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Original Article

Comparison of postoperative femoral nerve block, epidural block and intravenous patient-controlled analgesia in pain control and postoperative rehabilitation after total knee arthroplasty

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Abstract: Background: Total knee arthroplasty (TKA) is a commonly used and successful procedure for the treatment of degenerative diseases of the knee joint. However, postoperative pain remains inevitable. We performed this study to compare femoral nerve block (FNB), epidural block and patient-controlled analgesia (PCA) in terms of postoperative pain control and rehabilitation course. Methods: From 2014.1 to 2015.1, we included 82 patients with unilateral TKA in our study. Participants were randomized into three treatment groups: FNB, epidural block and PCA. Postoperative pain was measured with Visual Analogue Scale (VAS) at different time points (0 h, 2 h, 6 h, 12 h, 24 h and 72 h) after surgery. Secondary outcomes include hemodynamic changes, rehabilitation course, complications and side effects. Results: In rest situation, FNB group had the lowest VAS score in the first 6 hours (0 h, 2 h and 6 h) after surgery and the PCA group seemed to suffer most pain in the first 6 hours after surgery. But 24 hours after the surgery, the PCA group had the lowest VAS score. In moving situation, we found that after 24 hours (24 h and 72 h), the PCA group had the lowest VAS score. No difference was found in hemodynamic changes at all time points. The FNB analgesia has the least complications and side effects. Conclusions: FNB and epidural analgesia has a better effect on controlling the acute pain after TKA surgery. The PCA analgesia is more effective in controlling long term pain after the surgery and is more effective in controlling the pain caused by movement. PCA analgesia has a significant advantage in motion rehabilitation and the FNB analgesia suffered least side effects and complications.

Keywords: Femoral nerve block, epidural block, patient-controlled analgesia, total knee arthroplasty, visual analogue scale

Introduction

Total knee arthroplasty (TKA) is a commonly used and successful procedure for the treatment of degenerative diseases of the knee joint. However, postoperative pain remains inevitable [1] and might last for a long span [2]. Effective pain control allows for earlier ambulation and reduces the risk of postoperative complications [3, 4].

Femoral nerve block (FNB), epidural block and intravenous patient-controlled analgesia (PCA) are commonly used analgesic options for TKA. PCA of opioids are the primary analgesic for TKA [5]. However, opioids are associated with side effects which might have negative effects on patient comfort and delaying the start of physiotherapy [5-7]. Epidural analgesia provides better pain relief. There are, however, many side effects such as perioperative hypotension, urinary retention and respiratory depression [8-11]. FNB is now the most admired method of analgesia for TKA. It is accurate under the guidance of ultrasound and has a low risk of complications [10, 11]. Controversy between these analgesic options for TKA should be settled by more studies.

The aim of this randomized clinical trial was to compare ultrasound-guided FNB, epidural block and PCA in terms of postoperative pain control. Secondary outcomes include hemodynamic changes, rehabilitation course, complications and side effects.

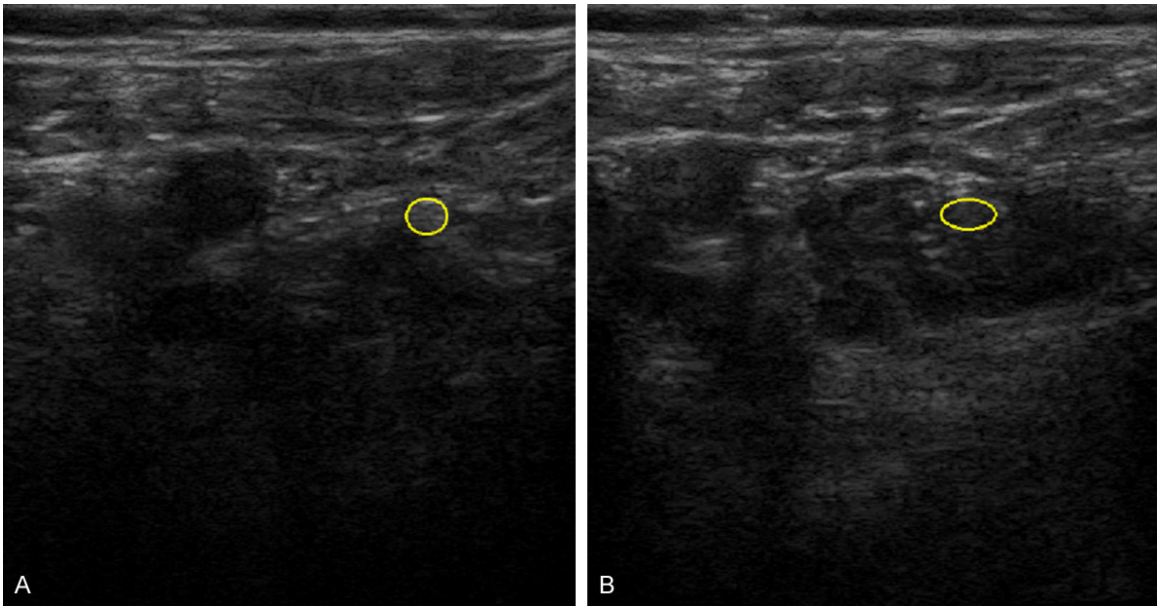

Figure 1. Ultrasound-guide femoral nerve block. A. Before. B. After.

Materials and methods

Patients

This study was approved by the Ethics Committee of Shanghai Ninth People's Hospital, affiliated with the Shanghai Jiaotong University School of Medicine (Shanghai, China), patients' consent was obtained prior to enrollment. The trial was conducted in Shanghai Ninth People's Hospital from 2014 to 2015. Patients undergoing primary unilateral TKA for osteoarthritis were recruited at least one day prior to the scheduled surgery. The inclusion criteria were: aged between 50 and 80 years; American Society of Anesthesiologists (ASA) physical status I to III; body mass index (BMI) less than 35 kg m^{-2}; competent in using the Visual Analogue Scale (VAS) pain score. The exclusion criteria included: renal and hepatic insufficiency; abnormal state of blood coagulation; having a contraindication for femoral block; local infection at the injection site; lower extremities thromboembolic diseases (e.g. deep vein thrombosis and varicose veins); preexisting neuropathy (e.g. protrusion of intervertebral disc and ischialgia); allergy to any involved medications; taking opioids within the past two weeks prior to surgery.

Participants were randomized prior to surgery using a computer-generated random number sequence into three treatment groups: femoral nerve block (FNB group), epidural block (EB group) and intravenous patient-controlled analgesia (PCA group).

Treatment allocation

PCA group: At the Post-Anesthesia Care Unit (PACU), the PCA was initiated immediately after surgery via a pump set to deliver analgesic including opioids (fentanyl 10 mcg/kg), NSAIDs and others like tramadol in a dose of 2 ml/h. patients can have a bolus of 0.2 ml dose with 30 min lockout. The intravenous opioids were discontinued on the morning of Day 3.

FNB group: Patients received single-injection femoral nerve blocks (20 ml of 0.375% ropivacaine) under ultrasound guidance immediately after the surgery before deliver to the PACU (**Figure 1**). The nerve was localized with the Sonosite M-Turbo ultrasound machine using the linear 13-6 MHz probe. Once the nerve was identified, a nerve block needle (B-Braun Stimuplex A) was inserted either in-plane or out-of-plane to the probe. Needle placement was considered adequate when the tip was visualized near the femoral nerve on the ultrasound monitor.

EB group: Blocks were proceed with the patient lying in the lateral decubitus position, under

Table 1. Patients' characteristics

	FNB (n = 28)		Epidural (n = 25)		PCA (n = 29)	
	Mean	SD	Mean	SD	Mean	SD
Age (years)	52.3	8.7	54.2	9.9	50.2	7.6
BMI (kg/m^2)	30.2	5.1	31.1	4.8	33.3	5.1
Weight (kg)	66.5	8.9	64.2	9.8	64.8	11.5
Pre-op knee pain score rest*	1.1	1.2	0.9	0.9	1.2	0.8
Pre-op knee pain score movement*	3.9	1.5	4.1	1.8	3.7	1.7
Duration of surgery (h)	2.1	0.8	1.9	0.6	2.3	0.6
Length of hospital stay (days)	4.5	1.1	4.9	2.0	5.0	2.2

*Range from 0 (no pain) to 10 (extreme pain). FNB, femoral nerve block; PCA, patient-controlled analgesia.

strict sterile preparation and precautions. The L3-4 or L2-3 interspace was identified and infiltrated locally with 2% lidocaine. The epidural catheter was inserted using an 18 G Tuohy needle, secured in place, and a test dose was administered (3 ml of 1.5% lidocaine with epinephrine). Then a bolus dose of 0.25% bupivacaine was administered. The patient was then taken to the operating room and received general anesthesia. The EB group received a 12±4.4 cc bolus of bupivacaine on average. All epidural catheters were removed on the morning of Day 3.

For the surgery, general anesthesia was performed with 2 mcg/kg fentanyl and 2 mg/kg propofol, and a laryngeal airway mask (LMA) was inserted thereafter. The patients were mechanically ventilated, and Sevoflurane in air/oxygen without N_2O was used for maintenance. Intraoperative boluses of fentanyl (50-100 mcg), fluid, blood pressure and blood management were administered by the attending anesthesiologists based on clinical criteria.

Outcome measurements

Primary outcomes

Postoperative pain measured with Visual Analogue Scale (VAS) on a 10 cm scale (0 = no pain to 10 = extreme pain). Each of these outcomes was recorded at different time points after the patient's discharge from post-anesthesia recovery unit (PACU) for up to 72 hours. We asked the patients to complete the VAS in rest and movement status. All these measurements were collected by the anesthetists who were unaware of the study.

Secondary outcomes

(1) Postoperative hemodynamic changes: recorded as mean blood pressure (MAP) and heart rate variation in the first 72 hours after discharge from PACU. (2) Postoperative rehabilitation course: which was assessed once daily as follows: number of patients achieved knee joint movement more than 90 degree; maximum distance that the patient can walk (meter) during the rehabilitation section; measuring the range of the knee joint motion using a goniometer.

Statistical analysis

One way analysis of covariance (ANCOVA) was used for continuous data. Differences in categorical data for the primary outcome were assessed using logistic regression. Statistical significance was set at $P<0.05$. The results were analyzed on the basis of the intention-to-treat principle. All measurable data were analyzed using SAS statistics software (SAS System for Windows, Version 9.2; SAS Institute Inc, Cary, North Carolina).

Results

From 2014.1 to 2015.1 there were 131 patients who had total knee arthroplasties performed at our hospital. Of these patients, only 82 unilateral TKA were included in our study; 25 of them had epidural, 29 had PCA and 28 had FNB. The remaining 49 patients were not included in the study as they had bilateral TKA or a combination of two analgesia methods for postoperative management. **Table 1** show that there were no differences in patient characteristics.

Primary outcomes

Postoperative pain was measured with VAS pain score in both rest and movement situations. The results showed that in rest situation, the FNB group had the lowest VAS score in the first 6 hours (0 h, 2 h and 6 h) after recovery from anesthesia and the PCA group seemed to suffer most pain in the first 6 hours (0 h, 2 h and 6 h) after surgery. But 24 hours (24 h) after

Table 2. Patients' rest and movement VAS Scores

	FNB rest (n = 28)		Epidural rest (n = 25)		PCA rest (n = 29)		FNB movement (n = 28)		Epidural movement (n = 25)		PCA movement (n = 29)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
0 h	1.5	0.6	1.7	0.7	3.0	0.5	na	na	na	na	na	na
2 h	2.8	0.7	3.5	0.6	4.5	0.8	na	na	na	na	na	na
6 h	3.7	1.1	4.6	0.9	5.5	1.4	6.9	1.3	7.0	1.2	7.3	1.7
12 h	3.0	0.6	3.3	1.1	3.0	1.0	6.5	1.2	6.2	1.6	6.5	1.4
24 h	1.5	0.7	1.8	0.6	0.9	0.4	6.2	1.8	6.5	1.9	4.8	1.2
72 h	0.8	0.5	0.6	0.4	0.7	0.3	4.2	0.6	4.0	0.7	3.2	1.1

FNB, femoral nerve block; PCA, patient-controlled analgesia; na, not assessed.

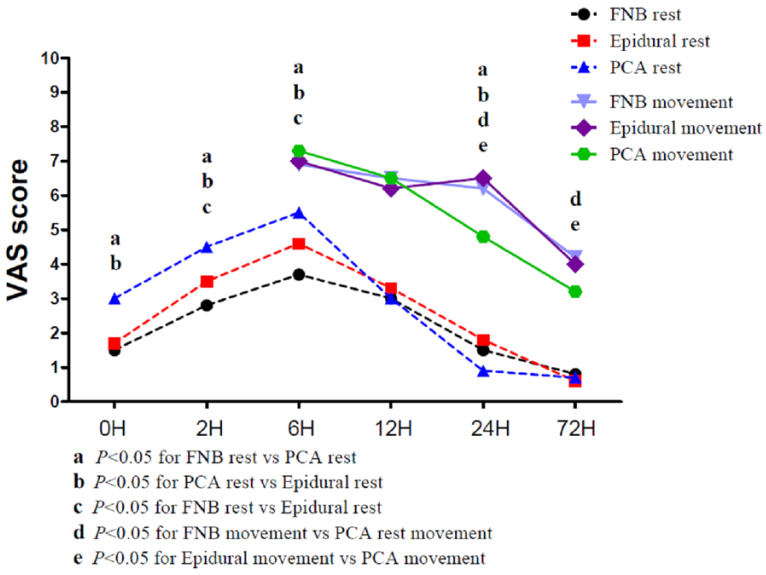

Figure 2. Trend of rest and movement VAS scores.

the surgery, the PCA group had a lower VAS score compared to the other two groups. When asking the patients to reassess the VAS score during moving their knee, we found that after 24 hours (24 h and 72 h), the PCA group had the lowest VAS score compared to other groups. (**Table 2** and **Figure 2**). There was no significant difference between these three groups in other time points.

Secondary outcomes

In this study, we found no difference in the mean arterial pressure and the heart rate in the first 72 hours after recovery from anesthesia in all three groups (**Figure 3A** and **3B**) which indicates that these three analgesic methods have similar effect in postoperative hemodynamic stability.

Postoperative rehabilitation course showed that PCA group has a better recovery of motion (**Figure 3C** and **3D**). For daily movement test, PCA group patients had a longer distance of maximum mobilization (PCA 13.0±4.0 m vs FNB 8.3±3.5 m and Epidural 8.9±4.2 m) in the first day after surgery, but no significant difference in the Day 2 and Day 3. For range of motion, the PCA group showed a better range of knee joint motion in Day 1 (PCA 84.2±8.1° vs FNB 77.2±8.3° and Epidural 73.3±7.8) and Day 2 (PCA 99.3±9.2° vs FNB 88.2±9.2° and Epidural 83.8±8.3°) after surgery. **Table 3** summarizes different methods of rehabilitation assessment that also shows that the PCA group has a better postoperative rehabilitation in the recovery of motion.

For side effects and complications, the results were showed in **Table 4**. We found that the FNB group suffered least complications compared to Epidural and PCA group (**Figure 4**).

Discussion

In this study we found that FNB analgesia has a better effect on controlling the acute pain in the first 6 hours after TKA surgery. The PCA analgesia is more effective in controlling long term pain 24 hours after the surgery and is more effective in controlling the pain caused by movement. All these three analgesia methods

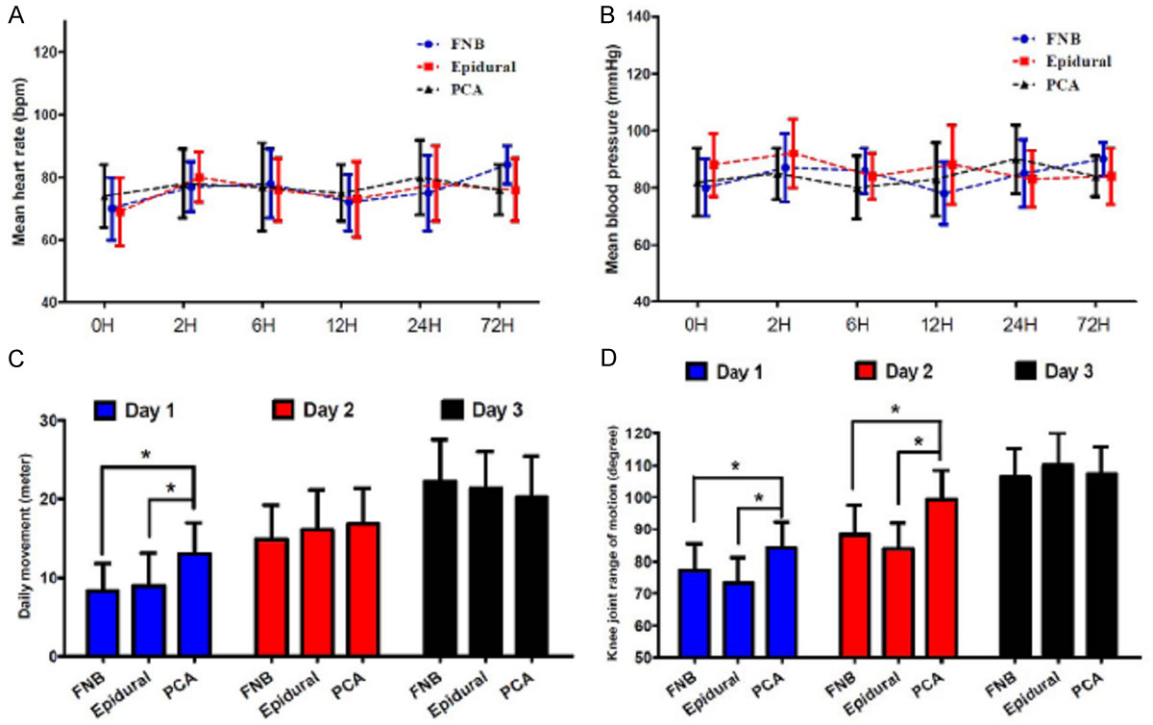

Figure 3. Hemodynamic profile and rehabilitation course comparison between three groups. Presented as mean and SD. A. Heart rate (bpm); B. Mean blood pressure (mmHg); C. Daily mobilization (meter); D. Daily assessment of knee joint range of motion (degree). *Significant statistical differences (P<0.05).

have no difference in postoperative hemodynamic stability. For postoperative rehabilitation, PCA analgesia was confirmed to have a significant advantage in motion rehabilitation in the very first two days after the surgery compared to FNB and epidural analgesia.

There is concordance between our study and that of a meta-analysis combining small trials, that single-injection FNB provided better pain control than PCA after TKA [12]. Sciatic blocks were not included with the FNB in this study for posterior knee pain and might have reduced the effect of continuous FNB. Despite this, we still were able to find significant advantage of FNB and epidural analgesia in pain control in the first 6 hours after surgery compared to PCA.

Theoretically, peripheral nerve block has the advantage of sparing motor control in one leg to allow for early mobilization with crutches. However, it is controversial in the equivalence of pain control with epidural analgesia. Epidural analgesia used to be the "gold standard" of pain control after TKA [13], and some studies have suggested that it is superior to FNB for pain control, especially in the early postoperative hours [14, 15]. While other studies showed superiority of FNB over epidural [16]. In our study, epidural analgesia showed no advantage in both pain control and postoperative rehabilitation compared to FNB. Several studies showed that the systemic side effect after epidural analgesia was higher. Lorenzini et al reported that 68% of patients had nausea or vomiting, 66% had urinary retention, and 58% had pruritus after 24 hours of epidural infusion [17]. And Zaric et al found one or more side effects were present in 87% of patients in the epidural group while only 35% of patients in the FNB groups were affected on the first postoperative day [13]. On the other hand, FNB has been found to reduce the incidence of postoperative delirium [18]. And the use of ultrasound guidance renders the FNB more accurate. No wonder that FNB is now more popular in clinical use.

Similar to a recent study [5], our study showed that FNB was more effective than PCA in pain control after surgery in a short period. We further found that, 24 hours after surgery, PCA

Table 3. Postoperative rehabilitation course

	FNB (n = 28)			Epidural (n = 25)			PCA (n = 29)		
	Day 1	Day 2	Day 3	Day 1	Day 2	Day 3	Day 1	Day 2	Day 3
Number of patients achieved knee joint movement (>90°)	14 (50)	17 (61)	22 (79)	13 (52)	14 (56)	19 (76)	20 (68)	22 (76)	25 (86)
Knee joint range of motion (degree)	77.2 (8.3)	88.2 (9.2)	106.4 (8.8)	73.3 (7.8)	83.8 (8.3)	110.0 (9.9)	84.2 (8.1)	99.3 (9.2)	107.4 (8.3)
Daily movement (meter)	8.3 (3.5)	14.8 (4.4)	22.3 (5.2)	8.9 (4.2)	16.1 (5.0)	21.3 (4.7)	13.0 (4.0)	16.9 (4.4)	20.2 (5.2)

Data presented as number and percent (%) or mean (SD). FNB, femoral nerve block; PCA, patient-controlled analgesia.

Table 4. Incidence of postoperative complications and side effect

Outcomes	FNB (n = 28)	Epidural (n = 25)	PCA (n = 29)
Nausea/Vomiting	1 (3.6)	4 (16.0)	5 (17.2)
Urinary retention	0 (0)	5 (20.0)	3 (10.3)
Hypo/hypertension	1 (3.6)	3 (12.0)	3 (10.3)
Respiratory depression/desaturation	0 (0)	2 (8.0)	2 (6.9)
Headache	0 (0)	3 (12.0)	1 (3.4)

Data presented as number and percent (%). FNB, femoral nerve block; PCA, patient-controlled analgesia.

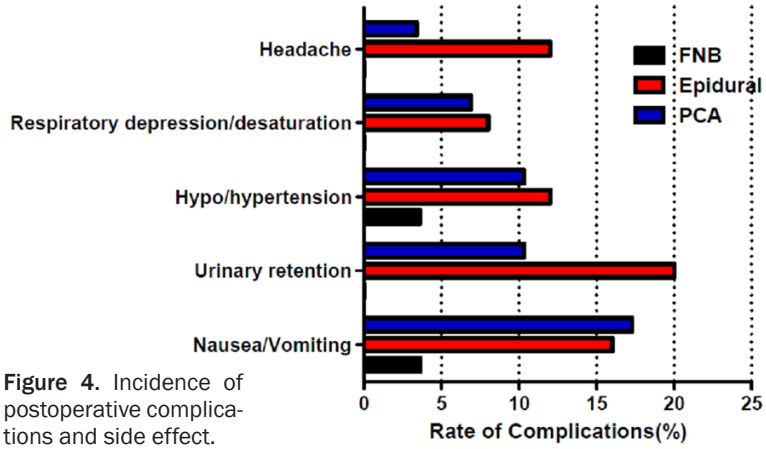

Figure 4. Incidence of postoperative complications and side effect.

showed a better pain control. The reason might be the fading of the local anesthetics in both FNB and epidural analgesia and the PCA analgesia usually lasts for more than 2 days.

The ideal analgesia for TKA should provide enough pain control, less side effects, with minimal effect on motion facilitating early postoperative mobilization and rehabilitation. A clear benefit of epidural and FNB over systemic analgesia (PCA) has been demonstrated in reducing postoperative pain, morphine consumption, and opioid-related adverse effects [19]. In our study, we demonstrate a better analgesia effect of the FNB and epidural block in first 6 hours but a poor effect of postoperative mobilization in first two days. This might caused by the local anesthetic that also blocking the motor nerve in the first two days. Combination of multiple analgesia technique might further studied to solve this problem.

Complications caused by postoperative analgesia after TKA are major concerns for healthcare providers and patients. In our study, we found that the FNB analgesia has the least side effects compared to epidural and PCA group. No headache, no respiratory depression and desaturation, no urinary retention was found in all the patients in FNB group. And a significant lower rate in nausea and vomiting, cardiac complications were showed in FNB group compared to epidural and PCA group. As Patel et al [11] and Chan et al [5] said, a reduction in side effects allows for early ambulation. This allows for early ambulation and participation in physical therapy, improving postoperative rehabilitation and patient satisfaction, while decreasing length of hospital stay and risk for nosocomial infections.

Several limitations were identified during the course of this study. First is the fact that preoperative mental health status was not assessed, which might play an important role in the patient's pain and the results of this study. Second, patients and treating clinicians were not strictly blinded to treatment allocation. To blind patients would have required injection of placebo causing unnecessary discomfort and potential infection risk to the patients. Further, we were unable to standardize the intraoperative anesthetics, type of PCA opioids (morphine/fentanyl) and adjunct analgesia (cox-2 inhibitor/ibuprofen/tramadol/NSAIDs) as we had to follow our center's protocols or clinicians' preferences.

In conclusion, our study found that FNB and epidural analgesia has a better effect on controlling the acute pain particularly in the first 6 hours after TKA surgery. The PCA analgesia is more effective in controlling long term pain 24 hours after the surgery and is more effective in controlling the pain caused by movement. PCA analgesia was confirmed to have a significant advantage in motion rehabilitation in the very first two days after the surgery compared to FNB and epidural analgesia and the patients received FNB analgesia suffered least side effects and complications.

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Disclosure of conflict of interest

None.

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