sit five times as quickly as possible without physical assistance [25]; (iii) the QMS, measured using a handheld dynamometer (microFET®2, Hoggan Health Industries, USA), requiring the patient to sit with legs hanging from the bed with 0° and 90° angulations of the knee joint. For each degree, three consecutive measurements were made with 30 s intervening rest periods,

and the average was calculated. (iv) The ROM measured the degree of maximum active flexion and extension of the operated knee. Nausea and vomiting and dizziness scores were assessed on a visual analog scale (0 = none, 10 = severe) until POD 2; patient satisfaction and quality of sleep were recorded on a Likert scale (0–7); length of hospital stay was defined as the time from surgery until discharge; and other postoperative complications included local anesthetic toxicity, motor weakness of the peroneal nerve, and incidence of falls.

Sample size

Sample size was calculated by reviewing the patient records at our institution and was based on the findings of our previous study [22] that NRS pain scores on movement 12 h postoperatively were 3.3 ± 2.8 in patients who had received spinal anesthesia combined with postoperative CACB without intrathecal morphine or PAI. Assuming a standard deviation of 3 points, which corresponds to an effect size of 0.67, with a significance level of 0.05 and 80% power, 36 patients would be required in each group to detect a minimally clinically important difference of 2 points in NRS pain scores on movement 12 h postoperatively between patients receiving AFCNB + FTB and FTB alone. We planned to include 80 patients altogether to compensate for potential dropouts.

Statistical analysis

The primary outcome, pain scores, and functional outcomes measured at a single postoperative time point were compared between the groups using multivariable linear regression. Regression based on a generalized estimating equation (GEE) approach [26] with an unstructured correlation structure was used to compare outcomes measured longitudinally. The GEE method accounts for the correlation between repeated measurements for the same patient. Continuous variables between the groups were compared using the unpaired t test, and categorical variables were analyzed using the chi-square test. All variables were tested for normality using the Shapiro–Wilk test. Data are presented as the mean ± standard deviation with 95% CI, or median (Q1, Q3), according to the normality of data distribution, or as a number (proportion). We did not impute values when data were missing, and an effect was considered statistically significant at P < 0.05 (95% CI excluded zero). Statistical analysis was conducted using STATA version 14.0 (STATA Corp., USA).

Results

A total of 80 patients met the inclusion criteria and were enrolled in the study. One patient in the AFCNB + FTB group was withdrawn from the analysis because of protocol violation due to inadvertent intraoperative PAI. The CONSORT diagram for the study is shown in Fig. 2. Preoperative patient characteristics were similar between the two groups (Table 1).

Pain outcomes

Although the mean NRS pain scores in both groups were lower than 4 (Table 2), patients in the AFCNB + FTB group showed sta-
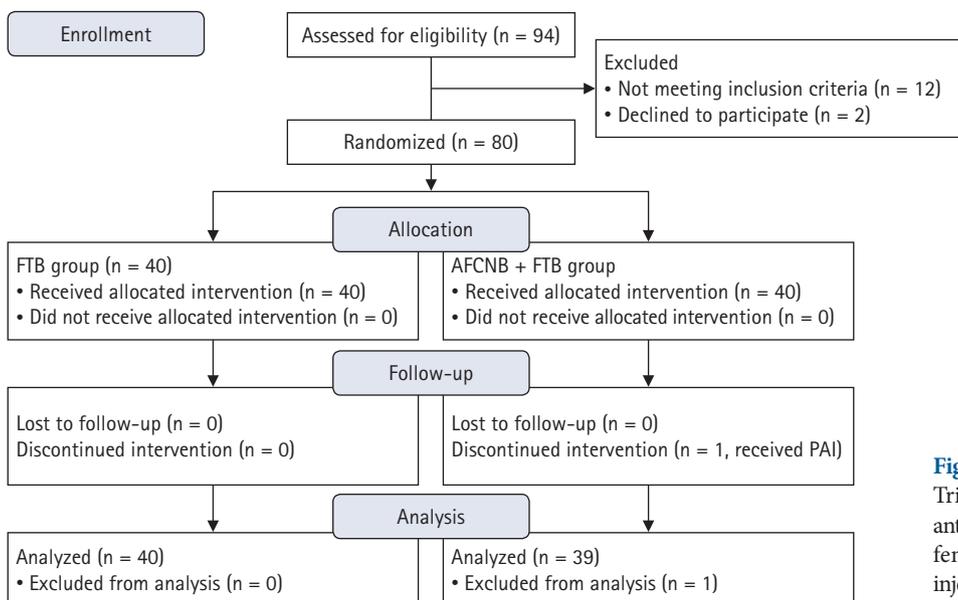

Fig. 2. Consolidated Standards of Reporting Trials (CONSORT) flow diagram. AFCNB: anterior femoral cutaneous nerve block, FTB: femoral triangle block, PAI: periarticular injection.

Table 1. Baseline Patient Characteristics

Variable	FTB group (n = 40)	AFCNB + FTB group (n = 39)
Sex		
Male	5 (12.5)	4 (10.3)
Female	35 (87.5)	35 (89.7)
Age (yr)	70.9 ± 7.6	71.1 ± 7.5
Weight (kg)	65.2 ± 10.6	61.9 ± 11.2
Height (cm)	153.9 ± 6.9	153.4 ± 6.3
Body mass index (kg/m^2)	27.6 ± 4.2	26.3 ± 4.0
ASA PS (I/II/III)	2/34/4	2/34/3
Preop NRS pain score		
At rest	1.5 ± 2.2	1.0 ± 2.1
During movement	4.4 ± 2.9	4.9 ± 2.3
Preop TUG (s)	24.9 ± 9.4	24.5 ± 11.8
Preop FTSST (s)	25.7 ± 12.2	23.6 ± 10.5
Preop QMS 0 degree (n)	47.6 ± 15.5	51.3 ± 14.6
Preop QMS 90 degree (n)	56.1 ± 24.6	77.9 ± 29.4
Preop active ROM (°)	117.9 ± 17.4	120.4 ± 11.4
Operative side		
Left	14 (35.9)	20 (52.6)
Right	25 (64.1)	18 (47.4)
Duration of surgery (min)	116.3 ± 24.8	115.0 ± 21.6
Duration of anesthesia (min)	150.1 ± 28.2	152.7 ± 24.1

Values are presented as mean ± SD or number (%). AFCNB: anterior femoral cutaneous nerve block, ASA PS: American Society of Anesthesiologists physical status, FTB: femoral triangle block, FTSST: five times sit-to-stand test, NRS: numeric rating scale, Preop: preoperative, QMS: quadriceps strength, ROM: range of motion, TUG: timed up and go.

tistically significant reduction in their scores during movement compared to those in the FTB group 12 h postoperatively (FTB: 2.2 ± 1.8 vs. AFCNB + FTB: 0.8 ± 1.3; mean difference: −2.02, 95 CI: −3.14, −0.89, P < 0.001). In addition, patients in the AFCNB + FTB group revealed significantly lower NRS pain scores at rest 6 h postoperatively (FTB: 2.3 ± 2.9 vs. AFCNB + FTB: 0.2 ± 0.7; mean difference: −1.61, 95% CI: −2.4, −0.81, P < 0.001), and on movement 6 and 24 h postoperatively (FTB: 3.1 ± 3.4 vs. AFCNB + FTB: 0.3 ± 0.8; mean difference: −3.47, 95% CI: −4.59, −2.35, P < 0.001 and FTB: 2.3 ± 2.1 vs. AFCNB + FTB: 1.7 ± 2; mean difference: −1.27, 95% CI: −2.4, −0.15, P = 0.025, respectively). Additionally, the incidence of moderate-to-severe pain at the surgical incision site was significantly lower in these patients than in patients in the FTB group 24 h after surgery (15.8% vs. 41%, P = 0.014).

The end-of-analgesia time (NRS ≥ 4) was significantly longer in the AFCNB + FTB group than in the FTB group (19.6 ± 6.2 vs. 5.4 ± 5.4 h, P < 0.001). The IV morphine consumption was lower in the AFCNB + FTB group than in the FTB group at 12 h (0

[0, 0] vs. 0 [0, 2], P < 0.001), 24 h (0 [0, 0] vs. 0 [0, 2], P < 0.001), and 48 h (0 [0, 0] vs. 2 [0, 4], P < 0.001). However, this difference was not clinically significant. Likewise, no patient in either group required IV PCA.

Performance outcomes

The mean TUG test time on POD 2 in the AFCNB + FTB group was significantly lower than in the FTB group (FTB: 70.2 ± 34.3 s vs. AFCNB + FTB: 50.9 ± 21.4 s; mean difference: −18.95 s, 95% CI: −35.23, −2.67, P = 0.023) (Table 3). The mean QMS in the AFCNB + FTB group on PODs 0–2 was greater in both degrees of knee joint movement than in their FTB group counterparts, and the number of patients able to perform the QMS test in all degrees of knee joint movement on POD 0 was higher in the AFCNB + FTB group (27 vs. 36 in 90°, P = 0.006). However, there was no difference in the mean QMS at 90° between the groups on POD 0 (FTB: 37.6 ± 24.6 vs. AFCNB + FTB: 55.6 ± 28.5; mean difference: −4.8, 95% CI: −14.15, 4.54, P = 0.313), while the FTB group showed significantly reduced QMS at 0° compared to the AFCNB + FTB group on POD 0 (FTB: 26.8 ± 12.2 vs. AFCNB + FTB: 45.3 ± 43.5; mean difference: 11.21, 95% CI: 0.5, 21.89, P = 0.04) (Table 3). There were no significant differences between the two groups in other measures at various time points.

Other outcomes

There were no clinically relevant or statistically significant differences between the two groups in terms of nausea and vomiting, dizziness, quality of sleep, patient satisfaction, and length of hospital stay (FTB: 57 ± 13.5 h vs. AFCNB + FTB: 53.2 ± 7.8 h; P = 0.14). No adverse events occurred in either group.

Discussion

This randomized controlled trial evaluated the effects of AFCNB in combination with FTB as part of a postoperative multimodal analgesia regimen including CACB after TKA. Our results indicated that AFCNB in combination with FTB can provide analgesia superior to that of FTB alone during the first 12 h after surgery. Moreover, it also increased the time to first analgesic request and reduced IV morphine consumption, although the results were not clinically significant.

Furthermore, AFCNB combined with FTB decreased the incidence of moderate-to-severe pain in the surgical incision area during the first 24 h after TKA, in comparison with FTB alone. These results suggest that AFCNB could provide cutaneous anes-

Table 2. Pain Assessment

Time points	FTB group Unadjusted (n = 40)		AFCNB + FTB group Unadjusted (n = 39)		Adjusted difference (95% CI)	P value
NRS at rest						
PACU	40	0.3 ± 0.9	39	0.1 ± 0.4	0.42 (−0.37, 1.21)	0.301
6 h	40	2.3 ± 2.9	39	0.2 ± 0.7	−1.61 (−2.4, −0.81)	< 0.001*
12 h	40	1.3 ± 1.8	39	0.5 ± 0.9	−0.28 (−1.07, 0.52)	0.494
24 h	40	1.0 ± 1.5	39	0.5 ± 0.9	−0.03 (−0.82, 0.76)	0.942
48 h	40	0.6 ± 1.3	39	0.3 ± 0.8	0.23 (−0.56, 1.02)	0.571
5 days	40	0.9 ± 1.1	39	0.8 ± 1.5	0.35 (−0.45, 1.15)	0.392
1 week	40	0.8 ± 1.0	39	0.9 ± 1.7	0.6 (−0.21, 1.4)	0.146
2 weeks	40	0.7 ± 1.3	39	0.6 ± 1.5	0.45 (−0.36, 1.26)	0.274
1 month	40	0.5 ± 1.1	39	0.3 ± 0.9	0.29 (−0.52, 1.1)	0.482
2 months	40	0.3 ± 1.0	39	0.1 ± 0.2	0.26 (−0.56, 1.07)	0.538
NRS during movement						
PACU	40	0.5 ± 1.7	39	0.1 ± 0.5	−0.96 (−2.09, 0.16)	0.093
6 h	40	3.1 ± 3.4	39	0.3 ± 0.8	−3.47 (−4.59, −2.35)	< 0.001*
12 h	40	2.2 ± 1.8	39	0.8 ± 1.3	−2.02 (−3.14, −0.89)	< 0.001*
24 h	40	2.3 ± 2.1	39	1.7 ± 2.0	−1.27 (−2.4, −0.15)	0.025*
48 h	40	2.8 ± 1.9	39	2.3 ± 1.5	−1.1 (−2.22, 0.03)	0.056
5 days	40	2.6 ± 1.9	39	2.8 ± 2.4	-0.52 (-1.65, 0.61)	0.368
1 week	40	2.5 ± 1.4	39	3.3 ± 2.4	0.03 (−1.11, 1.17)	0.959
2 weeks	40	2.3 ± 1.7	39	2.8 ± 2.2	−0.03 (−1.18, 1.11)	0.956
1 month	40	1.5 ± 1.5	39	2.1 ± 2.8	−0.02 (−1.16, 1.13)	0.976
2 months	40	1.4 ± 1.6	39	0.9 ± 1.3	−1.1 (−2.25, 0.06)	0.063

Values are presented as mean ± SD or number. AFCNB: anterior femoral cutaneous nerve block, FTB: femoral triangle block, NRS: numeric rating scale, PACU: postanesthesia care unit. *P value < 0.05.

Table 3. Postoperative Timed Up and Go Test, Five Times Sit-to-stand Test, Quadriceps Strength, and Active Range of Motion

Functional outcomes	FTB group Unadjusted (n = 40)		AFCNB + FTB group Unadjusted (n = 39)		Adjusted difference (95% CI)	P value
TUG (s)						
Day 1	40	93.5 ± 47.6	39	80.5 ± 35.0	−12.91 (−29.19, 3.37)	0.120
Day 2	40	70.2 ± 34.3	39	50.9 ± 21.4	−18.95 (−35.23, −2.67)	0.023*
FTSST (s)						
Day 1	37	53.2 ± 34.9	38	44.1 ± 24.6	−7.12 (−18.21, 3.98)	0.209
Day 2	40	35.4 ± 22.7	39	30.8 ± 13.9	−2.13 (−13.22, 8.97)	0.707
QMS 0° (n)						
Day 0	34	26.8 ± 12.2	36	45.3 ± 43.5	11.21 (0.5, 21.89)	0.040*
Day 1	40	38.7 ± 13.0	39	48.9 ± 17.3	4.36 (−6, 14.72)	0.409
Day 2	40	42.7 ± 15.6	39	49.2 ± 18.9	1.25 (−9.07, 11.61)	0.810
QMS 90° (n)						
Day 0	27	37.6 ± 24.6	36	55.6 ± 28.5	−4.8 (−14.15, 4.54)	0.313
Day 1	40	48.4 ± 25.6	39	68.3 ± 30.0	−7.21 (−15.35, 0.93)	0.083
Day 2	40	56.4 ± 30.3	39	71.1 ± 28.8	−12.19 (−20.33, −4.05)	0.003*
Active ROM (°)						
Day 0	40	124.4 ± 13.1	39	124.9 ± 9.2	−1.6 (−8.19, 4.98)	0.633
Day 1	40	91.8 ± 15.3	39	92.5 ± 11.8	−1.84 (−8.45, 4.78)	0.586
Day 2	40	105.8 ± 15.9	39	101.6 ± 14.2	−6.34 (−12.96, 0.27)	0.060

Values are presented as mean ± SD or number. AFCNB: anterior femoral cutaneous nerve block, FTB: femoral triangle block, FTSST: five times sit-to-stand test, QMS: quadriceps muscle strength, ROM: range of motion, TUG: time up and go. *P value < 0.05.

thesia in the region of the surgical incision and medial aspect of the knee after TKA, whereas FTB or proximal ACB cannot. Hence, AFCNB can be beneficial for cases in which surgical incisions for TKA are relatively large. However, we were unable to accurately determine the effects of combining AFCNB with FTB on the immediate functional performance outcomes after TKA, because we found a reduction in muscle strength only in the 0° knee joint on POD 0 in the FTB group compared to that in the AFCNB + FTB group. Moreover, there were no significant differences in the other immediate performance test measures, except for the TUG test and QMS results on POD 2. However, patients in the AFCNB + FTB group had lower pain scores and greater cooperation in physical performance measures on POD 0. Therefore, the motor-sparing anterior knee block (AFCNB with FTB) combined with the motor-sparing posterior knee block (IPACK block) may prove effective in cases requiring early ambulation after TKA.

The needle injection point for FTB in our study was located just above the apex of the femoral triangle or the SFA, beneath the medial border of the SM in the ultrasound images. This is the same location as in previous studies, defined as "FTB" and "proximal ACB" [8–11]. Our results and anatomical findings also support the possibility of an analgesic effect in this location extending to the saphenous nerve, infrapatellar branch of the saphenous nerve, vastus medialis nerve, and some branches of the MCNT that course anteromedial to the SFA at this level [18–20], which are not involved in other techniques of motor-sparing anterior knee analgesia. This could be because the FTB or proximal ACB can anesthetize more branches of the femoral nerve than the distal ACB and may lead to quadriceps muscle weakness. However, results of previous studies did not show quadriceps muscle weakness [21,22,27]. The continuous catheter technique at this location should be explored in future studies for longer pain relief after TKA.

To the best of our knowledge, this is the first clinical study to investigate the efficacy of AFCNB in combination with FTB in patients undergoing TKA. Sogbein et al. [16] examined the use of AFCNB as part of motor-sparing knee blocks (including the lateral femoral cutaneous nerve block, AFCNB, ACB, and IPACK block) and demonstrated longer analgesia compared with the PAI technique. However, no ACB or FTB group was defined for direct comparison. Moreover, the trajectory of the ICNT is fairly constant, in contrast to that of the MCNT [18–20]. Therefore, the location of the block of the MCNT varies. Our technique for MCNT block was similar to that used by Johnston et al. [17], who devised it from a literature review of the anatomy and innervation of the knee joint. However, the quantity of local anesthetic used at each

injection point in that trial was relatively small. Hence, it might not have been sufficiently distributed to most of the branches of the MCNT. Moreover, we did not inject the local anesthetic between the SM and posterior fascia above the adductor canal (subsartorial space), because local anesthetic distribution by FTB also includes this space. The anatomical and volunteer trial by Bjørn et al. [12] demonstrated a block of the ICNT in which duplication of the fascia lata superficial to the SM can be visualized in ultrasound images and a block of the MCNT by the FTB with the needle tip located only lateral to the femoral artery. In our injection, the needle tip was further advanced anteromedial to the femoral artery for adequate local anesthetic distribution. Further studies are needed to investigate the optimal needle injection point and the required volume of local anesthetic to block the branches of the MCNT.

Our study had several limitations. First, use of the CACB in our postoperative multimodal analgesic regimen might have led to an absence of obvious differences in the pain scores and IV morphine consumption between the two groups. However, the duration of the effect of single-shot ACB is generally 24–36 h [22,28], and breakthrough pain may occur after the effect of a single shot subsides, which can cause delays in the initiation of physical therapy and hospital discharge [29,30]. Second, all preoperative block procedures were performed by a single anesthesiologist who could not be blinded to the study group; therefore, an involuntary bias may have been introduced in the performance of the blocks. However, the minimal pain scores in both groups suggested that both block techniques were comparable. Third, as the patients were under sedation, we could not clearly examine the differences in the anesthetized areas after blocks between the groups. The assessment was performed only by cold sensation on the anteromedial knee 20–30 min after the respective procedures. Lastly, because of the clinical setting and study protocol, we could not assess the efficacy of these blocks in outpatient settings. Future studies on the efficacy of AFCNB combined with FTB in outpatient settings are warranted.

In conclusion, the motor-sparing knee blocks, including the FTB (with or without AFCNB) and IPACK blocks, as part of the multimodal analgesic regimen, provide effective postoperative analgesia in patients undergoing TKA. They also reduce postoperative opioid requirements. Moreover, the addition of AFCNB to FTB decreased pain scores at 12 h after surgery and the incidence of moderate-to-severe surgical incision pain compared to FTB alone, and it could enhance the immediate physical performance of the patients on the day of surgery.

Conflicts of Interest

No potential conflict of interest relevant to this article was reported.

Author Contributions

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