

Comparison of Single-injection and Continuous Femoral Nerve Block after Primary Total Knee Arthroplasty on Postoperative Pain Control and Length of Hospital Stay: A Randomized, Double-blind Study

Suwimon Tangwiwat¹, Arissara Iamaroon¹, Vimolluck Sanansilp¹, Angkana Lurngnateetap¹, Pacharapol Udomkiat², Somsak Areewatana¹, Sutatip Wanchiang¹, Aungsumat Wangdee¹, Chuthamas Asavavallobh²

¹Department of Anesthesiology, Faculty of Medicine Siriraj Hospital, Mahidol University, Thailand

²Department of Orthopaedic Surgery, Faculty of Medicine Siriraj Hospital, Mahidol University, Thailand

Introduction: Effective pain management, including the use of peripheral nerve block (PNB) and multimodal analgesia is important to facilitate and enhance recovery after painful total knee arthroplasty (TKA) surgery.

Objective: This study aimed to compare the analgesic efficacy between single-injection (sFNB) and continuous femoral nerve block (cFNB) in patient undergoing TKA within 48 hours.

Materials and Methods: This prospective, randomized double-blind study was conducted in 56 elective primary TKA. Patients were allocated to receive either sFNB (n=28) or cFNB (n=28). In sFNB received 0.25% levobupivacaine 30 ml for single injection, while cFNB received 0.1% levobupivacaine 30 ml single injection then infusion 0.08% levobupivacaine 4 ml/hr. The primary outcome was morphine consumption within 48 hours after surgery. The secondary outcomes included postoperative numerical pain score (NRS), PNB-related and opioid-related side

effects, patient satisfaction and length of stay (LOS).

Results: Demographic data was not statistically different between the two groups. Mean difference postoperative morphine consumption was significantly lower in group cFNB compared to sFNB at 24 hours (MD 8.15 mg; 95% CI=0.60-15.70, $p<0.05$), and 48 hours (MD 10.33 mg; 95% CI=0.35-20.32, $p<0.05$). There was no statistical difference in the secondary outcomes. Higher rate of quadriceps weakness occurred significantly more in group cFNB than sFNB (48% vs 3.8%; $p<0.05$) in the physiotherapist's documentation while the rate of falls was 3.7% in cFNB.

Conclusion: CFNB displayed better analgesia properties compared to a single-injection FNB after TKA, however, the perineural technique was associated with higher rate of quadriceps muscle weakness and increased risk of falls.

Keywords: Analgesic efficacy, continuous femoral nerve block, quadriceps weakness, single-injection femoral nerve block

วิสัยทัศน์ 2564; 47(4): 337-47. • Thai J Anesthesiol 2021; 47(4): 337-47.

Total knee arthroplasty (TKA) is a postoperative painful surgical procedure. Multiple modalities of pain management including preoperative education, peripheral nerve block (PNB), periarticular infiltration (PAI), intrathecal opioid and multimodal analgesia have been recommended to enhance the recovery after total knee arthroplasty.¹⁻³ Iamaroon A et al. reported in their retrospective study that the incidence of moderate to severe pain was 50% within postoperative 24 hours in

patients who underwent TKA despite multimodal analgesia regimen was implemented. The independent risk factors of inadequate pain management included pre-existing pain before surgery and type of postoperative analgesia. In those patients who had no or mild postoperative pain were associated with applying the following techniques including intrathecal opioid, PNB, PAI and postoperative analgesics ≥ 4 drugs⁴.

Correspondence to: Suwimon Tangwiwat, M.D., E-mail: stangwiwat@gmail.com

Received 2 June 2021, Revised 12 June 2021, Accepted 12 June 2021

The goals after TKA are to facilitate early mobilization with effective pain control, improve joint function, increase patient satisfaction and shorten hospitalization time. Common analgesia technique for TKA include local anesthetic infiltration, single-injection, or continuous nerve block to cover the anterior and posterior innervation of the knees which come from the femoral nerve, obturator nerve and sciatic nerve. Femoral nerve block has shown the effective analgesia and improvement of joint function after TKA⁵ whereas adductor canal block has shown the better benefits compared to femoral nerve block in term of motor weakness.³

A continuous femoral nerve block (cFNB) has been used to extend the duration of analgesic properties as a single injection of the femoral nerve block has the capability to provide analgesia for up to 24 hours.⁶ The perineural catheter technique was associated with lower postoperative opioid consumption within 24 to 48 hours, a lower pain score that was not clinically significant 24 hours after surgery, and a similar pain score at 48 hours after TKA.⁷ The cFNB procedure requires expertise and additional time for the anesthesiologist and is more costly compared to the single-injection technique. A problem linked to TKA in Thailand is lack of adequate pain management after surgery resulting in delayed mobilization. This can affect a patient's suffering and extend the length of hospital stay. The aim of this study was to compare the analgesic efficacy within 48 hours between cFNB and sFNB technique in patients undergoing TKA surgery.

Methods

This randomized, placebo-controlled, double-blind study was conducted to evaluate morphine consumption, pain score at different time points within 48 hours of operation, opioid side effects and nerve block-related adverse events after primary TKA. The ethical approval was granted by the Institution Research Board (IRB) number Si 007/2009. Between February 2009 and April 2010, recruited patients were aged between 18-80 years, had an American Society of Anesthesiologists

physical status ranging from I-III, and were scheduled to receive primary TKA. The exclusion criteria included a patient's refusal, inability to understand the pain assessment tool, inability to use the intravenous patient-controlled analgesia technique (IV PCA), contraindications for spinal anesthesia, inability to receive nerve blocks or a catheter insertion (previous motor weakness, neuropathy, allergy to local anesthetics, coagulopathy, insertion site infection, previous femoral bypass graft surgery), chronic opioid usage, cognitive dysfunction, morbid obesity ($\text{BMI} \geq 35 \text{ kg/m}^2$).

Prior to the operation, patients were educated on the PNB technique and its adverse effects, the pain assessment tool (numerical rating score; NRS 0-10, 0 = no pain, 10 = worst pain), and pain management with IV PCA pump. Patients were randomly assigned into two groups (group single-injection FNB; sFNB and group continuous FNB; cFNB) according to a computer-generated list of random numbers. The primary outcome was morphine consumption within 48 hours after surgery. The secondary outcomes included postoperative numerical pain score (NRS), PNB-related and opioid-related side effects, patient satisfaction and length of stay (LOS).

Study intervention

All nerve block procedures were carried out by a regional anesthesiologist or a regional anesthesia resident under supervision by using peripheral nerve stimulator (PNS) (Stimuplex[®] HNS 12; B. Braun, Germany) in a regional block room. The standard monitoring measurements included noninvasive blood pressure, pulse oximetry and electrocardiography (ECG). Midazolam 1-3 mg was administered intravenously as needed. The PNB procedures were performed under sterile conditions in the supine position.

In group sFNB, the femoral artery was palpated at the inguinal crease and the skin was infiltrated with 2 ml of 2% lidocaine at 1cm lateral to the femoral artery pulsation, after which a stimulating needle (Stimuplex[®] A, No.22G, 5 cm, B.Braun, Germany) was inserted just below the inguinal crease in the cephalad direction at an angle of

45°. The PNS was initially set at current 1.5 mA and frequency 2 Hz to localize the femoral nerve. The insulated needle was pushed further until it elicited the quadriceps muscle twitch with the current between 0.2-0.5 mA. Thirty ml of 0.25% levobupivacaine with epinephrine 2.5 ug/ml was administered incrementally after negative aspiration for blood. After the single-injection PNB was finished, a PNB catheter was taped to the skin and covered with the opaque dressing to blind an assessor. The catheter was connected with a disposable infusion pump (Coopdech Syrinjector® 120 ml, Japan) which was filled with water and set the rate at 0 ml/h. The infusion pump was covered in an opaque bag to conceal its content.

In group cFNB, patients received a stimulating femoral nerve catheter insertion through the Tuohy needle (StimuLong Plus plexus catheter set, Pajunk®, Germany). The catheter was inserted and then advanced 2-5 cm beyond the needle's tip, with an acceptable current ranging 0.2-0.5 mA indicating correct position of catheter tip. Three ml of 2% lidocaine with epinephrine 5 ug/ml was then bolused through the catheter to rule out intravenous placement, followed by 30 ml of 0.1% levobupivacaine in incremental injection. Sensory cutaneous nerve block area after single bolus both sFNB and cFNB groups was tested using cold sensation after 10 minutes FNB. All patients received spinal anesthesia technique for surgical anesthesia at L3-4 or L2-3 in lateral decubitus position with 3 ml of 0.5% isobaric bupivacaine.

Postoperative analgesia was administered by continuous infusion in cFNB group through a disposable elastomeric pump (Coopdech Syrinjector® 120 ml, Japan) with a fixed infusion rate of 4 ml/h of 0.08% levobupivacaine until POD3 in the morning in group cFNB. Physiotherapists, surgeons, the research nurse who collected data, and members of the Acute Pain Service were kept blind to the randomized groups. Multimodal analgesia included paracetamol 1,000 mg delivered orally every 6 hours for 3 days and etoricoxib 120 mg delivered orally once daily for 5 days. Intravenous morphine PCA with 2 mg bolus every 5 minutes lockout interval, and maximal limit 30 mg in 4 hours were

prescribed for rescue pain. Treatment for postoperative nausea and vomiting included ondansetron 8 mg IV, prescribed as needed every 8 hours.

All patients were evaluated pain score using NRS post-operation at 4,8,12,16,20,24,36,48 hours by ward nurses. The NRS before and during physical therapy ranging from POD1-5 was assessed once daily by physiotherapists. One of the research nurses included an Acute Pain Service nurse or anesthetist nurse who visited patients once daily or as needed to collect the data starting from POD0 in the evening until POD3 in the morning. The nurse monitored for the following factors: morphine requirement by IV PCA pump in 4 hour-interval within 48 hours, opioid-related side effects including nausea, vomiting, pruritus, PNB-related adverse events include motor weakness, falls, local anesthetic systemic toxicity (LAST), potential nerve injury by the symptoms of persistent impairment of sensory or motor blockades and patient satisfaction. In case a patient had significant motor weakness but pain was manageable, the volume of infusion was halved by another unblinded research nurse. The patient followed the physiotherapy protocol by being mobilized out of the bed under the direction of a physiotherapist on first postoperative day (POD1) and walked in a room on POD2. Range-of-motion (ROM) exercises were encouraged as much as possible during hospital stay. Before being discharged, home program exercises including ambulate training, ROM and strengthening exercise were taught to all patients. Patients who were discharged had to be able to ambulate with a walker ≥ 10 meters, climb up and down stairs under supervision, flex their knee at least 90 degrees (active/passive), not require intravenous pain medication for at least 12 hours, and have no signs of surgical site infection.

Statistical analysis: All analysis were performed with PASW Statistics (SPSS) 18.0 (SPSS Inc., Chicago, IL., USA). Patients' demographic data was presented by mean with standard deviation (SD), median with interquartile range for continuous data or frequency for categorical data. The independent t-test, Mann-Whitney

U test, chi-squared test, and Fisher's test were used to compare the demographics data between the two groups. The primary outcome of postoperative morphine requirement within 48 hours was analyzed and differences in means and 95% confidence interval (95% CI) between groups using the independent t-test. The Mann-Whitney U test was used to examine differences in pain score and length of hospital stay. Patient satisfaction and adverse events were analyzed by Fisher's exact test and chi-square test. A *p-value* <0.05 was considered as significant.

Power analysis: Based on a previous study unblinded RCT study by Salinas FV et al, postoperative morphine requirement differed at 24 hours at 40 ± 14 mg and 15 ± 12 mg when comparing single-injection femoral nerve block versus continuous femoral nerve block in a total of 36 patients.⁸ We considered a clinically significant difference in postoperative morphine consumption to be 30%. A total of 50 patients, 25 in each group, was required to detect an effect size of 0.8 in postoperative morphine consumption between the two experimental groups with a power of 80% using a two-sided $p = 0.05$ level test. Allowing room for approximately 10% patient dropout, we enrolled 27 patients per group or a total of 54 patients.

Results

A total of 70 patients were recruited in this study. Fourteen patients were excluded. The remaining 56 patients were randomized to receive either sFNB ($n=28$) or cFNB ($n=28$). Two patients were dropped out due to inability to perform spinal anesthesia (sFNB=1) and

insertion femoral catheter (cFNB= 1) as shown in Figure 1. The demographic data was shown and it can be seen that there was no statistical significant difference in age, body mass index (BMI), and duration of surgery ($p>0.05$) (Table 1). The patients in group sFNB required statistically reduced postoperative morphine consumption in 4 hour-intervals to 48 hours, mean difference at 24, 48 hours respectively [8.15 mg (95% CI, 0.60, 15.70), 10.33 mg (95% CI, 0.35, 20.32)] (Table 2). There was no statistical difference in the pain scores at rest, during movement (Figure 2), during physiotherapy (Figure 3), opioid-related side effects, patient satisfaction, length of hospital stay, incidence of quadriceps weakness and falls (Table 3). The incidence of nausea (50% vs 27.3%, $p=0.140$) and vomiting (44.4% vs 22.7%, $p=0.145$) in group sFNB was higher than that of group cFNB in POD0 evening, respectively. However, it was not different significantly. One patient in group cFNB fell while walking from the hospital bed to bathroom with the assistance of her family member on POD2 at night. The patient underwent a subsequent washing and reclosure surgery for wound dehiscence and two days delayed hospital discharge with satisfied pain control before and after the falls. One patient in group cFNB had quadriceps weakness that required dose reduction. One patient in group sFNB developed hematoma after a blockade which was diagnosed by ultrasound but required no further treatment. Local anesthetic systemic toxicity (LAST) or postoperative neurological injury did not occur. Common problems noted in group cFNB included leakage of the catheter (22%) and dislodgement (3.7%).

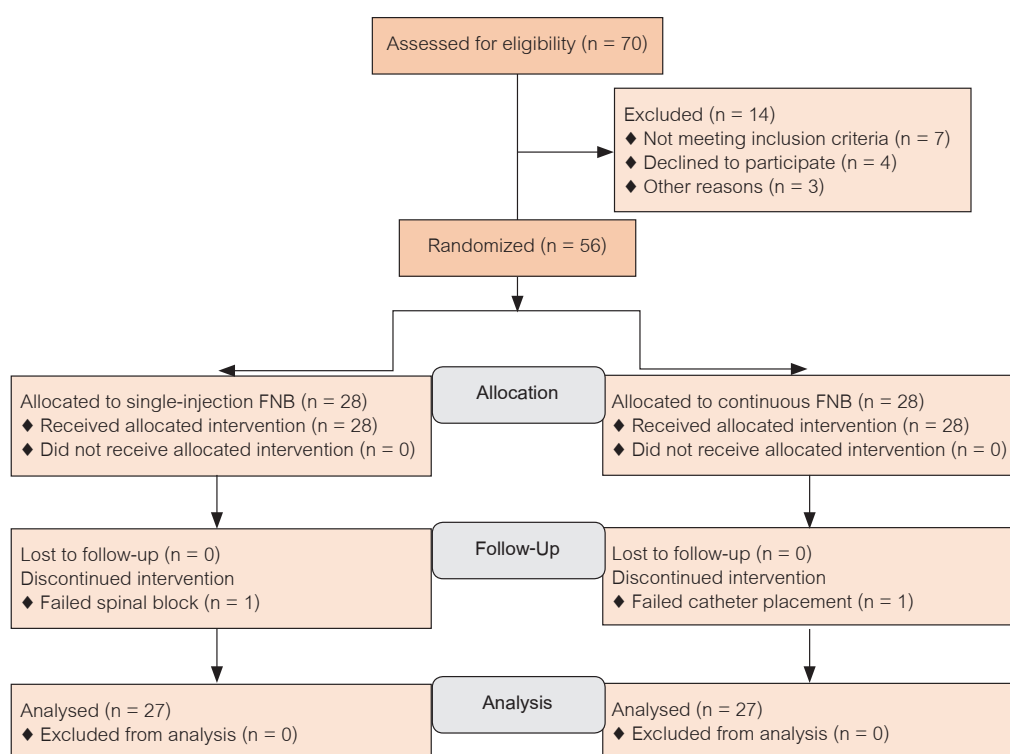


Figure 1 CONSORT flow diagram of the study population (FNB = femoral nerve block)

Table 1 Demographic data

	sFNB (n=27)	cFNB (n=27)	P-value
Age (years)	65.41 ± 8.01	66.15 ± 8.17	0.346
Sex (female/male)	23/4	22/5	0.715
ASA (I, II, III)	1/25/0	2/24/1	0.513
BMI (kg/m ²)	26.03 ± 3.87	26.16 ± 4.48	0.565
Preoperative pain score on movement (NRS)(median, IQR)	4 (3,5)	4 (3,5)	0.273
Duration of surgery (minutes)	86.40 ± 25.66	76.88 ± 18.34	0.134

The data is expressed as mean ± SD. Group sFNB = single-injection femoral nerve block; group cFNB = continuous femoral nerve block. NRS = numerical rating scale 0-10 (0 = no pain, 10 = worst pain).

Table 2 Postoperative cumulative dose of morphine requirement within 48 hours

Postoperative	sFNB (n=27)	cFNB (n=27)	Difference (95% CI)	P-value
4 h	4.96 ± 5.86	2.41 ± 2.84	2.55 (0.03, 5.08)	0.048*
8 h	9.85 ± 9.63	5.30 ± 3.25	4.55 (0.57, 8.54)	0.026*
12 h	12.88 ± 11.05	6.88 ± 4.02	6.00 (1.30, 10.70)	0.014*
16 h	16.04 ± 13.37	8.37 ± 4.82	7.67 (2.10, 13.23)	0.008*
20 h	18.74 ± 15.85	11.00 ± 5.86	7.74 (1.11, 14.37)	0.024*
24 h	21.19 ± 18.21	13.04 ± 6.30	8.15 (0.60, 15.70)	0.035*
36 h	26.19 ± 21.64	17.11 ± 7.55	9.08 (0.09, 18.06)	0.048*
48 h	31.11 ± 23.40	20.78 ± 10.32	10.33 (0.35, 20.32)	0.043*

The data is expressed as mean ± SD, mean difference and 95% confidential interval (95%CI). Group sFNB = single-injection femoral nerve block; group cFNB = continuous femoral nerve block. Postoperative morphine consumption in sFNB versus cFNB at different time points were statistically different within 48 hours ($p < 0.05$). Significant results are marked by an asterisk.

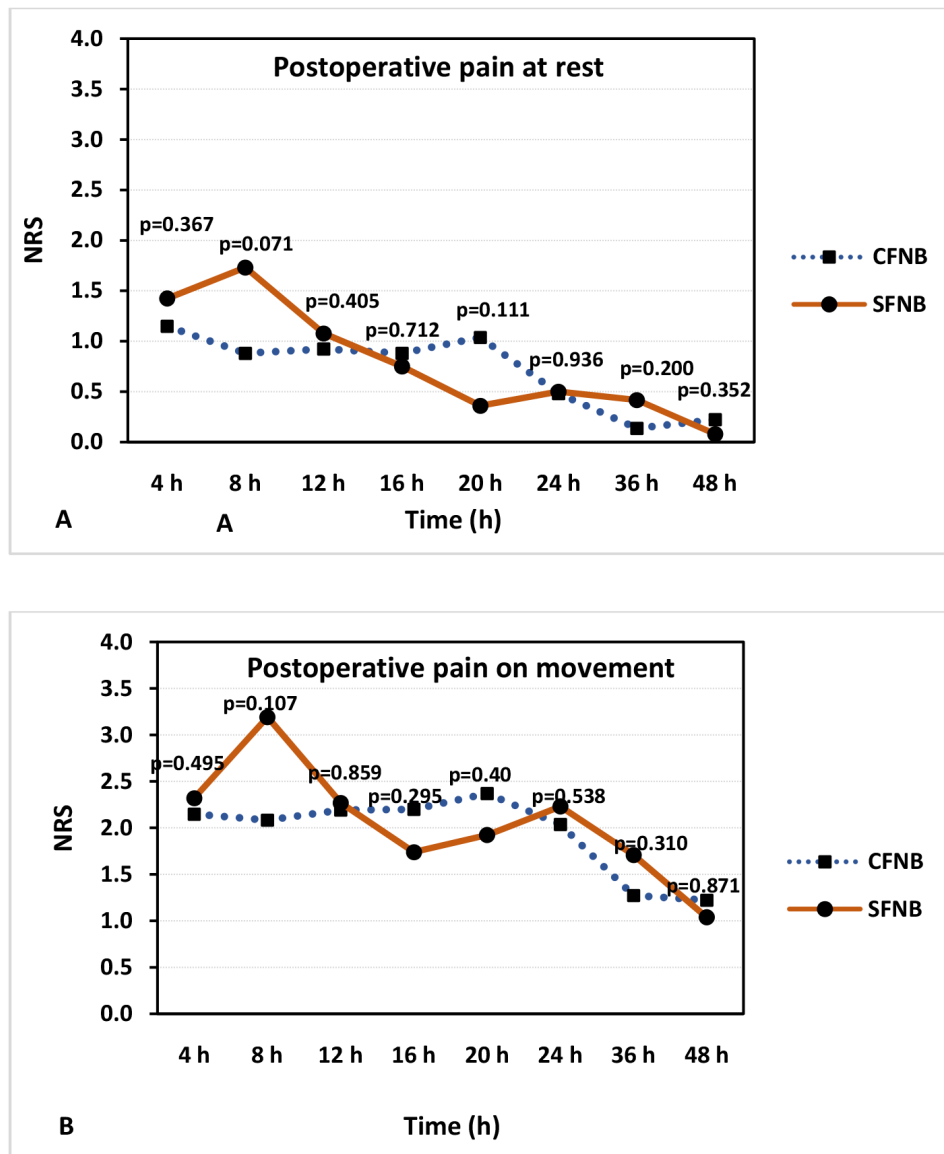


Figure 2 Postoperative pain score (NRS) within 48 hours at rest (A) and during movement (B); Group sFNB = single-injection femoral nerve block; group cFNB = continuous femoral nerve block.

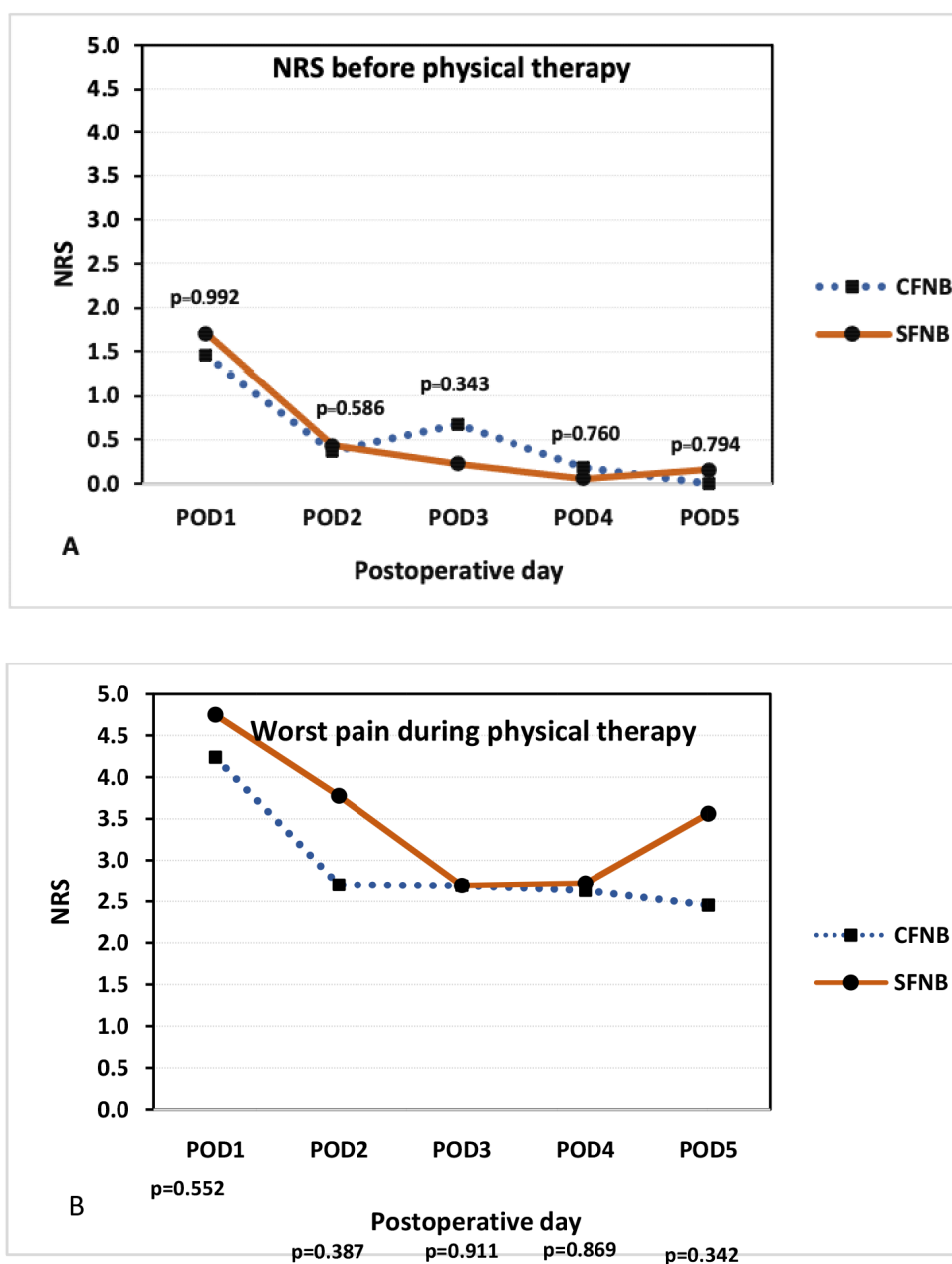


Figure 3 Postoperative pain score (NRS) before (A) and during physical therapy (B); POD1 = postoperative day 1, Group sFNB = single-injection femoral nerve block; group cFNB = continuous femoral nerve block. NRS= numerical rating scale 0-10 (0=no pain, 10=worst pain).

Table 3 Adverse events, opioid-related side effects, patient satisfaction and length of hospital

Postoperative	sFNB (n=27)	cFNB (n=27)	P-value
Falls	0 (0%)	1 (3.7%)	0.313
Documented thigh muscle weakness by physiotherapists			
• POD1 morning	1 (3.8%)	13 (48%)	< 0.001*
• POD2 morning	0 (0%)	2 (7.4%)	0.150
Nausea			
• POD0 evening	9 (50%)	5 (27.3%)	0.140
• POD1 evening	7 (38.9%)	8 (36.4%)	0.870
Vomiting			
• POD0 evening	8 (44.4%)	5 (22.7%)	0.145
• POD1 evening	6 (33.3%)	7 (38.1%)	0.919
Pruritus			
• POD0 evening	1 (5.6%)	0 (0%)	0.450
• POD1 evening	6 (33.3%)	3 (13.6%)	0.253
Patient satisfaction (1-5) at POD3	1 (5.6%)	0 (0%)	0.450
• unsatisfied (1)	1 (4.0%)	0 (0%)	
• Satisfied (4-5)	23 (92.0%)	25 (92.6%)	0.553
Length of hospital stay (days) (median, IQR)	6 (6,7)	6 (6,7)	0.584

Group sFNB = single-injection femoral nerve block; group cFNB = continuous femoral nerve block. IQR = interquartile range 25, 75 percentile), patient satisfaction 1-5 (1 = unsatisfied, 5 = strongly satisfied). Significant results are marked by an asterisk.

Discussion

This prospective RCT investigated the analgesic efficacy of cFNB compared to sFNB regarding postoperative morphine consumption, pain severity, opioid-related side effects within 48 hours and length of hospital stay after total knee arthroplasty. CFNB was significantly more effective in reducing postoperative opioid consumption at 24 and 48 hours than single-injection FNB. The continuous FNB had the tendency to decrease immediate postoperative nausea and vomiting. However, when the single injection and continuous femoral nerve block were combined with postoperative multimodal analgesia, there were no statistical differences regarding postoperative pain severity both at rest and during movement, pain during receiving physical therapy at any time point within 48 hours, opioid-related side effects within 48 hours, length of hospital stay, or patient satisfaction. Yet, an increased risk of weakened quadriceps muscle and patient falls during the postoperative period remains a major concern of the perineural technique.

Multiple studies have shown the analgesic efficacy of FNB after TKA in which analgesia may last up to 12-16 hours⁹ and perineural technique provides better pain control than sFNB because it extends the duration of analgesia.^{8, 10, 11} In a recent systematic review and meta-analysis, patients who underwent total knee arthroplasty treated with cFNB and sFNB were included. The analgesic outcomes of the cFNB group included a decreased VAS pain score at 24 hours after TKA, however, it did not achieve the minimal clinically importance difference. The VAS pain score at 48 hours was also not significantly different.⁷ CFNB was associated with better analgesic properties than sFNB in reducing opioid consumption at 24 hours^{7, 12} and 48 hours after operation.⁷ The other outcomes included a length of hospital stay and incidence of postoperative nausea that were not statistically different.^{7, 12} Patel AH et al. studied retrospectively a national database of 300,000 medical records reporting negative effects of FNB compared to non-FNB patients after TKA. It was found that patients who received FNB were associated with higher risks of falls at both 6 months and 1 year

after TKA, readmissions within 90 days, deep vein thrombosis (DVT), myocardial ischemia (MI), and cerebrovascular disease (CVA) within 30 days of operation. Although the amount of opioids required was less within 6 months postoperative in the FNB group, the cFNB group was associated with higher rates of readmissions, MI and DVT especially in the elderly compare to sFNB. However, the limitation of this retrospective study and the actual postoperative opioid requirement may not be accurate. Furthermore the study group was enrolled mostly older age individuals who had higher rates of pre-existing comorbidities include DM and hypertension. These factors may have been confounding factors to postoperative complications.¹³

Femoral nerve block is associated with an increased incidence of quadriceps muscle weakness and falls. The femoral nerve originates from the posterior divisions of anterior rami of lumbar spinal nerves 2,3,4 and it innervates the anterior thigh muscles and skin at the anteromedial thigh. Its flat cross-sectional anatomy is divided into anterior and posterior branches near the inguinal ligament. The anterior branches give into (1) the motor branch that innervate the sartorius muscle which allows knee flexion and medial rotation of the knee (2) motor branch that innervates the pectineus muscle and (3) sensory cutaneous branches which innervate the anteromedial thigh. The posterior branches give into (1) the sensory saphenous nerve, intermediate cutaneous nerve of thigh, medial cutaneous nerve of thigh and (2) motor branches supplying the quadriceps muscle: vastus medialis, vastus intermedius, vastus lateralis and rectus femoris muscles from medial to lateral side which are important to stand and walk.¹⁴ Femoral nerve block targets the local anesthetic injection site at the femoral nerve trunk near inguinal ligament. It increases the risk of falls and impedes early mobilization. Previous studies presented the incidence of falls related to cFNB between 1.6-7.0%.¹⁵⁻¹⁷ Ilfeld BM et al. reported seven falls in six patients receiving ropivacaine infusions in cPNB after knee and hip arthroplasty versus no falls in those receiving saline ($p=0.013$). The pooled data from 3 RCTs (two cFNB and

one continuous lumbar plexus block) suggested there was a link between cPNB and quadriceps muscle weakness and the risk of falling after knee and hip surgery¹⁶ and even after cFNB discontinuation¹⁷ but not in the sFNB group.¹⁸ Other risk factors included old age (mean age 69 ± 9 years), obesity (33 ± 6 kg/m²) and high comorbidities increasing the risk of falls after TKA. Sixty-seven percent of these cases usually occurred within the first 48 hours after surgery.¹⁸ The results of our study were similar to a previous study¹⁵ in which 48% vs 3.8% and 7.4% vs 0% of patients in the cFNB and sFNB groups showed signs of thigh weakness by the physiotherapist on POD1 and POD2, respectively. The incidence of falls in our study was 3.7% (one female aged 55 years, ASA classification II, BMI 22) and it occurred during walking on POD2 with an indwelling cFNB. The proposed mechanism involved impairment of the quadriceps muscle strength which is important for standing and walking. The factors that potentially minimize the risk of falls include reducing the local anesthetic dose, preoperative education about perineural techniques to surgeons, nurses, physical therapists and patients¹⁹, and choosing the distal location of nerve block such as adductor canal block (ACB)^{20, 21} or local infiltration analgesia (LIA).^{22, 23} In a volunteer study, maximum voluntary isometric contraction of knee extension was preserved with ACB compared with FNB at 30 and 60 minutes and it was noted that FNB substantially decreases quadriceps motor function and increases the risk for falls as measured by psychomotor test.²⁴

This study carried out femoral nerve block under peripheral nerve stimulation, which is a nerve localization method. In our study, vascular punctures or local anesthetic toxicity did not occur. Vascular puncture was reported in 10-15% of patients as complications of femoral nerve block under PNS. Branches of the femoral artery (profunda femoral artery and lateral circumflex femoral artery) were observed to be lying lateral to the femoral artery at femoral crease in 12% of patients.²⁵ Since these smaller arteries and veins at the inguinal crease are not likely to be palpable, there is a theoretical

risk of intravascular needle tip placement and vascular trauma. The ultrasound-guided nerve blocks to assess the vascular relationships may reduce the incidence of vascular punctures.²⁶

The limitations of our study included difficulty in comparing the risk of rare adverse events such as nerve injuries and catheter site infections, and a relatively small sample size and the discontinuity of receiving the physiotherapy on the weekend may affect the postoperative pain intensity.

Conclusion

We conclude that postoperative morphine consumption within 48 hours was significantly reduced in patients who received continuous femoral nerve block when compared to those received a single injection of femoral nerve block after total knee arthroplasty. A major concern of continuous femoral nerve block use is significantly impaired quadriceps muscle strength and increased risk of falls during the postoperative period. However, the pain severity at rest and during physiotherapy, the length of hospital stay, patient satisfaction and opioid-related side effects were similar in both single-injection and continuous femoral nerve block methods with multimodal analgesia after operation.

Acknowledgments

This study was funded by a grant from the Faculty of Medicine, Siriraj Hospital, Mahidol University, Bangkok, Thailand (grant no. R015232030). The authors gratefully thank Nichapat Thongkaew, Department of Anesthesiology for her administrative assistance, Julaporn Pooliam, Division of Clinical Epidemiology, Department of Research and Development, Faculty of Medicine Siriraj Hospital, for her assistance with statistical analysis, and Aditya Rana for English manuscript editing on behalf of the Siriraj Medical Research Centre, Faculty of Medicine Siriraj Hospital.

Conflict of interest: None declared

References

1. Korean Knee Society. Guidelines for the management of postoperative pain after total knee arthroplasty. *Knee Surg Relat Res* 2012;24:201-7.
2. Karlsen AP, Wetterslev M, Hansen SE, Hansen MS, Mathiesen O, Dahl JB. Postoperative pain treatment after total knee arthroplasty: A systematic review. *PLoS One* 2017; 12:e0173107.
3. Rutherford RW, Jennings JM, Dennis DA. Enhancing recovery after total knee arthroplasty. *Orthop Clin North Am* 2017;48:391-400.
4. Iamaron A SA, Tangiwat S, Saetang S, Rungwattanakit P, Thanakiattinwibun C. Moderate -to-severe pain after knee arthroplasty: a retrospective study of incidence and risk factors. *Thai J Anesthesiol* 2020;2:71-9.
5. Paul JE, Arya A, Hurlburt L, et al. Femoral nerve block improves analgesia outcomes after total knee arthroplasty: a meta-analysis of randomized controlled trials. *Anesthesiology* 2010;113:1144-62.
6. Allen HW, Liu SS, Ware PD, Nairn CS, Owens BD. Peripheral nerve blocks improve analgesia after total knee replacement surgery. *Anesth Analg* 1998;87:93-7.
7. Ma HH, Chou TA, Tsai SW, Chen CF, Wu PK, Chen WM. The efficacy of continuous versus single-injection femoral nerve block in total knee arthroplasty: a systematic review and meta-analysis. *BMC Musculoskelet Disord* 2020;21:121.
8. Salinas FV, Liu SS, Mulroy MF. The effect of single-injection femoral nerve block versus continuous femoral nerve block after total knee arthroplasty on hospital length of stay and long-term functional recovery within an established clinical pathway. *Anesth Analg* 2006;102:1234-9.
9. Szczukowski MJ, Jr., Hines JA, Snell JA, Sisca TS. Femoral nerve block for total knee arthroplasty patients: a method to control postoperative pain. *J Arthroplasty* 2004;19:720-5.
10. Cappiello G, Camarda L, Pulito G, et al. Continuous femoral catheter for postoperative analgesia after total knee arthroplasty. *Med Arch* 2020;74:54-7.
11. Albrecht E, Morfey D, Chan V, et al. Single-injection or continuous femoral nerve block for total knee arthroplasty? *Clin Orthop Relat Res* 2014;472:1384-93.
12. Li S, Zhou J, Li X, et al. Analgesic impact of single-shot versus continuous femoral nerve block after total knee arthroplasty: A systematic review and meta-analysis. *Adv Ther* 2020;37:671-85.
13. Patel AH, Ross BJ, Ofa SA, Flick TR, Sanchez FL, Sherman WF. The impact of femoral nerve anesthesia on short-term clinical outcomes and opioid claims after total knee arthroplasty. *Arthroplast Today* 2020;6:1016-21.e9.

14. Gustafson KJ, Pinault GC, Neville JJ, et al. Fascicular anatomy of human femoral nerve: implications for neural prostheses using nerve cuff electrodes. *J Rehabil Res Dev* 2009;46:973-84.
15. Sharma S, Iorio R, Specht LM, Davies-Lepie S, Healy WL. Complications of femoral nerve block for total knee arthroplasty. *Clin Orthop Relat Res* 2010;468:135-40.
16. Ilfeld BM, Duke KB, Donohue MC. The association between lower extremity continuous peripheral nerve blocks and patient falls after knee and hip arthroplasty. *Anesth Analg* 2010;111:1552-4.
17. Turbitt LR, McHardy PG, Casanova M, Shapiro J, Li L, Choi S. Analysis of inpatient falls after total knee arthroplasty in patients with continuous femoral nerve block. *Anesth Analg* 2018;127:224-7.
18. Wasserstein D, Farlinger C, Brull R, Mahomed N, Gandhi R. Advanced age, obesity and continuous femoral nerve blockade are independent risk factors for inpatient falls after primary total knee arthroplasty. *J Arthroplasty* 2013;28:1121-4.
19. Lin X, Zhou Y, Zheng H, et al. Enhanced preoperative education about continuous femoral nerve block with patient-controlled analgesia improves the analgesic effect for patients undergoing total knee arthroplasty and reduces the workload for ward nurses. *BMC Anesthesiol* 2019;19:150.
20. Gadsden JC, Sata S, Bullock WM, Kumar AH, Grant SA, Dooley JR. The relative analgesic value of a femoral nerve block versus adductor canal block following total knee arthroplasty: a randomized, controlled, double-blinded study. *Korean J Anesthesiol* 2020;73:417-24.
21. Zhang Z, Wang Y, Liu Y. Effectiveness of continuous adductor canal block versus continuous femoral nerve block in patients with total knee arthroplasty: A PRISMA guided systematic review and meta-analysis. *Medicine (Baltimore)* 2019;98:e18056.
22. Garg J, Kathuria S, Gautam PL, Luthra N, Gupta S. Comparison of intra-articular analgesia and femoral nerve block for postoperative pain relief in unilateral total knee arthroplasty: A randomized clinical study. *Anesth Essays Res* 2020;14:321-5.
23. Paglia A, Goderecci R, Ciprietti N, Lagorio M, Necozone S, Calvisi V. Pain management after total knee arthroplasty: A prospective randomized study. *J Clin Orthop Trauma* 2020;11:113-7.
24. Kwofie MK, Shastri UD, Gadsden JC, et al. The effects of ultrasound-guided adductor canal block versus femoral nerve block on quadriceps strength and fall risk: a blinded, randomized trial of volunteers. *Reg Anesth Pain Med* 2013;38:321-5.
25. Muhly WT, Orebaugh SL. Ultrasound evaluation of the anatomy of the vessels in relation to the femoral nerve at the femoral crease. *Surg Radiol Anat* 2011;33:491-4.
26. Marhofer P, Schrögender K, Koinig H, Kapral S, Weinstabl C, Mayer N. Ultrasonographic guidance improves sensory block and onset time of three-in-one blocks. *Anesth Analg* 1997;85:854-7.