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Original Article / Özgün Araştırma

Relieving Pain After Arthroscopic Knee Surgery: Ultrasound-Guided Femoral Nerve Block or Adductor Canal Block?

Artroskopik Diz Cerrahisi Sonrasında Ağrının Giderilmesi: Ultrason Eşliğinde Femoral Sinir Bloğu mu, Addüktör Kanal Bloğu mu?

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Abstract / Öz

Objective: To compare the analgesic effects of femoral nerve block (FNB) and adductor canal block (ACB) after arthroscopic knee surgery.

Methods: This was a prospective randomised clinical trial that enrolled 92 patients undergoing arthroscopic knee surgery. Ultrasound-guided FNB or ACB was performed immediately after surgery for pain relief. Visual analogue scale (VAS) scores and modified sedation-agitation scale (SAS) were recorded and analysed immediately following block and at 3, 6, 12 and 24 hours. The satisfaction level was also evaluated using a Likert-based patient questionnaire.

Results: VAS scores decreased to 4.1±0.8 from 5.6±1.2 immediately after any nerve block, and within 3 hours, they continued to decrease to 2.0±0.6 in the FNB group and 3.4±1.0 in the ACB group (P=0.014). More patients in the FNB group were satisfied with the quality of the pain control compared to the ACB group. Additionally, patients in the ACB group required more supplemental analgesia compared to the FNB group.

Conclusion: This study demonstrated that patients with FNB had denser analgesia after arthroscopic knee surgery and had less analgesic requirement compared with ACB. Greater satisfaction scores also reflected superior analgesia in patients receiving FNB.

Keywords: Knee arthroscopy, femoral nerve, saphenous nerve, ultrasound

Amaç: Bu çalışmanın amacı artroskopik diz cerrahisi sonrasında kullanılan femoral sinir bloğu (FSB) ve addüktör kanal bloğunun (AKB) analjezik etkilerini karşılaştırmaktır.

Yöntemler: Bu prospektif randomize klinik çalışmaya artroskopik diz ameliyatı geçiren 92 hasta dahil edildi. Ağrıyı dindirmek amacıyla cerrahiden hemen sonra ultrason eşliğinde FSB veya AKB uygulandı. Bloğun hemen ardından ve 3., 6., 12. ve 24. saatlerde vizüel analog skalası (VAS) ve modifiye sedasyon-ajitasyon skalası (SAS) skorları kaydedildi ve analiz edildi. Aynı zamanda Likert tipi hasta anketi kullanılarak memnuniyet düzeyi de değerlendirildi.

Bulgular: VAS skorları her iki sinir bloğundan hemen sonra 5,6±1,2'den 4,1±0,8'ye düştü ve 3 saat içerisinde FSB grubunda 2,0±0,6'ya ve AKB grubunda 3.4±1.0 değerine kadar düştü (p=0,014). AKB grubu ile kıyaslandığında, ağrı kontrolünün kalitesinden memnuniyet duyma oranı FSB grubunda daha yüksekti. Ek olarak, AKB grubundaki hastalarda ilave analjezi ihtiyacının, FSB grubundaki hastalara göre daha yüksek olduğu görüldü.

Sonuç: Çalışmanın sonucuna göre, artroskopik diz cerrahisi sonrasında FSB daha yoğun analjezi ve AKB ile kıyaslandığında bu hastalarda daha az analjezik gereksinimi görülmüştür. Ayrıca daha yüksek memnuniyet skorları, FSB uygulanan hastalarda daha iyi analjezi sağlandığını göstermiştir.

Anahtar Sözcükler: Diz artroskopisi, femoral sinir, safenöz sinir

Introduction

Knee arthroscopy is a common orthopaedic procedure worldwide (1, 2). Despite its minimally invasive nature compared to the traditional knee surgery, post-arthroscopic pain may be severe, and the patients generally require a significant amount of opioid-based analgesics after such procedures. Several patients experience narcotic-related complications, such as sedation, respiratory depression, nausea, vomiting and constipation following excessive use of opioid analgesics. Peripheral nerve blocks offer effective analgesia and decrease the need for opioids, thereby reducing the complications associated with the use of this class of drug (3-6). Moreover, postoperative pain relief is an important factor in the early ambulation and rehabilitation of patients after knee surgery (5, 7).

The lumbar plexus consists of sensory and motor nerves, which innervates visceral organs in the pelvis and anterior and anterolateral dermatomes of the thigh and the medial dermatome of the lower leg, as well as provides motor control for the quad-

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riceps femoris muscle (8, 9). The femoral nerve is one of the most important nerves of the anterior division group of nerves in the lumbar plexus, which mainly supplies the sensation for the anterior and medial parts of the lower extremities (7, 9). Femoral nerve block (FNB) is a simple technique with a low risk of complications and has a high success rate. This method is appropriate for anterior thigh surgery and pain management after hip and knee surgeries (3, 5, 10). The femoral nerve can be anaesthetised at a number of different locations along its course. The main theoretical advantage of blocking the FNB at the level of the adductor canal compared with the more proximal block at the level of the inguinal ligament is sparing of the motor function of the anterior thigh muscles (4, 5).

The study objective was to compare pain relief achieved using femoral nerve block at the level of the inguinal ligament compared to anaesthetising the femoral nerve at the level of the adductor canal. We hypothesised that the pain relief after knee arthroscopy is comparable in both techniques while the motor function of the quadriceps femoris is preserved with the adductor canal block.

Methods

The protocol and informed consent process were reviewed and approved for its scientific and ethical merit by the institutional review board of the affiliated university. This clinical trial was registered within the Iranian Registry for the Clinical Trials (IRCT2014111219924N1). The study design was a double-blinded randomised clinical trial performed on patients undergoing arthroscopic knee surgery in a major university-affiliated hospital from March 2014 to June 2015.

Inclusion and Exclusion Criteria: All patients within the ages 15-70 years old and with the American Society of Anesthesiology (ASA) physical Status 1 and 2 were screened and enrolled after they signed informed consent to participate in the study. Exclusion criteria consisted of the presence of coagulation abnormalities, body mass index of >35, current use of illicit drugs or prescribed opioids, and pre-existing neuropathic pain over the affected extremity. We also excluded patients with advanced uncontrolled diabetes with glycated haemoglobin (HbA1c) percentage >7%.

Sample size determination, enrolment, and randomisation: The primary outcome variable for this study was the visual analogue scale (VAS) of pain, which is an ordinal data ranging from 0 for no pain to 10 for the worst imaginable pain. The clinical significance was set at the differences of >2 in the scale of 11. A mean difference of 2 for VAS scores with a standard deviation of ±3 and alpha error of 0.05 revealed that a minimum of 36 patients in each group were required to produce a power of 80%. After initial screening for inclusion and exclusion criteria, a total of 92 patients (46 in each group) were enrolled in the study and randomised into two groups using the block randomisation method based on block of 4 (Figure 1).

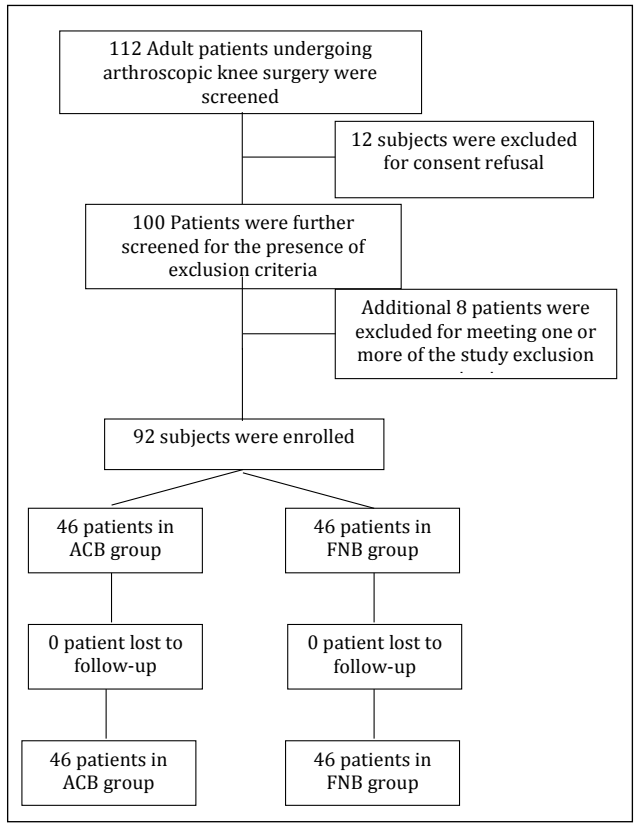

Figure 1. The schematic diagram (PRISMA) flow chart depicting the process for patient inclusion and randomisation and exclusions

All patients were pre-medicated in the holding room with intravenous administration of midazolam hydrochloride (0.05 mg kg^{-1}). Following their transfer to the operating room, general anaesthesia was induced with intravenous administration of propofol (2 mg kg^{-1}) and fentanyl citrate (3 μg kg^{-1}), and endotracheal intubation was facilitated with cis-atracurium (0.2 mg kg^{-1}) for muscle paralysis. Anaesthesia was maintained with intravenous infusion of propofol at a rate of 100 μg kg^{-1} m in^{-1}. Muscle paralysis was maintained with intermittent boluses of cis-atracurium required to maintain 1-2 twitches in train of four-nerve stimulation. The patients then were transferred to the recovery room after extubation. All patients were blocked under ultrasound guidance after surgery in the recovery room. After positioning of the lower extremity in slight external rotation and 30° knee flexion, the thigh was prepped with 2% chlorhexidine in 70% isopropyl alcohol. In the FNB group, the femoral nerve was blocked at the level of the inguinal ligament. In brief, the femoral artery was identified just below the inguinal ligament under ultrasound guidance with a linear probe. The femoral nerve was detected laterally adjacent to the artery using nerve stimulator and subsequently 12 mL of bupivacaine 0.125% was injected along the nerve sheet after negative aspiration. In the adductor canal block (ACB) group, a linear ultrasound probe was placed in the inner thigh. The femoral artery was located at one-third of the inner thigh under the Sartorius muscle. The ultrasound probe was then moved to the caudal direction until the technically the superficial femoral artery or just femoral artery was identified. After identifying the adductor hiatus and canal, the saphenous nerve was visualised as a hyperechoic structure superficial and lateral

to the femoral artery. Similar to the other treatment group, 12 mL of bupivacaine 0.125% was injected along the nerve sheet using nerve stimulator to elicit dysesthesias in the distribution of the saphenous nerve.

After the block, the severity of pain was measured using VAS scale by a member of the study team, who had no prior knowledge of the type of the nerve block, at 0 (in the recovery room), 3, 6, 12 and 24 hours after nerve block. Anxiety and apprehension were evaluated based on modified Ramsey sedation-agitation scale (SAS) from 0 to 5 where 0=Unresponsive; 1= drowsy and sleepy; 2=calm and cooperative patient; 3=apprehension; 4=agitation; and 5=excessive agitation and combative behaviour (11). The level of anxiety and agitation was assessed before and 1 hour after performing nerve block in all patients. Patient satisfaction with the quality of analgesia was assessed using a Likert-based questionnaire given to the patients where a score of 1 indicated strongly dissatisfied and score of 5 indicated strongly satisfied. To standardise supplemental pain control in two groups, parenteral acetaminophen 1000 mg was administered every 6 hours in each group and in the case of no improvement; additional 1000 mg was administered up to a maximum dose of I believe 6 grams in 24 hours exceeds MDD in 24 hours.

The extent of motor block was assessed using a modification made on the Bromage scale as follows: 0: if there was no residual motor weakness in leg muscles; 1: if the patient was unable to flex the hip joint against gravity; 2: if the patient was unable to extend the knee against gravity; and 3: if the patient was unable to flex the hip joint and extend the knee joint against gravity. The presence and the degree of motor blockade were assessed at the same time points as we performed for the presence of pain.

Statistical analysis

Data were collected into a Microsoft Excel worksheet and transferred to a datasheet in the IBM Statistical Package in Social Sciences (IBM SPSS Statistics ver. 23.0, IBM©, Armonk, NY, USA) for further analysis. Categorical data were analysed using chi-square tests, and the results were depicted as the frequencies with related percentages. Numerical variables were analysed using t-tests if they were normally distributed, and the variable where the normality was rejected, the comparisons were made using Mann-Whitney U test. Repeated measures analysis was used to examine the difference in the VAS score between the two groups over different time points. Multivariate linear regression model was constructed to examine the role of various independent variables, such as the involvement of cruciate ligament or age, in VAS score of pain along with the type of the block. Null hypotheses were rejected if p values were less than 0.05.

Results

An equal number of 92 patients were assigned to either the FNB or the ACB group (N=46 in each group). The average age of the subjects was 36.4±15.5 years. There was no difference in age, gender and the ASA class distributions between the two study groups. There was also no difference between the two groups involving either anterior or posterior cruciate ligaments (Table 1).

Table 1. Demographic data of patients in two groups of study

	ACB Group (n=46)	FNB Group (n=46)	Total (n=92)	p
Gender				
Male (%)	32 (69.6%)	29 (63.0%)	61 (66.3%)	0.659
Female (%)	14 (30.4%)	17 (37.0%)	31 (33.7%)	
Age (years)	35.3±15.8	37.5±15.2	36.4±15.5	0.49
ASA Class (%)				
Class 1	30 (65.2%)	35 (76.1%)	65 (70.7%)	0.360
Class 2	16 (34.8%)	11 (23.9%)	27 (29.3%)	
Ligament involvement				
Anterior cruciate	12 (26.1%)	17 (37.0%)	29 (31.5%)	0.370
Posterior cruciate	3 (6.5%)	7 (15.2%)	10 (10.9%)	0.315
None	31 (67.3%)	22 (47.8%)	53 (57.6%)	

ACB: Adductor Canal Block; FNB: Femoral Nerve Block; ASA: American Society of Anesthesiologists

VAS scores prior to the placement of block were similar among the patients assigned to either group (5.2±1.1 in the FNB group vs. 5.3±1.1 in the ACB group). Within 3 hours after placement of the nerve block, patients in the FNB group reported higher quality of pain relief compared to those in the ACB group (Figure 1; p<0.001). This significant difference in the VAS pain score lasted for 12 hours and disappeared thereafter as they were similar at the 24-hour time point (Figure 2). Patients within both groups were relatively comfortable at the 24-hour time point as the VAS pain scores were 2.0±0.6 in the FNB group and 2.3±0.7 in the ACB group. There were no differences in the VAS pain score among the patients in either group according to the involvement of anterior or posterior cruciate ligaments. Prior to the placement of nerve block, VAS pain scores were 5.4±0.8 in patients with no ligament involvement, which were not different from the scores of 5.0±0.8 and 5.1±1.1, with involvement of anterior and posterior ligaments, respectively.

The maximum reported VAS pain score was 7 and minimum was 3 prior to the placement of nerve blocks. From the factors that may have affected the maximum intensity of the postoperative pain prior to the placement of nerve block, we evaluated age, gender and ASA class in addition to the involvement of the knee ligaments. In univariate analyses, women tended to report higher VAS scores compared to men by 0.5±0.2; p=0.014. Younger patients reported lower pain scores because for every 1 year increase in the age the reported maximum VAS scores were 0.1 higher (p=0.001 in linear regression). Additionally, patients with ASA class 2 reported 0.6±0.2 higher VAS scores compared to ASA class 1 patients

(p=0.005). There was no difference in the maximum pain scores according to the ligamental involvement among our patients. In the multivariate analysis, none of these factors was independently associated with higher VAS pain scores (Table 2).

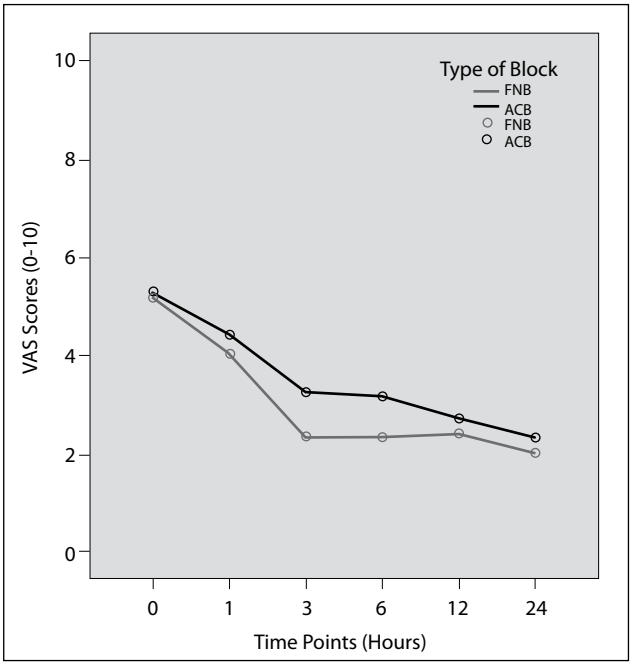

Figure 2. Repeated measures analysis for the difference in VAS scores of pain measured at different time points; time point 0: before nerve block; time point 1: immediately after nerve block; time point 3, 6, 12 and 24 refer to the hours after performing nerve block. FNB: Femoral Nerve Block; ACB: Adductor Canal Block

The majority of the patients (54.8%) were apprehensive prior to performing nerve blocks, while there was no difference in the state of anxiety or agitation between the two groups. Following performing the nerve block, a significant majority of the patients in both groups (70.7%) were cooperative and calm (Table 3). The percentage of calm and cooperative patients was significantly higher in the FNB group compared to the ACB group (90.3% vs. 50.0%; p<0.001). The degree of patient satisfaction with the quality of analgesia for the first 24 hours after surgery was significantly higher among the patients who received FNB compared to those in the ACB group (p<0.001), as 95.7% of the patients were strongly satisfied with the level of pain control (Table 4). Adequate analgesia was also evident in the FNB group as the patients in this group received 4.090±354 mg of acetaminophen within 24 hours after surgery compared to those in the ACB group who received 5.040±1.010 mg of the same medication (p<0.001).

Following the deposition of the bupivacaine solution at the block site, significant weakness of quadriceps femoris was observed in an equal number of patients in either group, as 30 patients in each group were unable to extend their knees against the gravity (Table 5). Weakness of quadriceps femoris more commonly manifested as inability to extend the knee rather than inability to flex the hip joint against the gravity. No patient at any time manifested difficulty in both flexing the hip and extending the knee joints simultaneously. Over

Table 2. Multi-variable analysis for the maximum reported VAS pain scores after arthroscopic knee surgery prior to the placement of the nerve blocks

	Unstandardised		Standardised		
Model	**Coefficients**	**SD**	**Beta**	**t**	**p**
(Constant)	4.444	0.341		13.045	<0.001
Age (years)	0.013	0.008	0222	1.528	0.130
ASA class (II/I)	0.205	0.259	0.108	0.791	0.431
Sex (Female/Male)	0.088	0.235	0.048	0.375	0.709
Ligament Involvement	–0.081	0.141	–0.064	–0.577	0.565

VAS: Visual Analogue Scale; SD: standard deviation; ASA: American Society of Anesthesiologists

Table 3. State of anxiety and distress before and after block

	Before the nerve block			After the nerve block		
	FNB (n=46)	**ACB (n=46)**	**p**	**FNB (n=46)**	**ACB (n=46)**	**p**
Calm and co-operative	16 (34.8%)	11 (23.9%)	0.238	42 (91.3%)	23 (50.0%)	<0.001
Apprehensive	25 (54.3%)	29 (63.0%)		3 (6.5%)	21 (45.7%)	
Agitated	3 (6.5%)	6 (13.0%)		1 (2.2%)	0 (0.0%)	
Angry and furious	2 (4.3%)	0 (0.0%)		0 (0.0%)	2 (4.3%)	

FNB: Femoral Nerve Block; ACB: Adductor Canal Block

Table 4. Level of patient satisfaction by the quality of pain within 24 hours after nerve block. Asterisk denotes a significant difference

	FNB[1] (n=46)	ACB[2] (n=46)	Total (n=92)	p
Strongly dissatisfied	0 (0.0%)	16 (34.8%)	16 (17.4%)	<0.001
Somewhat dissatisfied	0 (0.0%)	3 (6.5%)	3 (3.3%)	
Neutral	1 (2.2%)	4 (8.7%)	5 (5.4%)	
Somewhat satisfied	1 (2.2%)	4 (8.7%)	5 (5.4%)	
Strongly satisfied*	44 (95.7%)	19 (41.3%)	63 (68.5%)	

FNB: Femoral Nerve Block; ACB: Adductor Canal Block

95% of the patients in both groups were free of motor weakness by 12 hours after the placement of nerve block. There was no difference between the FNB and ACB groups in the development of muscle weakness at any time point.

Discussion

The maximum reported pain scores following arthroscopic knee surgery were higher among women and ASA class 2 patients and they linearly correlated to age. Surgery on the anterior or the posterior cruciate ligaments had no effect in the intensity of pain after arthroscopic surgery. None of these factors were independently associated with reporting higher VAS pain scores. Based on the results of this study, pain scores up to 12 hours after the block were significantly lower in the FNB group than that in the ACB group. Postoperative agitation quickly faded after the placement of nerve block in both groups, while there were more calm and cooperative patients after they were anaesthetised with FNB. Additionally, more patients were highly satisfied with their pain control in the FNB group compared to those who received ACB. Patients of the ACB group received additional analgesic treatment more often than those in the FNB group. Another salient point of this study was the fact the block-related weakness of quadriceps muscle was similar between the FNB and ACB.

In a study conducted by Ludwingson and colleagues, the investigating team found that single-injection ACB offered similar pain control and earlier discharge compared to continuous FNB in patients undergoing total knee arthroplasty (12). Findings of our study rejected the hypothesis that ACB provides significantly better analgesia than FNB. In other similar studies, different results in pain scores were obtained. In a study by Memtsoudis et al. (6), no significant difference was found between the pain scores at any time in the ACB compared to the FNB group. In another study, which evaluated pain scores during 45° knee flexion at 0, 30, 60, 90 and 120 minutes after the block, no significant difference was observed between the two groups (13).

In our study, patients in the ACB group received more analgesic medication at all times compared to the patients in the FNB group. Jaeger et al. (14) reported no significant difference between the two groups regarding morphine consumption within 2, 4, 8 and 24 hours after surgery. In another study by Kim et al. (15), no significant difference in supplemental analgesia was observed within 24 and 48 hours after general anaesthesia between the ACB and the FNB groups. In our study, patients in the FNB group were more satisfied with pain control than was the ACB group at all times. In a study by Kim et al. (15), there was no difference in patient satisfaction at 8 hours and 24 hours post anaesthesia between the ACB and the FNB groups. A study by Memtsoudis et al. (6) reported similar findings regarding patient satisfaction. It is important to know that the level of patient satisfaction was directly related to the quality of pain control in all of these studies.

Our study results do not contradict the recently published study by Abdallah et al. (16), which showed that ACB was not inferior to FNB for analgesia following arthroscopic repair of the anterior cruciate ligament while preserving muscle strength. Using the weaker clinical criteria and combining it with preserved anterior muscle strength allowed the authors to reach a conclusion of non-inferiority in providing postoperative pain relief. However, even the authors acknowledged that ACB was theoretically an inferior analgesic peripheral nerve block for arthroscopic knee procedures. In the same study, the patients who received ACB did require on an average more supplemental morphine analgesia.

Li et al. (17) found that after total knee arthroplasty, ACB provided better ambulation ability and faster functional recovery along with a better pain control at rest compared to FNB. In the present study, the strength of thigh muscles mainly quadriceps femoris was assessed using a modified Bromage scale. We found no difference in the strength of this muscle between the ACB and the FNB groups. Similarly, in a study by Memtsoudis et al. (6), motor strength as assessed manually using a dynamometer (Lafayette Manual Muscle Test System) was not significantly different between ACB and FNB. Kim et al. (15) reported that patients in the ACB group had significantly higher dynamometry than patients in the FNB group up to 8 hours after anaesthesia. However, there was no significant difference in the results of dynamometry after 8 hours between these two groups. Although significant weakness of quadriceps femoris can be explained by proximal propagation of the local aesthetic along the nerve sheath, excessive amount of pain can also limit the strength of thigh muscles in individuals who have

Table 5. Motor deficit following nerve block at various time points

	FNB[1] Group (n=46)	ACB[2] Group (n=46)	Total (n=92)	p
1 hour after block				
No motor weakness	0 (0.0%)	2 (4.3%)	2 (2.2%)	0.344
Unable to flex the hip	16 (34.8%)	14 (30.4%)	30 (32.6%)	
Unable to extend the knee	30 (65.2%)	30 (65.2%)	60 (65.2%)	
Both	-	-	-	
3 hours after block				
No motor weakness	12 (26.1%)	18 (39.1%)	30 (32.6%)	0.399
Unable to flex the hip	3 (6.5%)	2 (4.3%)	5 (5.4%)	
Unable to extend the knee	31 (67.4%)	26 (56.5%)	57 (62.0%)	
Both	-	-	-	
6 hours after block				
No motor weakness	28 (60.9%)	26 (56.5%)	54 (58.7%)	0.979
Unable to flex the hip	1 (2.2%)	1 (2.2%)	2 (2.2%)	
Unable to extend the knee	16 (34.8%)	18 (39.1%)	34 (37.0%)	
Both	-	-	-	
12 hours after block				
No motor weakness	39 (84.8%)	42 (91.3%)	81 (88.0%)	0.335
Unable to flex the hip	7 (15.2%)	4 (8.7%)	11 (12.0%)	
Unable to extend the knee	-	-	-	
Both	-	-	-	
24 hours after block				
No motor weakness	45 (97.8%)	46 (100.0%)	91 (98.9%)	0.368
Unable to flex the hip	1 (2.2%)	-	1 (1.1%)	
Unable to extend the knee	-	-	-	
Both	-	-	-	

[1]Femoral Nerve Block
[2]Adductor Canal Block

received ACB. Therefore, despite the anatomic advantage to bypass the motor branches of the femoral nerve, ACB may be associated with quadriceps weakness independent of local anaesthesia-related motor blockade due to inferior analgesia compared to FNB.

Sztain et al. (18) have compared continuous ACB with continuous FNB in a study. They evaluated the effectiveness of the two blocks on discharge criteria and found that a continuous ACB did not decrease the median number of hours to readiness for discharge. Although in the current study, only a single-shot injection was performed, the results from continuous ACB blockade were still not quite superior to FNB in early ambulation and discharge.

One of the limitations of our study is the lack of monitoring for bupivacaine side effects and obtaining the serum levels of this local aesthetic. However, the use of lower concentrations of the local aesthetic agent (0.125%) makes bupivacaine toxicity unlikely. While we recorded the total amount of medication administered within each period, the exact timing of the patient's request for additional dose of parenteral analgesics was not recorded. This study was also limited due to lack of documentation of dynamic pain during movement involving the knee joint, and all reported pain scores were obtained during rest. The process for the assessment of the muscle strength was also very subjective and suffered from inter-observer variability. We recommend methodologies to overcome these limitations in future studies.

Based on the finding of this study, we recommend placing FNB after arthroscopic surgery of the knee joint for its superior analgesia, especially in settings where mild weakness of the thigh

muscles would not interfere with postoperative rehabilitation. Early ambulation is not generally limited with the use of femoral block, and the theoretical advantage of adductor canal block being "muscle sparring" was not observed in our study probably due to its sub-optimal pain control.More comprehensive studies are required to examine overall patient satisfaction including a variety of questions asking for the quality of pain, stress, and anxiety and the level of ambulation for these patients before making single-shot or continuous FNB as the practice of choice for pain management after arthroscopic knee surgery.

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Informed Consent: Written informed consent was obtained from patients who participated in this study.

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