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A comparison of continuous femoral nerve block combined with sciatic nerve block and epidural analgesia for postoperative pain management after total knee replacement

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Background: Epidural analgesia (EPA) has been used for postoperative pain control in total knee replacement (TKR). However, many patients have suffered various side effects after epidural blockade. Peripheral nerve block (PNB) has been shown to provide effective pain relief after TKR. We compared the benefits of continuous femoral nerve block (FNB) combined with single-injection sciatic nerve block (SNB) with those of EPA for postoperative pain management after TKR.
Methods: Eighty participants undergoing unilateral TKR were randomized to receive either EPA (EPA group) or continuous FNB combined with SNB (PNB group). All patients received general anesthesia for TKR. Ropivacaine 2 mg/ml plus fentanyl 2 μg/ml was administered for EPA. Ropivacaine 2 mg/ml was administered through the femoral nerve catheter. The pain score, side effects (dizziness, sedation, nausea, vomiting, pruritus, hypotension and urinary retention), motor blockade, knee range of motion, and rehabilitation were measured postoperatively. The primary outcome measure was the number of patients experiencing side effects.
Results: The incidence of patients with side effects was 86.8% in the EPA group but only 35.1% in the PNB group ($P < 0.001$). There were no significant differences between the two groups in terms of pain score, motor blockade of the operative limb, knee range of motion, or rehabilitation.
Conclusions: Continuous FNB combined with SNB can be an effective alternative to EPA for postoperative pain management in TKR. **(Anesth Pain Med 2017; 12: 176-182)**

Key Words: Epidural analgesia, Femoral nerve, Knee replacement, Postoperative pain, Sciatic nerve.

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INTRODUCTION

Pain after total knee replacement (TKR) is likely to delay rehabilitation and prolong hospital stays. Epidural infusion of local anesthetics and opioids is commonly performed to provide postoperative analgesia in TKR. However, many patients experience various side effects after epidural blockade, such as nausea, vomiting, urinary retention, pruritus, dizziness or sedation [1,2].

Femoral and sciatic nerve blocks have been shown to be as effective as epidural analgesia for pain relief after TKR [3,4]. Although femoral nerve block is a well-established analgesic regimen after TKR [5], adding sciatic nerve block can provide better pain relief by delivering sufficient analgesia to the posterior region of the operative knee [6]. Additionally, even single-injection sciatic nerve block performed with long acting local anesthetics provides prolonged postoperative analgesia (average 16-26 h, maximum 40 h) [7] and reduces severe pain after TKR [8]. However, it has also been reported that active exercise and walking are difficult in patients undergoing TKR with combined femoral and sciatic nerve block [9], and most adverse events have been found to be similar to those of epidural block [3].

Therefore, in this prospective randomized study, we compared the relative benefits of continuous femoral nerve block with single-injection sciatic nerve block versus those of continuous epidural infusion in terms of postoperative pain management, the incidence of side effects and knee rehabilitation.

MATERIALS AND METHODS

This study was approved by the Institutional Review Board and was registered in a clinical trial registry before recruitment of the first subject. Patients who were scheduled to undergo TKR from March 2014 to February 2016 were invited to participate and provided written informed consent. Eighty participants receiving American Society of Anesthesiologists Physical Status Classification I–II were randomly assigned to either the epidural block group (EPA group) or the continuous femoral nerve block with single sciatic nerve block group (PNB group) for postoperative analgesia, assignment was performed via computer-generated randomization. The exclusion criteria were as follows: allergy to local anesthetics, cognitive impairment, coagulopathy, motor and sensory impairment, patient refusal, infection at the wound site, age younger than 18 years or older than 90 years, BMI over 39, and rheumatoid arthritis. Participants were also excluded when epidural block and peripheral nerve block failed. To standardize the completion time of the operation among the participants as much as possible, we performed TKR of participant at the first schedule on the day of surgery.

All participants arrived at the operation room by 8 a.m. In the patients randomized to the EPA group, an epidural catheter (18 G Tuohy needle, Perifix Soft Tip 700 Filter Set, BRAUN, Melsungen, Germany) was placed at the L3-4 or L4-5 interspace using the loss-of-resistance technique. Six to ten milliliters of 0.75% ropivacaine was administered to reach the T10 level. In the PNB group, femoral and sciatic nerve blocks were established before general anesthesia. The femoral nerve was identified via ultrasonography below the inguinal crease. An 18-gauge nerve stimulating needle (Stimulex HNS, Braun, Germany) was inserted using the in-plane method. When movement of the patella or contraction of the quadriceps was apparent at a current setting of 0.5 mA, a 20 ml bolus of 0.2% ropivacaine with 1 : 200,000 epinephrine was injected, and a 20-gauge catheter was then inserted 3 cm past the needle [10]. The sciatic nerve was identified at a level before it branched into the tibial and peroneal nerves in the mid-thigh using ultrasonography. A nerve stimulating needle was inserted via the in-plane method. When dorsiflexion or plantar flexion of the ankle was apparent at a current setting of 0.5 mA, 20 ml of 0.2% ropivacaine and 1 : 200,000 epinephrine were administered [11]. No indwelling catheter was inserted for the sciatic nerve block. Peripheral nerve blocks were verified using the pinprick method. One experienced anesthesiologist performed epidural analgesia and peripheral nerve block. After the completion of epidural or peripheral nerve block, general anesthesia was induced with 1–1.5 mg/kg of propofol and 2–3 volume% of sevoflurane with a continuous infusion of remifentanil at 0.5–1 μg/kg/min. A laryngeal mask airway (LarySeal, flexicare Medical Ltd., UK) was inserted for ventilation. Blood pressure, electrocardiography, heart rate and oxygen saturation were monitored during surgery and anesthetic agents were adjusted in accordance with changes in vital sign.

In the postoperative care unit (PACU), patient-controlled analgesia (PCA) infuser (Accumate 1000, WooYoung Medical, Korea) was connected to the epidural catheter in the EPA group. Ropivacaine (0.2%) and fentayl (2 μg/ml) were infused at a rate of 5 ml/h. The bolus infusion volume was 2 ml, and the lockout time was set to 15 minutes. For the PNB group, 0.2% ropivacaine was infused through the femoral catheter at a rate of 5 ml/h using a PCA infuser (Accumate 1000, WooYoung Medical, Korea). The lockout time was set to 15 minutes and the PCA bolus was set to 2 ml. In the PACU, patients were instructed in the use of the numerical rating scale (NRS) and the PCA infuser. The patients were instructed to press the PCA button for a bolus injection if their self-reported pain score exceeded 4 at rest. If pain did not subside after the bolus injection, an intravenous painkiller was administered. Fifteen mg of ketorolac was injected every 8 hours for 2 days. If the pain did not subside with ketorolac, fentanyl 1 μg/kg was injected intravenously with the dose limited to 200 μg/day. The local analgesic infusion continued until 72 hours after surgery.

Both the epidural and femoral catheter insertion sites were hidden with a hospital gown before measurements were performed, and an orthopedist blinded to the group assignment of each patient evaluated the patients. Postoperative pain was measured using the NRS (0 = no pain, 10 = worst pain imaginable). The NRS score was recorded upon arriving in the PACU, at 4 hours after the end of surgery and at 4 o'clock every afternoon on postoperative days (POD) 1–7. Side effects were checked at the same time. Side effects included dizziness, sedation, nausea, vomiting, pruritus, hypotension and urinary retention. Urinary retention was classified as a bladder volume greater than 400 ml with inability to void spontaneously, and single catheterization was performed. Bladder ultrasonography was undertaken for measuring the bladder volume. Hypotension was defined as greater than 30% decrease from mean arterial pressure just before arrival in the operating room.

Motor blockade of both limbs, the degree of active knee flexion/extension and rehabilitation were measured once a day at 4 p.m. on PODs 1–7. Motor blockade was estimated using a modified Bromage score (0 = no blockade: extension of the limb off the bed; 1 = flexion/extension at the knee and ankle joint; 2 = no flexion/extension at the knee and ankle joint, 3 = complete blockade). The degree of active knee flexion and extension was checked with a goniometer. Rehabilitation was initiated on POD 1. The patients were asked to sit on the side of bed and stand without help on the first day. If they succeeded, they were expected to walk using a walker. An orthopedist determined when the patients were successful in sitting, standing and walking. The criteria for discharge from the hospital included an NRS score below 3 at rest, active knee flexion of more than 80°, leg extension of less than 10°, the ability to walk without help and a surgical wound devoid of discharge and infection. When the discharge criteria were met, the patients were asked to grade their satisfaction with the applied postoperative analgesia using the NRS (0 = good, if required, I will repeat it again, to 10 = bad, I will never repeat it). We also recorded whether additional postoperative analgesics were given to each patient.

The primary outcome measure was the total number of patients with complications. The incidence of side effects in patients with epidural analgesia after TKR has been reported to be 87% [1]. A minimum sample size of 37 patients per group was required to determine a significant difference with a probability of type I error of 0.05 and power of 80% based on the assumption that a 30% reduction in side effects would be clinically significant. Statistical analyses were performed with SPSS 21.0 (IBM Corp., USA). The data are presented as numerical values, the mean (SD), or the median (range) where appropriate. Continuous variables were analyzed with the independent sample t-test. Ordinal and non-normally distributed variables were analyzed via the Mann-Whitney *U*-test. Nominal variables were analyzed using the chi-square test or Fisher's exact test as applicable. $P < 0.05$ was considered statistically significant.

Table 1. Demographic and Clinical Characteristics of the Patients

	EPA group (n = 38)	PNB group (n = 37)	P value
Age	69.45 ± 7.34	69.51 ± 6.89	0.968
Sex (M/F)	28/10	29/8	0.419
Body mass index (kg/m^2)	27.48 ± 3.09	27.79 ± 3.84	0.706
Duration of surgery (min)	105.92 ± 21.68	107.30 ± 24.40	0.797
Tourniquet time (min)	65.53 ± 23.04	72.84 ± 34.29	0.281
Preoperative knee flexion (degree)	113.16 ± 19.19	106.89 ± 13.09	0.103
Preoperative knee extension (degree)	7.76 ± 4.14	9.05 ± 4.38	0.194

Values are expressed as the mean ± SD or number of patients. EPA: epidural analgesia, PNB: peripheral nerve block.

Table 2. Numerical Rating Pain Score Measured at Rest and during Knee Mobilization

	Resting			Flexion			Extension		
	EPA	PNB	P value	EPA	PNB	P value	EPA	PNB	P value
PACU	0 (0,5)	0 (0,3)	0.162						
4 h	0 (0,7)	0 (0,6)	0.342						
POD 1	1 (0,6)	1 (0,7)	0.633	3 (0,10)	4 (0,8)	0.168	2 (0,7)	2 (0,8)	0.656
POD 2	0 (0,7)	0 (0,4)	0.951	3 (0,7)	4 (0,8)	0.195	2 (0,7)	2 (0,6)	0.467
POD 3	0 (0,5)	0 (0,3)	0.658	3 (0,7)	3 (0,8)	0.952	3.5 (0,7)	3 (0,6)	0.688
POD 4	0 (0,5)	0 (0,2)	0.700	3 (0,7)	3 (0,5)	0.867	2.5 (0,6)	4 (0,7)	0.387
POD 5	0 (0,3)	0 (0,2)	0.797	3 (0,9)	2 (0,5)	0.927	2 (0,6)	3 (0,5)	0.324
POD 6	0 (0,2)	0 (0,2)	0.800	2 (0,10)	2 (0,5)	0.710	2.5 (0,6)	3 (0,5)	0.435
POD 7	0 (0,2)	0 (0,2)	0.800	2.5 (0,10)	2 (0,5)	0.872	2.5 (0,6)	3 (0,5)	0.659

Values are expressed as the median (range). EPA: epidural analgesia, PNB: peripheral nerve block, PACU: postoperative care unit, POD: post-operative day.

RESULTS

Of the 80 patients enrolled, 75 completed the trial. There were 38 patients in the EPA group and 37 patients in the PNB group. Five patients were excluded from the study for the following reasons: refusal to provide consent (1 in the EPA group and, 2 in the PNB group) and failure of nerve block (1 in the EPA group, 1 in the PNB group). No statistically significant differences were found between the groups regarding patient demographic profiles or clinical characteristics (Table 1).

There were no significant differences between the EPA and PNB groups in the NRS at rest or knee flexion/extension during the first 7 days postoperatively (Table 2). The total number of patients showing complications was significantly lower in the PNB group than in the EPA group (Table 3). The frequency of dizziness, pruritus and sedation did not differ between the groups. Urinary retention and nausea/vomiting were more common in the EPA group (Table 3). Motor blockade in the operative limb did not differ, whereas the contralateral block was more pronounced during the first three days in the EPA group (Table 4). There was no significant difference regarding going through a rehabilitation program or the degree of knee flexion/extension (Table 5). The time until discharge criteria were met similar and supplementary postoperative analgesia with ketorolac and fentanyl was not significantly different between the two groups (Table 5). The patients in the PNB group felt better about their postoperative pain management than those in the EPA group (Table 5).

Table 3. Incidence of Side Effects

	EPA group (n = 38)	PNB group (n = 37)	P value
No of patients with Cx.	33 (86.8%)	13 (35.1%)	< 0.001
Dizziness	8 (21.1%)	3 (8.1%)	0.113
N/V	12 (31.6%)	3 (8.1%)	0.011
Hypotension	0	0	
Pruritus	0	0	
Urinary retention	28 (73.7%)	9 (24.3%)	< 0.001

Values are expressed as the number of patients (%). EPA: epidural analgesia, PNB: peripheral nerve block, No: number, Cx: complications, N/V: nausea and vomiting.

DISCUSSION

Our results demonstrated that continuous femoral nerve block with single-injection sciatic nerve block showed significantly fewer side effects and provided similar pain relief after TKR when compared with epidural analgesia. Participants with peripheral nerve block had significantly fewer incidences of urinary retention, nausea and vomiting among various side effects.

Although epidural analgesia has been considered the gold standard for pain management after TKR, some studies have shown that many patients suffer various side effects after epidural blockade. Frequent adverse effects include urinary retention, pruritus, hypotension, nausea and vomiting [1-3], and at least one side effects occurs in 58-87% of patients [1,2]. Zaric et al. [1] compared combined continuous femoral-sciatic nerve block with epidural analgesia after TKR. The frequency of side effects was lower in the peripheral nerve block group than in the epidural group. Davies [3] reported that the

Table 4. Bromage Score for Limbs

	Op. limb			Nonop. limb		
	EPA	PNB	P value	EPA	PNB	P value
POD 1	1 (0,3)	1 (0,2)	0.360	1 (0,2)	0 (0,0)	< 0.001
POD 2	1 (0,1)	1 (0,2)	0.758	0 (0,1)	0 (0,0)	< 0.001
POD 3	0 (0,1)	0 (0,1)	0.690	0 (0,1)	0 (0,0)	0.012
POD 4	0 (0,1)	0 (0,1)	0.482	0 (0,0)	0 (0,0)	1.000
POD 5	0 (0,1)	0 (0,0)	0.324	0 (0,0)	0 (0,0)	1.000
POD 6	0 (0,0)	0 (0,0)	1.000	0 (0,0)	0 (0,0)	1.000
POD 7	0 (0,0)	0 (0,0)	1.000	0 (0,0)	0 (0,0)	1.000

Values are expressed as the median (range). Op: operative, Nonop: nonoperative, EPA: epidural analgesia, PNB: peripheral nerve block, PACU: postoperative care unit, POD: post-operative day.

Table 5. Postoperative Recovery and Satisfaction

	EPA (n = 38)	PNB (n = 37)	P value
Sitting at the bedside (day)	1.16 ± 0.37	1.08 ± 0.28	0.311
Standing without help (day)	3.26 ± 1.03	3.41 ± 1.01	0.549
Walking with the walker (day)	4.11 ± 1.20	3.86 ± 1.03	0.357
Discharge time (day)	4.63 ± 1.03	4.35 ± 0.79	0.190
No. of patients medicated analgesics			
Ketolorac	13 (34.2%)	11 (29.7%)	0.677
Fentanyl	2 (5.3%)	3 (8.1%)	0.674
Satisfaction with pain management	8 (1,10)	9 (1,10)	0.006

Values are expressed as the mean ± SD, median (range), or number of patients (%). EPA: epidural analgesia, PNB: peripheral nerve block, d: day, No: number.

observed adverse events were similar when using the two methods; however, urinary retention, which is a common side effect of epidural analgesia, was not included in their analysis. Exaggerated dermatomal spreading of neural blockade and epidural opioids are associated with frequent side effects after epidural blockade [2,12]. In particular, local anesthetic block of S2-4 and epidural opioid can cause urinary retention by interfering with normal voiding after epidural blockade [12]. The addition of opioids to local anesthetics for epidural blockade also causes postoperative nausea and vomiting [2]. In comparison, peripheral nerve block provides a more localized neural blockade. We did not add an opioid to local anesthetics for PNB. Side effects occurred in 86.8% of the patients in the epidural group in our study, whereas only 35.1% of the patients in the femoral and sciatic nerve block group experienced side effects (Table 3). Urinary retention and nausea/vomiting were more common in the EPA group (Table 3). Several other research groups have obtained similar findings and suggested peripheral nerve block an alternative to epidural analgesia for TKR [13,14].

Peripheral nerve block presents the advantages of preserving motor control in one leg for early rehabilitation and fewer side effects than neuraxial analgesia. However, there is controversy regarding whether peripheral nerve block is as effective as epidural analgesia for pain relief after TKR. While Sakai et al. [15] have suggested that continuous femoral nerve block is better pain management method for TKR, other studies have found that epidural analgesia is superior to femoral nerve block for pain control [16,17]. However, these studies did not combine sciatic nerve block with femoral nerve block. The addition of sciatic nerve block can provide better pain relief by reducing posterior knee pain [6]. In our study, we found that continuous femoral nerve block combined with sciatic nerve block was equivalent to epidural analgesia in terms of pain management, and both methods provided excellent pain control at rest and during knee movement (Table 2). In accordance with our findings, previous randomized controlled studies have also shown that the addition of sciatic nerve block to femoral nerve block reduces postoperative pain to a level comparable to epidural analgesia after TKR [3,18]. Sato et al. [19] suggested that single-injection sciatic nerve block shows no benefit due to being too brief to provide analgesia for TKR. However, even single-injection sciatic nerve block with long acting local anesthetics provides prolonged postoperative analgesia (average 16–26 h, maximum 40 h) [7] and more effectively reduces severe pain on the day of surgery than continuous femoral nerve block alone [8]. There were no differences between the single-injection sciatic nerve block and continuous sciatic nerve block groups in terms of the pain score after surgery except on POD 1. The patients in the single-injection sciatic nerve block group exhibited only mild pain on POD 1 (median NRS $<$ 2 and mean visual analogue scale $<$ 30 mm) [8,19]. These pain scores are quite similar to those reported for epidural groups by Zaric et al. [1] and Al-Zahrani et al. [18] during postoperative pain management after TKR. Therefore, the efficacy of analgesia via continuous femoral nerve block combined with single-injection sciatic nerve block is comparable to that of epidural analgesia.

Regarding motor blockade, we found that only the operated lower limb exhibited motor blockade in the PNB group, whereas both limbs were blocked in the EPA group. However, the intensity of motor blockade was not sufficiently high to significantly prolong the duration of rehabilitation or the hospital stay. Using low concentrations of analgesic drugs appears to minimize the influence on motor strength. Zaric et

al. [1] employed the same analgesic concentration and volume (5 ml/h 0.2% ropivacaine) for epidural analgesia and peripheral nerve block after TKR and came to the same conclusion reached in the present study: motor blockade was not strong and did not hinder mobilization at this dose.

One limitation of our study is related to the use of different drugs in the two groups, which increases risk of bias. Specifically, only the epidural technique included fentanyl, which may increase the risk of adverse events such as urinary retention and nausea/vomiting [2,12]. As such, we cannot rule out a significant effect of epidural opioid on postoperative side effects in the epidural group. However, the addition of an opioid to epidural analgesia can provide better pain management [2] and there is no evidence that adding opioids to local anesthetics for peripheral nerve block is effective [20,21]. Therefore, we considered that the use of the same drugs in all patients regardless of the analgesic technique, whether fentanyl is combined with local anesthetics, may be unethical. Previous studies comparing epidural analgesia with peripheral nerve block after TKR also used opioids in epidural infusion only groups [4,18].

In conclusion, this study showed that the two applied techniques were not significantly different in terms of post-operative analgesia and the course of rehabilitation. However, the incidence of postoperative adverse outcomes was lower in the PNB group than in the EPA group. Continuous femoral nerve block combined with sciatic nerve block can be recommended as an effective alternative to epidural analgesia for postoperative pain management in TKR.

REFERENCES

1. Zaric D, Boysen K, Christiansen C, Christiansen J, Stephensen S, Christensen B. A comparison of epidural analgesia with combined continuous femoral-sciatic nerve blocks after total knee replacement. Anesth Analg 2006; 102: 1240-6.
2. Lorenzini C, Moreira LB, Ferreira MB. Efficacy of ropivacaine compared with ropivacaine plus sufentanil for postoperative analgesia after major knee surgery. Anaesthesia 2002; 57: 424-8.
3. Davies AF, Segar EP, Murdoch J, Wright DE, Wilson IH. Epidural infusion or combined femoral and sciatic nerve blocks as perioperative analgesia for knee arthroplasty. Br J Anaesth 2004; 93: 368-74.
4. Barrington MJ, Olive D, Low K, Scott DA, Brittain J, Choong P. Continuous femoral nerve blockade or epidural analgesia after total knee replacement: a prospective randomized controlled trial. Anesth Analg 2005; 101: 1824-9.
5. Paul JE, Arya A, Hurlburt L, Cheng J, Thabane L, Tidy A, 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. Pham Dang C, Gautheron E, Guilley J, Fernandez M, Waast D, Volteau C, et al. The value of adding sciatic block to continuous femoral block for analgesia after total knee replacement. Reg Anesth Pain Med 2005; 30: 128-33.
7. Fournier R, Faust A, Chassot O, Gamulin Z. Levobupivacaine 0.5% provides longer analgesia after sciatic nerve block using the Labat approach than the same dose of ropivacaine in foot and ankle surgery. Anesth Analg 2010; 110: 1486-9.
8. Wegener JT, van Ooij B, van Dijk CN, Hollmann MW, Preckel B, Stevens MF. Value of single-injection or continuous sciatic nerve block in addition to a continuous femoral nerve block in patients undergoing total knee arthroplasty: a prospective, randomized, controlled trial. Reg Anesth Pain Med 2011; 36: 481-8.
9. Morin AM, Kratz CD, Eberhart LH, Dinges G, Heider E, Schwarz N, et al. Postoperative analgesia and functional recovery after total-knee replacement: comparison of a continuous posterior lumbar plexus (psoas compartment) block, a continuous femoral nerve block, and the combination of a continuous femoral and sciatic nerve block. Reg Anesth Pain Med 2005; 30: 434-45.
10. Chan EY, Fransen M, Sathappan S, Chua NH, Chan YH, Chua N. Comparing the analgesia effects of single-injection and continuous femoral nerve blocks with patient controlled analgesia after total knee arthroplasty. J Arthroplasty 2013; 28: 608-13.
11. Hadzic A. Hadzic's peripheral nerve blocks and anatomy for ultrasound-guided regional anesthesia. 2nd ed. New York, McGrawHill. 2012, pp 442-5.
12. Butterworth JF, Mackey DC, Wasnick JD. Clincal anesthesilolgy. 5th ed. New York, McGrawHill. 2013, pp 966-72.
13. Capdevila X, Barthelet Y, Biboulet P, Ryckwaert Y, Rubenovitch J, d'Athis F. Effects of perioperative analgesic technique on the surgical outcome and duration of rehabilitation after major knee surgery. Anesthesiology 1999; 91: 8-15.
14. Chelly JE, Greger J, Gebhard R, Coupe K, Clyburn TA, Buckle R, et al. Continuous femoral blocks improve recovery and outcome of patients undergoing total knee arthroplasty. J Arthroplasty 2001; 16: 436-45.
15. Sakai N, Inoue T, Kunugiza Y, Tomita T, Mashimo T. Continuous femoral versus epidural block for attainment of 120° knee flexion after total knee arthroplasty: a randomized controlled trial. J Arthroplasty 2013; 28: 807-14.
16. Shanthanna H, Huilgol M, Manivackam VK, Maniar A. Comparative study of ultrasound-guided continuous femoral nerve blockade with continuous epidural analgesia for pain relief following total knee replacement. Indian J Anaesth 2012; 56: 270-5.
17. Sundarathiti P, Ruananukul N, Channum T, Kitkunasathean C, Mantay A, Thammasakulsiri J, et al. A comparison of continuous femoral nerve block (CFNB) and continuous epidural infusion (CEI) in postoperative analgesia and knee rehabilitation after total knee arthroplasty (TKA). J Med Assoc Thai 2009; 92: 328-34.

18. Al-Zahrani T, Doais KS, Aljassir F, Alshaygy I, Albishi W, Terkawi AS. Randomized clinical trial of continuous femoral nerve block combined with sciatic nerve block versus epidural analgesia for unilateral total knee arthroplasty. J Arthroplasty 2015; 30: 149-54.
19. Sato K, Adachi T, Shirai N, Naoi N. Continuous versus single-injection sciatic nerve block added to continuous femoral nerve block for analgesia after total knee arthroplasty: a prospective, randomized, double-blind study. Reg Anesth Pain Med 2014; 39: 225-9.
20. Weller RS, Butterworth J. Opioids as local anesthetic adjuvants for peripheral nerve block. Tech Reg Anesth Pain Manag 2004; 8: 123-8.
21. Axelsson K, Gupta A. Local anaesthetic adjuvants: neuraxial versus peripheral nerve block. Curr Opin Anaesthesiol 2009; 22: 649-54.