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The role of ultrasound-guided single-shot femoral and sciatic nerve blocks on pain management after total knee arthroplasty

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ABSTRACT

Background: Peripheral nerve blocks reduce postoperative pain and opioid consumption after total knee arthroplasty (TKA). The aim of this study was to evaluate the effects of single-shot femoral nerve and sciatic nerve blocks on postoperative pain management and opioid consumption after TKA.

Methods: This study included 100 patients who underwent TKA between July 2015 and September 2017. Fifty patients received pre-operative, single-injection, ultrasound-guided femoral and sciatic nerve blocks (Group 1) and 50 did not (Group 2). Multimodal analgesia was otherwise identical, and oxycodone was administered either intravenously or orally if the patients complained of postoperative pain ≥6 on the visual analog scale (VAS). Postoperative VAS scores, opioid consumption, and the fear of future TKA were compared between the groups.

Results: The mean VAS in the first 18 postoperative hours was significantly lower in Group 1 ($P \leq 0.002$). The mean amount of oxycodone taken in the first three postoperative days was significantly lower in Group 1 ($P = 0.001$). Patient fear of future TKA at 14 days postoperatively was significantly lower in Group 1 ($P = 0.027$).

Conclusions: Pre-operative ultrasound-guided, single-shot femoral and sciatic nerve blocks afforded effective pain control in the first 18 h after TKA, and significantly reduced oxycodone consumption in the first three postoperative days.

1. Introduction

Total knee arthroplasty (TKA) is an effective treatment for advanced degenerative knee arthritis, enabling patients to resume activities of daily living and improving quality of life [1,2]. However, TKA can induce severe postoperative pain [3]. Uncontrolled pain slows functional recovery and rehabilitation, and increases the length of hospital stay [4,5]. Such pain also increases the risk of persistent postsurgical pain, which may trigger patient dissatisfaction and compromise quality of life [6–8]. In addition, a fear of pain associated with TKA may render patients reluctant to undergo future TKA [3,6]. Therefore, pain management after TKA is very important [6–8].

Multimodal analgesia has recently been used to control pain after TKA [4,9,10]. Among the various drugs employed for this, nonsteroidal anti-inflammatory drugs (NSAIDs) afford effective analgesia but increase the risk of gastric ulceration/bleeding, renal dysfunction, and cardiovascular disease [11,12]. Opioids are recommended to control severe pain [11,12]; however, opioid

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side effects include addiction, vomiting, urinary retention, itching, lethargy, and constipation, as well as acute side effects such as respiratory depression [11–15]. Opioids may be more dangerous in older patients: [13,15] between 1999 and 2014, >165,000 deaths from opioid overdose and addiction were reported in the United States [15]. Thus, to reduce opioid use after TKA, local infiltration analgesia, peripheral nerve blocks, spinal anesthesia, and epidural anesthesia have been trialed [6,9,16–18].

Peripheral nerve blocks can selectively block particular nerves [19–21]. The efficiency and accuracy of peripheral nerve blocks are enhanced by ultrasound guidance [21,22]. Femoral nerve blocks are most commonly used for postoperative pain control after knee surgery, while sciatic nerve blocks minimize pain in the posterior aspect of the thigh [20,21,23]. In addition, lateral cutaneous femoral nerve and obturator nerve blocks can be added [21]. Recently, an adductor canal nerve block has also effectively been used after TKA [24–26].

Previous studies, when exploring the analgesic effects of peripheral nerve blocks, have evaluated the duration of pain relief, extent of patient-reported pain reduction, and amounts of opioid taken [10,20,23,26–29]. However, in most studies, several kinds of opioids were used in addition to baseline analgesics, such as NSAIDs and acetaminophen [9,27,29]. Therefore, such studies did not precisely evaluate the analgesic effects of peripheral nerve blocks.

This study aimed to evaluate the effect of pre-operative, ultrasound-guided, femoral nerve and sciatic nerve blocks on postoperative pain control in patients undergoing TKA. It was hypothesized that such blocks would effectively reduce early postoperative pain and fear of TKA, and significantly reduce opioid consumption.

2. Materials and methods

2.1. Patient selection

The Institutional Review Board approved this study (approval No. CNUH 2017-10-032). The records of 251 patients who underwent TKA between July 2015 and September 2017 were evaluated in this retrospective work.

Included patients were those who: 1) agreed to the use of their information in this comparative study; 2) were of Kellgren–Lawrence grade III or IV [38]; 3) were undergoing unilateral TKA; 4) were undergoing primary TKA; and 5) had American Society of Anesthesiologists scores ≤3 [39]. Excluded patients were those who: 1) had concurrent disease (rheumatoid arthritis, gout); 2) had a history of trauma affecting the pain score before and after TKA; 3) had an evaluation of pain after TKA that was affected by reoperation to treat surgical site infection or wound dehiscence; 4) experienced side effects of oxycodone and other analgesic agents; 5) were unable to take oral medications (NSAIDs, gabapentin, tramadol, or acetaminophen) because of underlying disease; and 6) did not agree to their information being used.

Of the 251 patients, 113 did not meet the inclusion criteria: 81 had American Society of Anesthesiologists scores ≥4, 20 had rheumatoid arthritis, and 12 underwent revision TKA. The remaining 138 patients met the inclusion criteria and were enrolled; of these, one developed deep infection, 14 required wound revision, and 23 experienced side effects of oxycodone (nausea, vomiting, dizziness, and/or hypotension) — all were excluded. The remaining 100 patients were included. These 100 patients were divided into two groups: those who underwent ultrasound-guided femoral or sciatic nerve block before TKA (Group 1: 50 patients) and those who did not (Group 2: 50 patients). Postoperative pain levels, fear of TKA, and the amounts of administered analgesics were compared between the groups.

2.2. Multimodal analgesia

Multimodal analgesia was given to all patients. Celecoxib (Celebrex 200 mg, Pfizer, USA), tramadol/acetaminophen (Maxnophen 37.5 mg/325 mg, Boryung, Korea), and pregabalin (Lyrica, 75 mg, Pfizer, USA) were administered 2 h before surgery. Patient-controlled analgesia (PCA) commenced immediately after surgery; oxycodone HCl (Oxynorm 60 mg, Mundipharma, USA) was dissolved in 100 ml normal saline. The baseline oxycodone dose was 0.6 mg/h. A bolus dose of 0.6 mg was administered when the patient pressed the PCA button; to prevent excessive opioid administration there was a 10-minute lockout interval between doses. During the lockout interval, only the baseline dose (0.6 mg/h) was administered, regardless of how often the button was pressed. The PCA solution was provided to all patients until day 3 postoperatively. After a postoperative fast of a mean 9.5 h, multimodal analgesia (celecoxib, tramadol/acetaminophen, and pregabalin) was administered twice daily. If the patient complained of pain ≥6 on the visual analog scale (VAS), oral oxycodone HCl/naloxone HCl (Targin 10 mg/five milligrams, Mundipharma, USA) was administered up to four times daily.

2.3. Peripheral nerve block

Patients in Group 1 underwent single-shot peripheral blocks of the femoral and sciatic nerves 30 min prior to induction of general anesthesia in the operating theater. All nerve blocks were created by a single surgeon (CK) with extensive anesthetic experience of over 7000 cases. Fifteen milliliters of 0.75% (w/v) Naropin (ropivacaine HCl, AstraZeneca, Sweden) and 25 ml of normal saline were mixed in a 50-ml syringe to make 40 ml of a 0.29% (w/v) ropivacaine solution. An intravenous extension line with an attached 23-gauge spinal needle was connected to the syringe. Femoral nerve block commenced via confirmation of the anatomical structures of the femoral vein, artery and nerve, using ultrasound (ACCUVIX V-20, Medison, Korea) to explore the femoral triangle distal to the inguinal ligament, with the patient supine and hip and knee at full extension (Figure 1a). After inserting the 23G spinal needle, the position of the needle was confirmed by ultrasound, and the tip was advanced to around the perineural

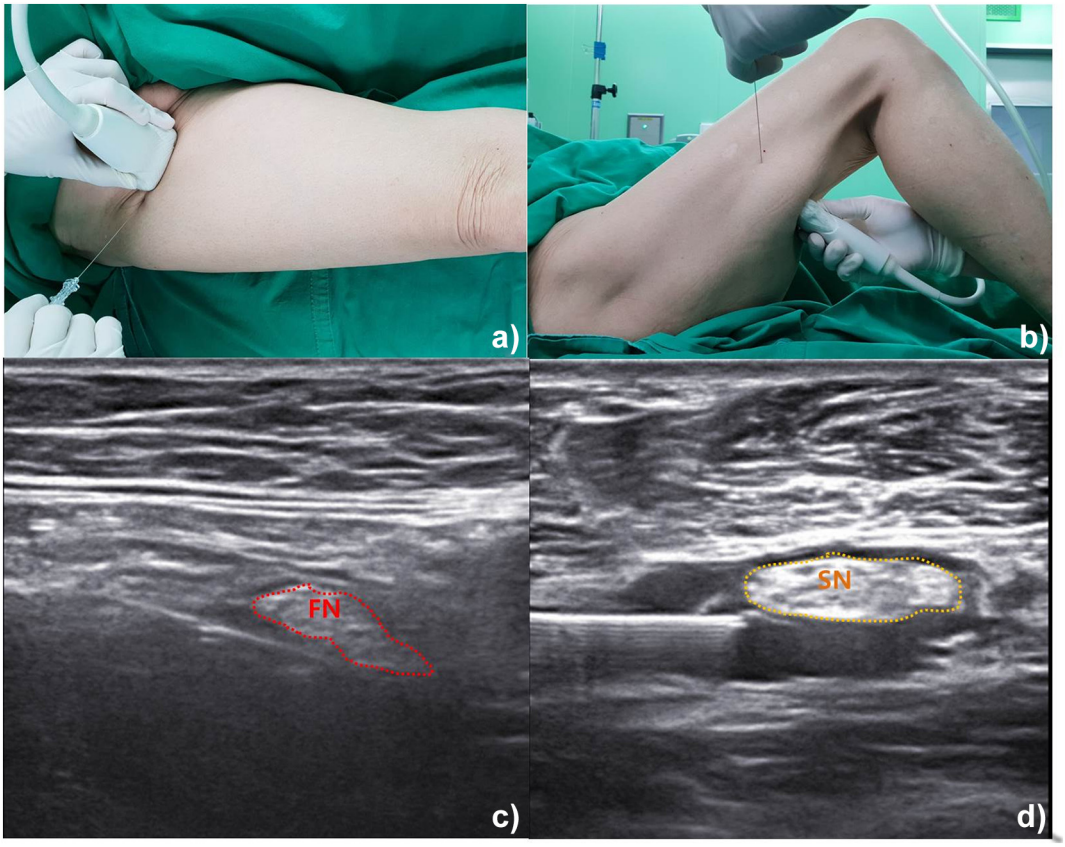

Figure 1. Nerve block: Patient positions and ultrasound images. Nerve block: Patient positions and ultrasound images. a) Femoral nerve block with the patient in the supine position at full hip and knee extension. b) Sciatic nerve block with the patient in the supine position at 90° knee flexion and 45° hip flexion. c) Ultrasonographic image after femoral nerve (FN) block. d) Ultrasonographic image after sciatic nerve (SN) block.

sheath of the femoral nerve; 20 ml of the anesthetic mixture was then injected (Figure 1c). Sciatic nerve blockade was performed with the patient in supine, with 90° knee flexion and 45° hip flexion (Figure 1b). An ultrasound probe was positioned near the posterior thigh and the popliteal artery and vein, and the tibial and peroneal nerves were located. After moving the probe to the proximal part of the thigh, the sciatic nerve was identified. The 23G spinal needle was inserted into the posterior border of the iliotibial band (from the lateral to the medial femoral side). The position was checked by ultrasound, and the injection proceeded around the perineural sheath of the nerve. The anesthetic mixture was distributed in a donut-like manner (Figure 1d). Successful nerve blockade was confirmed by loss of pinprick sensation, using a 23G needle, and compared with the contralateral leg. A sensory loss ≥60% indicated successful nerve blockade. Side effects (motor and sensory weakness) were monitored twice daily to 14 days postoperatively.

2.4. Surgical method

All operations were performed by a single orthopedic surgeon (YMK) with patients under general anesthesia. After placement of a tourniquet inflated to 300 mm Hg, a midline skin incision was created and the medial parapatellar approach was employed. A cemented, unconstrained, posterior-stabilized-type prosthesis (Optetrak Logic, Exactech, USA) was implanted in all patients. Patellar resurfacing was not performed in any case. No periarticular injection affording pain relief was performed. A drainage tube was inserted before joint suturing, and the tourniquet was deflated after skin suturing.

2.5. Postoperative care

Quadriceps, straight leg raising, and ankle pump exercises were encouraged immediately after surgery. A cold pack was applied to reduce pain and edema. All drainage tubes were removed on postoperative day 2. Continuous passive motion began on postoperative day 3 and continued until the knee range of motion was >90°. Ambulation commenced as soon as possible. To prevent deep vein thrombosis, compression stockings were applied for up to 14 days after surgery, and low-molecular-weight heparin (nadroparin; Fraxiparine, GlaxoSmithKline, France) was administered for up to 14 days.

2.6. Assessment of postoperative pain

The VAS [40] pain score was recorded at one, six, 12, 18, and 24 h postoperatively in both groups. The highest daily VAS scores were recorded on days 2–7 and 14. The total amount of oxycodone administered via PCA on postoperative days 1, 2 and 3, and the number of PCA button presses made by patients desiring pain control were recorded. The number of oxycodone HCl/naloxone HCl (10 mg/five milligrams) combination tablets given to patients with VAS scores ≥6, and who requested medication, was also recorded.

2.7. Survey of the fear associated with total knee arthroplasty

On pre-operative day 2, TKA pain-associated fear levels were recorded. On day 14, patients were asked how much they would fear TKA of the other knee. The responses were graded as follows: 0, no fear; 1, a little fear; 2, some fear; 3, moderate fear; 4, high level of fear; and 5, extreme fear.

2.8. Survey of the complications associated with nerve block

Complications after nerve block were surveyed. Complications such as infection and motor and sensory changes of the lower extremity due to nerve injury were evaluated immediately after nerve block, postoperatively, before discharge, and at follow-up in the outpatient clinic.

2.9. Statistical analysis

The Chi-squared test, Student *t*-test, and Mann–Whitney U test were used as appropriate to compare categorical data between groups. Student's *t*-test or the Mann–Whitney U test was used to compare VAS score, oxycodone dose, PCA dose, number of PCA infusion button pushes, and fear of TKA between groups. All statistical analyses were performed using SPSS for Windows software (ver. 23.0; SPSS Inc., Chicago, IL, USA); a P-value <0.05 was considered to reflect significance.

3. Results

There were no significant between-group differences in sex, age, height, weight, body mass index, surgical site, pre-operative VAS score, tourniquet time, operation time, or pre-operative Kellgren–Lawrence grade (Table 1). No patient experienced nerve block side effects such as sensory abnormality or motion problems. The average VAS scores over the first 18 postoperative hours were significantly lower in Group 1 than in Group 2 ($P \leq 0.001$ at one, six and 12 h; $P = 0.002$ at 18 h; Figure 2). The total amount of oxycodone supplied via PCA (Figure 3a) was significantly lower in Group 1 than in Group 2 on the first postoperative day ($P \leq 0.001$); the reverse was true on the next day ($P = 0.035$). On the third day, no significant between-group difference was apparent ($P = 0.0449$).

The number of PCA button presses (Figure 3b) was significantly lower in Group 1 than in Group 2 on the first postoperative day ($P \leq 0.001$). On the second postoperative day, the number of PCA button presses was significantly lower in Group 2 than in Group 1 ($P = 0.001$); on the third day, no significant between-group difference was apparent ($P = 0.014$).

The total amount of oxycodone supplied via PCA was 54.40 mg in Group 1 and 59.88 mg in Group 2 ($P = 0.001$; Table 2). A significant difference was evident in terms of how often patients pushed the PCA button; the mean number of pushes was 18.34 in Group 1 and 40.50 in Group 2 ($P \leq 0.001$; Table 2). Oral oxycodone HCl/naloxone HCl (10 mg/five milligrams) compound

Table 1
Patient demographics.

	Group 1 (n = 50)	Group 2 (n = 50)	*P*
Sex (F/M)	43/7	47/3	0.18[a]
Age (years)	70.74 ± 6.74	69.40 ± 8.10	0.37[b]
Height (cm)	154.11 ± 8.22	151.19 ± 6.11	0.15[c]
Weight (kg)	63.45 ± 12.08	61.68 ± 9.36	0.62[c]
Body mass index (kg/m^2)	26.66 ± 4.34	26.95 ± 3.68	0.72[b]
Operation time (minutes)	160.90 ± 14.30	163.32 ± 16.41	0.36[c]
Tourniquet time (minutes)	119.36 ± 10.79	122.56 ± 12.95	0.11[c]
K-L Grade (3/4)	20/30	16/34	0.40[a]
Pre-operative VAS score	7.92 ± 1.46	7.54 ± 1.31	0.15[c]
Operation site (right/left)	19/31	24/26	0.31[a]

Data are presented as Mean ± standard deviation.
Abbreviations: K-L grade, Kellgren–Lawrence system for classification of knee osteoarthritis; VAS, visual analog scale.
[a] Chi-square test.
[b] Student's *t*-test.
[c] Mann–Whitney U test.

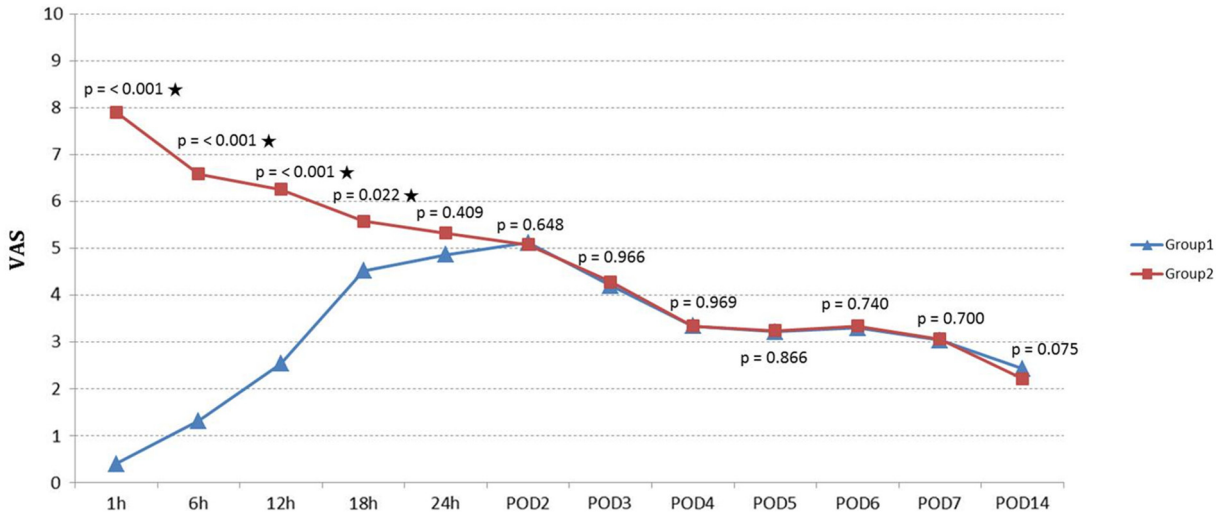

Figure 2. Visual analog scale pain scores over the first 14 postoperative days. ★ Student's *t*-test; statistically significant difference between the groups ($P < 0.05$). Abbreviations: VAS, visual analog scale; POD, postoperative day.

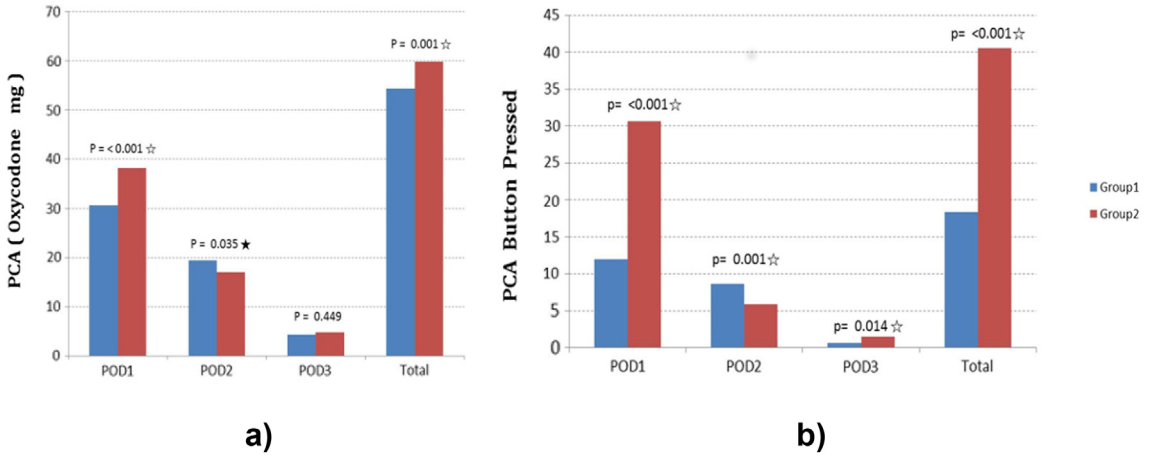

Figure 3. Patient-controlled analgesia (PCA). a) Total oxycodone consumption via intravenous PCA. ★ Student's *t*-test; statistically significant between-group difference ($P < 0.05$). ☆ Mann–Whitney U test; statistically significant between-group difference ($P < 0.05$). b) PCA button presses. ☆ Mann–Whitney U test; statistically significant between-group difference ($P < 0.05$).

consumption (Figure 4) was significantly lower in Group 1 (0.44 ± 0.50 tablets) than in Group 2 (1.16 ± 0.68 tablets) on the first postoperative day ($P \leq 0.001$) but did not significantly differ between the two groups thereafter. Patients in Group 1 required 5.48 mg less PCA-administered oxycodone to the third postoperative day, and 7.2 mg (0.72 tablets × 10 mg) less oral drug on the first postoperative day than patients in Group 2; the mean oxycodone dose reduction was 12.6 mg.

Table 2
Result of oxycodone consumption and patient-controlled analgesia button pressed times.

	Oxycodone amount supplied by PCA (mg)			PCA button pressed times		
	Group 1	Group 2	*P*	Group 1	Group 2	*P*
POD 1	30.56 ± 9.33	38.23 ± 7.41	<0.001[b]	11.96 ± 9.11	30.62 ± 10.13	<0.001[b]
POD 2	19.39 ± 5.62	17.04 ± 5.62	0.035[a]	8.68 ± 6.21	5.92 ± 6.45	0.001[b]
POD 3	4.25 ± 4.35	4.83 ± 4.49	0.449[b]	0.66 ± 1.81	1.54 ± 2.98	0.014[b]
Total	54.40 ± 10.45	59.88 ± 7.66	0.001[b]	18.34 ± 14.57	40.50 ± 13.41	<0.001[b]

Data are presented as mean ± standard deviation.
Abbreviations: POD, postoperative day; PCA, patient-controlled analgesia.
[a] Student's *t*-test.
[b] Mann–Whitney U test.

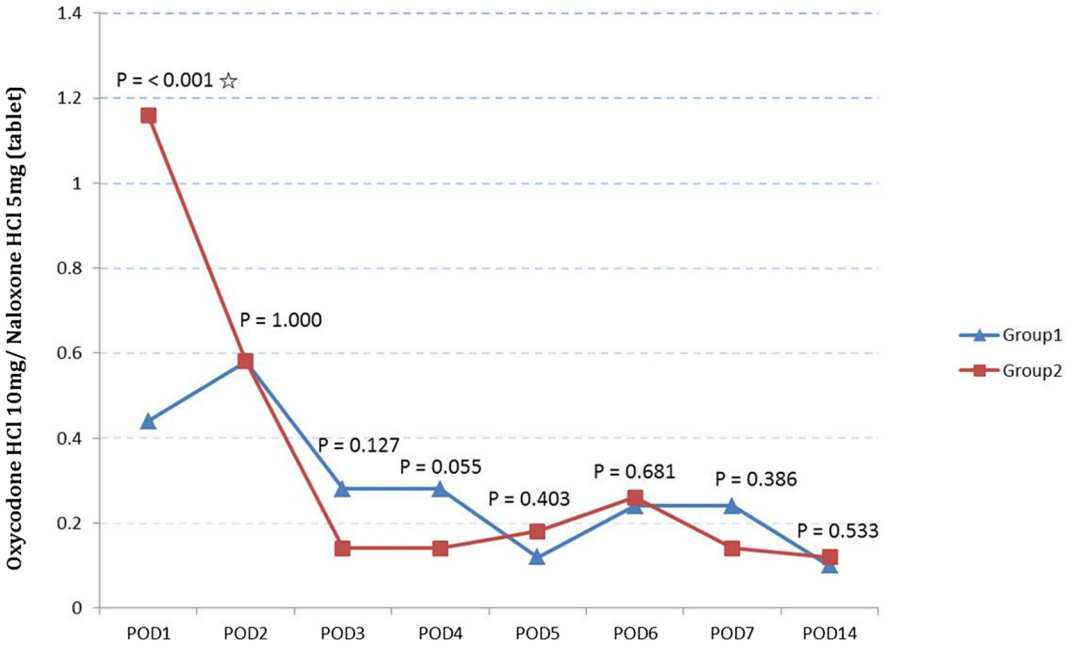

Figure 4. Total oxycodone/naloxone tablet consumption. ☆ Mann–Whitney U test; statistically significant between-group difference ($P < 0.05$). Abbreviations: POD, postoperative day.

Patient fear of TKA (Figure 5) did not differ between the groups pre-operatively ($P = 0.97$) but was significantly lower in Group 1 than in Group 2 patients at 14 days postoperatively ($P = 0.027$).

There were no specific complications related to nerve block in Group A.

4. Discussion

This study employed multimodal analgesia, including peripheral nerve block, to reduce opioid consumption and control pain after TKA. Ultrasound evaluation was used to improve nerve block accuracy and safety. The femoral nerve was blocked because it is the major sensory nerve of the knee; the sciatic nerve was also blocked to target the posterior aspect of knee, improving the pain control effect [19,20,31]. This afforded effective pain control over the first 18 postoperative hours and reduced opioid requirements. Chan et al. reported that single injections of 0.25% (w/v) bupivacaine (20 ml) and continuous femoral nerve blockade with 0.25% (w/v) bupivacaine afforded more effective pain relief over the first 24 h after TKA than intravenous PCA opioids [27].

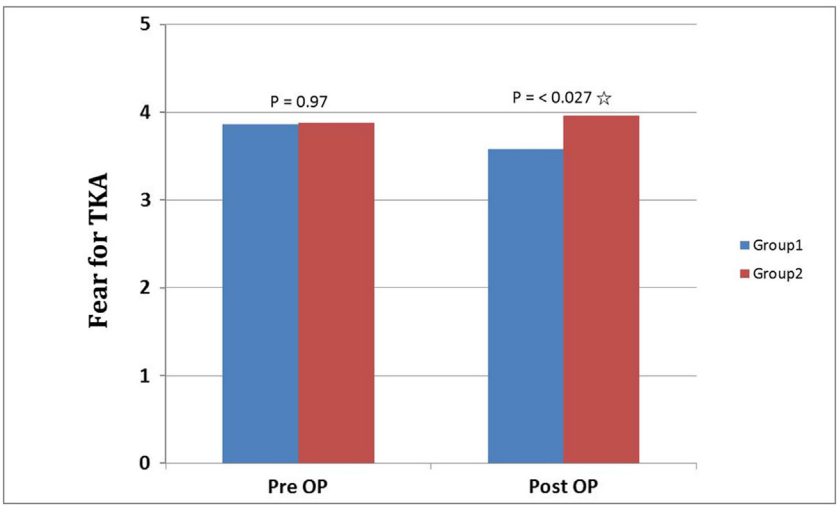

Figure 5. Fear of total knee arthroplasty (TKA) on the pre-operative day and 14 days postoperatively. ☆ Mann–Whitney U test; statistically significant between-group difference ($P < 0.05$).

Continuous femoral blockade was better than single-injection blockade. Hunt et al. found that pre-operative femoral and sciatic nerve blockade with 0.5% (w/v) bupivacaine (10–15 ml) significantly lowered postoperative pain over the first 48 h compared with placebo, and reduced intravenous PCA (morphine) over the first 36 h by 69.9% [20].

The current study used ropivacaine for blockade instead of bupivacaine. This drug is a comparatively long-acting local anesthetic with a good toxicity profile compared with bupivacaine [37]. The current study also used a low concentration of ropivacaine with 0.29% (w/v). It is believed that the lower concentration would be safer and have an equivalent effect to that of drugs with increased concentration [30]. Nerve blocks can cause transient or permanent neurological deficits, neuropathy, neuritis, local infections, hematoma, and edema, attributable to venous or arterial injury; the infection rate is higher on continuous blockade with an infusion catheter versus single blockade [34,35]. The single-shot nerve blockade under ultrasound guidance is free from these complications. Nerves can be accurately identified via ultrasound, improving blockade success and safety [27,34]. In addition, the current study created single blocks to minimize catheter-related infection, and no patient exhibited any side effects.

Recent reports indicate that adductor canal block affects motor function less so than femoral nerve block, but the analgesic effects do not significantly differ [24,25,36]. However, there is no well-established appropriate block infiltration technique for adductor canal; such blocks are thus more difficult than femoral nerve blocks [24,25,36]. Therefore, the current study combined femoral nerve and sciatic nerve blocks. The needle was inserted two to three times, for five minutes in total. Postoperative pain control was satisfactory.

Opioids effectively relieve moderate-to-severe pain, such as that associated with TKA; however, the higher the opioid consumption, the greater the risks of side effects and addiction [11–14,35]. Therefore, using opioids for pain control should be minimized. In a previous study, nerve blocks featured mixtures of two or more opioids (morphine, fentanyl, etc.) combined with additional pain control agents (NSAIDs, ketorolac, diclofenac, etc.), depending on the needs of the patients [9,27,29]. However, the current study only used oxycodone for additional pain control. No other analgesic was given at a level above that prescribed by the multimodal analgesic protocol (celecoxib, tramadol/acetaminophen compound, and pregabalin). Therefore, the opioid-reducing effect of nerve block was able to be accurately evaluated.

Group 1 required significantly less oxycodone (delivered via intravenous PCA) than Group 2 over the first three postoperative days (54.40 vs. 59.88 mg) and significantly less oral oxycodone (0.44 vs. 1.16 tablets) on the first postoperative day. The total number of PCA button presses in Group 1 was more than twice that of Group 2 (18.34 vs. 40.50 times). However, the amounts of oxycodone supplied were not doubled. A 10-minute lockout time was imposed each time the button was pressed. If a lockout time had not been imposed, the delivered opioid levels, by pressing the button, would have been 11 mg (18.34 times × 0.6 mg) in Group 1 and 24.3 mg (40.5 times × 0.6 mg) in Group 2. Thus, it is thought that the number of button presses reflected the patient's immediate response to postoperative pain rather than the total PCA dose delivered. The actual dose was 5.48 mg lower in Group 1 than in Group 2, which was equivalent to an oral dose reduction of 7.71 mg (the potency ratio of intravenous vs. oral oxycodone is 0.7:1 [32,33]. When the reduction in oral oxycodone (7.2 mg) was also considered, the total reduction in oral oxycodone afforded by single-injection nerve blockade was 14.9 mg (about 1.5 tablets). This will be clinically helpful because a lower intake of opioids decreases side effects such as constipation, addiction, and nausea [11–14].

Notably, on the second postoperative day, the total amount of oxycodone administered via PCA was significantly lower in Group 2 than in Group 1, as was the number of PCA button presses. After the nerve block effect waned in Group 1 patients, they required more pain control because of the rebound pain phenomenon [41]. Therefore, on that day, an additional nerve block that does not affect motor control may be appropriate.

The most common reason for resistance to a second TKA is fear of pain [3]. Patients in the current study experienced moderate-to-extreme fear before TKA. Postoperatively, those who received nerve blocks reported significantly less fear of future TKA than others. Thus, for patients who have to decide whether to perform TKA on the other knee, a nerve block can affect the patient's decision to go to surgery.

Limitations of this study included the retrospective nature of the work and selection bias due to the patient's records being retrospectively corrected. It did not examine pre-operative pain, nor pain associated with knee motion, which can vary by rest and exercise status. In addition, it did not compare between-group patient satisfaction in terms of postoperative pain control or satisfaction with the peripheral nerve block per se. Functional outcomes such as walking ability or time to weight-bearing were not assessed; therefore, further studies are needed. The sample size was also small. No adverse effects of nerve blockade were recorded; however, more cases with longer-term follow-up are required.

5. Conclusions

Pre-operative ultrasound-guided nerve block in patients undergoing TKA afforded excellent pain control in the first 18 postoperative hours compared with intravenous opioid or oral medication alone, reducing the consumption of oral opioids by as much as 14.9 mg over the first three postoperative days. Ultrasound-guided nerve blocks are safe and effective when used to control early postoperative pain, and they reduce the fear of later TKA.

Acknowledgments

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