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# Femoral Nerve Block versus Adductor Canal Block for Analgesia after Total Knee Arthroplasty

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Inadequate pain management after total knee arthroplasty (TKA) impedes recovery, increases the risk of postoperative complications, and results in patient dissatisfaction. Although the preemptive use of multimodal measures is currently considered the principle of pain management after TKA, no gold standard pain management protocol has been established. Peripheral nerve blocks have been used as part of a contemporary multimodal approach to pain control after TKA. Femoral nerve block (FNB) has excellent postoperative analgesia and is now a commonly used analgesic modality for TKA pain control. However, FNB leads to quadriceps muscle weakness, which impairs early mobilization and increases the risk of postoperative falls. In this context, emerging evidence suggests that adductor canal block (ACB) facilitates postoperative rehabilitation compared with FNB because it primarily provides a sensory nerve block with sparing of quadriceps strength. However, whether ACB is more appropriate for contemporary pain management after TKA remains controversial. The objective of this study was to review and summarize recent studies regarding practical issues for ACB and comparisons of analgesic efficacy and functional recovery between ACB and FNB in patients who have undergone TKA.

**Keywords: Knee, Arthroplasty, Pain management, Nerve block, Saphenous nerve, Femoral nerve**

## Introduction

Total knee arthroplasty (TKA) involves extensive bone resection and soft tissue manipulation, and patients can experience severe pain during the early postoperative period[1-5]. Appropriate pain management after TKA allows for faster recovery, reduces the risk of postoperative complications, and improves patient satisfaction. Although the preemptive use of multimodal measures is currently accepted as a principle of pain management after TKA, no gold standard pain management protocol has been established. Contemporary pain management regimens following TKA include oral analgesics, periarticular injection, peripheral nerve blocks (PNBs), and intravenous patient-controlled analgesia[4-7]. As PNBs provide effective and synergistic pain relief when used as part of a multimodal regimen, they are considered to be an essential part of the current multimodal pain management protocol following TKA[1,7-9].

Given excellent pain relief and the opioid sparing effect, femoral nerve block (FNB) is commonly used as an analgesic modality and is considered the standard PNB in patients undergoing TKA[10]. However, FNB is followed by a significant decrease in quadriceps muscle strength, resulting in delayed mobilization, which is associated with the potential risk of falling[11-16]. Recently, as the length of stay (LOS) in hospital has been shortened by the performance of TKA on an outpatient basis, a potent analgesia that preserves motor strength during early rehabilitation is becoming increasingly accepted as an essential part of the current perioperative protocol following TKA. In this context, a growing body of evidence supports the use of an adductor canal block

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(ACB) that offers almost pure sensory block with minimal motor involvement as part of a multimodal approach to pain control after TKA[17-32]. However, a limited number of studies have examined the anatomy and infiltration technique of ACB. In addition, studies comparing ACB to FNB in terms of analgesic efficacy and functional recovery in patients undergoing TKA remain limited.

Therefore, this comprehensive review was performed to 1) review current studies regarding the anatomy, infiltration technique, analgesic efficacy, and functional recovery of ACB for pain management following TKA and 2) compare the analgesic efficacy and functional recovery of ACB and FNB in patients who have undergone TKA.

## Methods

This comprehensive review included all types of study design, including randomized controlled trials (RCTs), retrospective comparative clinical trials, systematic reviews, and meta-analyses investigating the anatomy, infiltration technique, analgesic efficacy, and functional recovery of ACB, as well as comparison of analgesic efficacy and functional recovery between ACB and FNB in patients undergoing TKA. English language studies were identified by searching PubMed, MEDLINE, and EMBASE, and subsequently by searching the bibliographies of all relevant retrieved articles. The search included publications that 1) were publicly assessable on the internet; 2) were published in English after 2006; 3) presented the anatomy of the adductor canal; 4) presented the ACB infusion technique; 5) reported analgesic efficacy or functional recovery of ACB; and 6) reported comparative data regarding analgesic efficacy or functional recovery between ACB and FNB, as well as one of the followings: pain level, opioid consumption, frequency of opioid-related side effects, satisfaction, quadriceps strength, mobilization ability, risk of falls, and LOS. The following terms were used for the initial literature search: "adductor canal" OR "adductor canal block" OR "femoral nerve block" OR "knee arthroplasty" OR "knee replacement" OR "total knee arthroplasty" OR "total knee replacement" OR "TKA" OR "TKR". Two authors (CYJ and KMS) of this study reviewed the full texts of all identified articles, and studies that did not report on any of the outcome variables listed above were excluded. The authors discussed any difference of opinion on study inclusion until consensus was achieved. Of the 153 identified articles, 56 duplicates were removed and 62 were excluded because they did not meet the inclusion criteria. Thus, the detailed full articles of 35 studies were reviewed. Of these, 3 were excluded because the study population did not receive TKA. Finally, 32 articles remained in this systematic review (Fig. 1). This study was exempted from Institutional Review Board review because it did not involve human subjects.

## Results

### 1. Practical Issues for ACB

1) Anatomy

The adductor canal, also known as the subsartorial or Hunter canal, is an aponeurotic tunnel that begins at the apex of the femoral triangle and ends at the adductor hiatus, serving as a passageway for the major neurovascular bundle from the femoral triangle to the popliteal fossa (Fig. 2). It is roofed by the vasto-adductor membrane, also known as the anteromedial intermuscular septum or the subsartorial fascia, which is a strong aponeurosis between the adductor muscles and the vastus medialis muscle. It contains the femoral vessels, the saphenous nerve (SN), and the nerve to the vastus medialis muscle (NVM)[33-37]. One recent cadaveric study showed that the SN and NVM were consistently present, whereas branches of the anterior obturator nerve were inconsistently present. In addition, the NVM contributed significantly to innervation of the knee capsule through intramuscular,

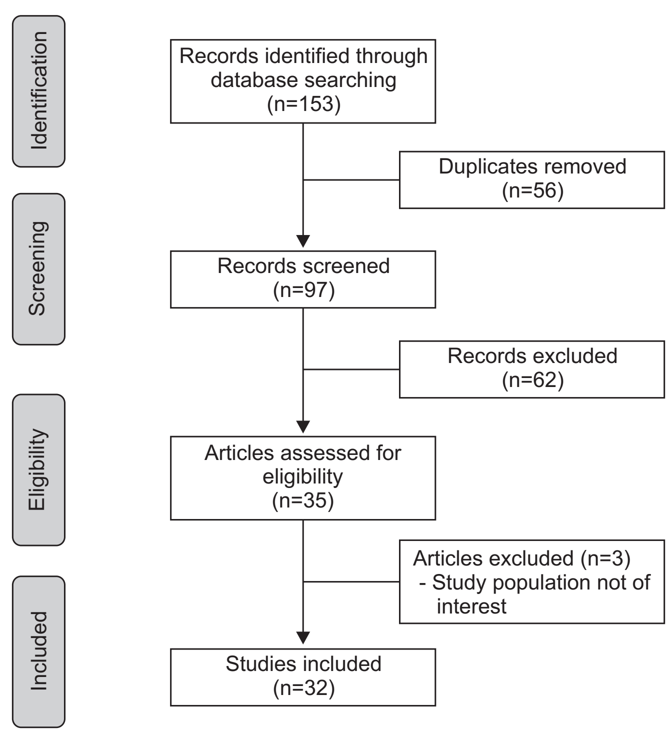


**Fig. 1.** Flowchart of the search strategy.

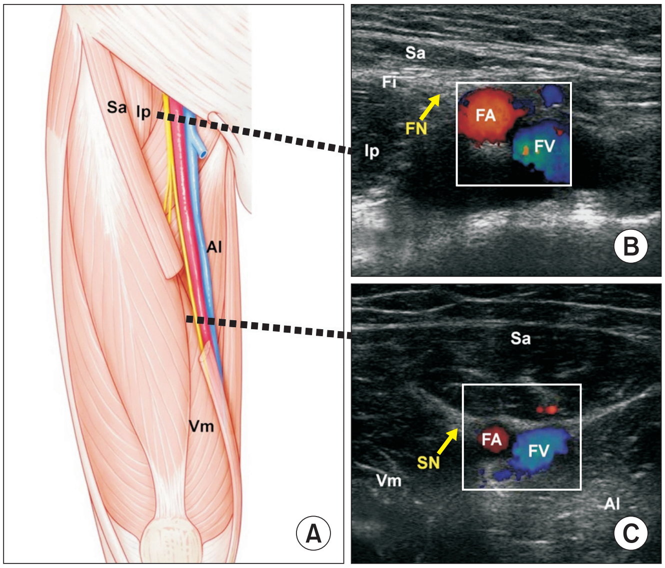


**Fig. 2.** (A) Schematic drawing of the anterior aspect of right thigh. The mid portion of the sartorius muscle was cut to show the inside of the adductor canal. (B) Cross-sectional ultrasonography image at the apex of the femoral triangle. (C) Cross-sectional ultrasonography image of the adductor canal. FN: femoral nerve, FA: femoral artery, FV: femoral vein, SN: saphenous nerve, Sa: sartorius muscle, Ip: iliopsoas muscle, Fi: fascia iliaca, Vm: vatus medialis muscle, Al: adductor longus muscle.

extramuscular, and deep genicular nerves[33].

2) Technique

Recent advances in high quality, portable ultrasound technology have made ultrasound-guided ACB a standard practice in most institutions. A high frequency linear ultrasound transducer was placed transverse to the longitudinal axis of the extremity at the mid-thigh, approximately midway along the distance between the iliac spine and the patella. Next, the femoral artery was found underneath the sartorius muscle with the vein in the short axis. At this level, the SN, which was shown as a hyperechoic structure, was placed lateral to the artery in the adductor canal (Fig. 2). For single shot adductor canal block (SACB), local anesthetics such as 15 mL of 0.25% to 0.5% bupivacaine or 15 mL to 30 mL of 0.2% to 0.5% ropivacaine was infiltrated around the SN[24-27,31,34,38-44]. For continuous adductor canal block (CACB), a 17- or 18-Tuohy cannula was inserted from the lateral side of the transducer, through the sartorius muscle, with the tip placed lateral to the artery. Normal saline or local anesthetics were then injected to expand the canal, and a flexible catheter was inserted through the cannula. Finally, an additional dosage of local anesthetics was injected as per the protocol[19,21-23,28-30,32,35,45].

3) Analgesic efficacy

After performing ACB, complete sensory loss of the medial, anterior, and lateral aspects of the knee extending from the superior pole of the patella to the proximal tibia, with no noticeable quadriceps strength loss, has been reported[20]. In addition, previous RCTs showed that ACB significantly decreased postoperative pain and opioid consumption during the first 24 hours in patients who underwent arthroscopic surgery[46-48]. Moreover, recent RCTs showed that CACB provided excellent analgesia and opioid sparing effects during the first 48 hours in patients who underwent TKA compared with placebo[19,34,35]. On the other hand, CACB with catheter use has been reported to offer superior analgesic effects, but similar functional recovery, compared with SACB[45].

4) Functional recovery

Jaeger et al.[49] reported that ACB preserved quadriceps strength and improved ambulation compared with FNB. In that study, quadriceps strength decreased 8% from baseline following ACB, but 49% following FNB, in 11 randomized healthy volunteers. Another healthy volunteer trial also showed that quadriceps strength and balance scores were similar to baseline following ACB, but decreased significantly following FNB[50]. In addition, patients receiving CACB showed superior quadriceps strength and distance ambulated compared with those receiving placebo following TKA[19]. CACB also resulted in significantly enhanced ambulation ability, as assessed with the Timed Up and Go (TUG) test[34].

## 2. Comparison of Clinical Results between ACB and FNB

In this study, we reviewed 12 clinical trials (Table 1) and 6 meta-analyses (Table 2). Seven of 12 clinical trials examined CACB with catheter use, and five studies examined SACB.

1) Clinical trials

(1) Analgesic efficacy

*Continuous block with catheter*

Analgesic efficacy within 2 postoperative days (PODs) was comparable between ACB and FNB in terms of pain level, opioid consumption, and frequency of opioid-related side effects across five RCTs[21,22,28,29,32] and two retrospective clinical trials[23,30], excluding one RCT that documented better pain relief in the FNB group on POD 0[21]. In addition, one RCT reported similar satisfaction between groups[21]. On the other hand, ACB was reported to offer provider benefits by decreasing catheter-related provider

**Table 1.** Summary of Previous Clinical Trials Comparing Analgesic Efficacy and Functional Recovery of ACB and FNB

| Author | Year | Country | Study design | No. (ACB/FNB) | Anesthesia | ACB≠FNB | ACB=FNB |
|---|---|---|---|---|---|---|---|
| CACB vs. CFNB | | | | | | | |
| Wiesmann et al.[21] | 2016 | Germany | RCT | 42 (21/21) | General | Lower pain level at rest in FNB on POD 0 | Within POD 3, pain level after POD 1, Opioid consumption, satisfaction, Q strength, TUG results, cumulated ambulation score, and mobilization score |
| Elkassabany et al.[22] | 2016 | USA | RCT | 62 (31/31) | Spinal or general | Higher Q strength in ACB on POD 1 | Within POD 2, pain level and opioid consumption, risk of falls, TUG results, ambulation distance, and Q strength on POD 2 |
| Rasmussen et al.[23] | 2015 | USA | Retrospective CCT | 45 (23/22) | General | Greater ambulation distance in ACB within POD 2<br>Fewer provider intervention in ACB (workload↓) | Opioid consumption within POD 2 |
| Zhang et al.[28] | 2014 | China | RCT | 60 (30/30) | cSEA | Higher Q strength in ACB within POD 2 | Pain level at rest or motion within POD 2 and complementary analgesic doses or related side effect |
| Shah and Jain[29] | 2014 | India | RCT | 98 (48/50) | Spinal | Superior TUG, 10-m walk, and 30 sec chair test results and shorter time for active SLR, quad stick ambulation, and staircase competency in ACB | Pain level and rescue analgesia within POD 2, and maximal flexion at discharge |
| Mudumbai et al.[30] | 2014 | USA | Retrospective CCT | 168 (66/102) | General | Greater ambulation distance in ACB on POD 1 | Pain level, opioid consumption within POD 2, LOS, and fall episode |
| Jaeger et al.[32] | 2013 | Denmark | RCT | 48 (22/26) | Spinal | Higher Q strength in ACB on POD 1 | Pain level, opioid consumption and its related side effect, adductor muscle strength and TUG results on POD 1, and fall episode |
| SACB vs. SFNB | | | | | | | |
| Memtsoudis et al.[25] | 2015 | USA | Simultaneous bilateral RCT | 59 (30 [Lt/Rt] vs. 29 [Rt/Lt]) | Spinal or epidural | Superior qualitative pain control in FNB on POD 1 | Within POD 2, quantitative pain level, Q strength, ability to extend the knee within 10° of full extension, and satisfaction |
| Ludwigson et al.[26] | 2015 | USA | Retrospective CCT | 297 (148/149) | Spinal or general | Greater ambulation distance in ACB within POD 2<br>Shorter LOS in ACB | Pain level and opioid consumption within hospital stay |
| Patterson et al.[24] | 2015 | USA | Retrospective CCT | 76 (35/41) | Spinal or general | Greater ambulation distance in ACB on POD 1 | Pain level and opioid consumption within POD 1 |
| Grevstad et al.[27] | 2015 | Denmark | RCT | 50 (25/25) | Spinal | Higher Q strength and faster TUG in ACB at postoperative 2 hr | Pain level and adductor strength at postoperative 2 hr |
| Kim et al.[31] | 2014 | USA | RCT | 95 (46/47) | cSEA | Higher Q strength in ACB at postoperative 6–8 hr | Pain level and opioid consumption within POD 2<br>Q strength after POD 1, "buckled" during physical session |

ACB: adductor canal block, FNB: femoral nerve block, CACB: continuous adductor canal block, CFNB: continuous femoral nerve block, RCT: randomized controlled trial, POD: postoperative day, Q: quardriceps muscle, TUG: Timed Up and Go, CCT: comparative clinical trial, cSEA: combined spinal-epidural anesthesia, SLR: straight leg raising, LOS: length of stay, SACB: single shot adductor canal block, SFNB: single shot femoral nerve block, Lt: left, Rt: right.

**Table 2.** Summary of Previous Meta-Analyses Comparing Analgesic Efficacy and Functional Recovery of ACB and FNB

| Author | Year | Study (no.) | ACB/FNB | Continuous/ single shot | ACB>FNB | ACB=FNB |
|---|---|---|---|---|---|---|
| Zhao et al.[44] | 2016 | 5 RCTs[25,27,29,31,32] (348) | 200/207 | 146/204 | Q strength and mobilization ability | Pain level, opioid consumption and related SE, satisfaction, and adductor strength |
| Li et al.[43] | 2016 | 8 RCTs[25,27-29,31,32,49,50] (434) | 249/255 | 222/212 | Resting pain within postoperative 8–24 hr<br>Q strength and mobilization ability | Pain level after POD 2, opioid consumption, satisfaction, adductor strength, and tourniquet time |
| Kuang et al.[41] | 2015 | 4 RCTs[28,29,31,32] 3 CCTs [24,26,30] (828) | 383/445 | 374/468 | Resting pain within postoperative 24 hr, postoperative nausea and vomiting, mobilization ability and ambulation distance, and LOS | Pain level and opioid consumption after POD 2 |
| Hussain et al.[40] | 2016 | 6 RCTs[25,27-29,31,32] (408) | 230/237 | 206/204 | Q strength within postoperative 8–24 hr | Pain level at rest or motion within POD 2, and complement analgesic doses or related SE |
| Dong et al.[39] | 2016 | 6 RCTs[25,27-29,31,32] 2 CCTs [24,30] (751) | 360/391 | 374/280 | - | Pain level, opioid consumption and related SE, Q and adductor strength, and LOS |
| Li and Ma[42] | 2016 | 7 RCTs[25,27-29,31,32] 2 CCTs [24,30] (639) | 295/344 | 374/318 | Q strength on POD 1–2 | Pain level, opioid consumption and related SE, risk of falls, and LOS |

ACB: adductor canal block, FNB: femoral nerve block, RCT: randomized controlled trial, Q: quardriceps muscle, SE: side effect, POD: postoperative day, CCT: comparative clinical trial, LOS: length of stay.

interventions per patient compared with FNB[23].

*Single shot block*

Pain level and opioid consumption did not differ between groups in three RCTs[25,27,31] and two retrospective clinical trials[24,26]. One simultaneous randomized bilateral trial showed comparable quantitative pain level within 2 PODs, but superior pain relief in the FNB group on POD 1[25]. In addition, no between-group difference in satisfaction was reported[25].

(2) Functional recovery

*Continuous block with catheter*

Most studies documented greater quadriceps strength and ambulation distance in ACB groups on POD 1 or 2[22,23,28-30,32]; however, the superiority of ACB was limited to POD 2[21,22]. Authors of three RCTs reported comparable TUG test outcomes between groups[21,22,32], whereas one study documented superior results in an ACB group[29]. Meanwhile, one trial showed a statistical trend toward greater fall risk in the FNB group (p=0.06), but the sample of that study was limited to 31 patients per group[22]. Another study showed no difference in the frequency of fall episodes between groups[30]. Finally, studies produced contradictory results regarding other ambulation ability assessment and functional recovery variables, such as the 10-m walk test, 30-second chair test, time for quad stick ambulation or staircase competency[29], cumulated ambulation score, and mobilization score[21].

*Single shot block*

Greater quadriceps strength in ACB groups at postoperative 2 hours[27], 6–8 hours[31], and longer ambulation distance on POD 1[24] or 2[26] were reported. However, quadriceps strength on POD 1[31] or 2[25] did not differ. One RCT documented faster TUG performance in the ACB group at postoperative 2 hours, and a retrospective study showed a shorter reduced LOS in hospital in the ACB group[26].

2) Meta-analyses

(1) Analgesic efficacy

Comparable pain level, opioid consumption, and opioid-related side effects were reported in all six meta-analyses reviewed in this study[39-44], excluding two studies reporting superior resting pain in ACB groups on POD 1[41,43]. In addition, similar satisfaction was reported in two studies[43,44].

(2) Functional recovery

Four of the six meta-analyses showed greater quadriceps muscle strength in ACB recipients on POD 1[40,42-44], but one study found no between-group difference[39]. In addition, similar adductor muscle strength was reported in three studies[39,43,44]. Two studies showed similar LOSs[39,42], whereas one study found a shorter LOS in the ACB group[41]. Similar risks of falls were also reported[42].

## Discussion

As the emphasis has been on faster recovery during the early postoperative period, recent trends in pain management protocols following TKA have shifted toward effective analgesia with limited motor involvement. Given the excellent analgesic effect, FNB is a commonly used modality as part of TKA pain control regimens and is considered to be the gold standard for postoperative analgesia after TKA. However, it may reduce quadriceps strength, which is essential for early mobilization and is associated with an increased risk of postoperative falls. Thus, ACB has emerged as a reasonable alternative to FNB that produces a predominantly sensory block with greater quadriceps strength preservation. However, whether ACB can be used as part of TKA multimodal pain management in clinical practice remains unclear, and comparisons of analgesic efficacy and functional recovery between ACB and FNB remain limited. This comprehensive review was conducted 1) to explore practical issues for ACB and 2) to compare analgesic efficacy and functional recovery between ACB and FNB in patients undergoing TKA.

The findings of this study need to be interpreted with considerations of the following limitations. First, as we only performed an extensive search, we could not identify statistical significance or concrete consensus. In addition, heterogeneities among studies regarding drug composition, infiltration techniques, concomitant pain management protocols, and outcome variables make it difficult to judge the practical value of ACB and we could not find any clinical relevance among infiltration techniques. Future studies that investigate these issues in more identical manners are required. Second, we did not compare the cost effectiveness, time required, or anesthesiologist's learning curve for satisfactory blockade. These data would increase our understanding of the appropriateness of ACB following TKA. Future studies investigating these issues in more detail are required. Third, we did not evaluate data on national health insurance systems, which may regulate postoperative pain management modalities after TKA. This difference in national health systems among countries should be considered before estimation of adjunct analgesic modality after TKA. Despite these limitations, we believe that this study provides valuable information on the usefulness of ACB in pain management after TKA.

Our findings in this review indicate that ACB is one of the most useful analgesic modalities in contemporary perioperative management protocols that focus on rapid recovery after knee surgery. ACB can be performed easily with recently introduced high quality, portable ultrasound technology during surgeries around the knee joint, with high success rates[27,29,31]. In addition, it provided excellent pain relief around the knee joint compared with placebo[19,20,35] and preserved motor strength with minimal differences from baseline[18,49,50]. Indeed, multiple recent studies showed that ACB offered satisfactory analgesic effects with well-preserved mobilization ability in patients who had undergone arthroscopic surgery or TKA[19,33,35,45-48]. These findings, together with current trends of perioperative protocols toward rapid recovery after TKA, suggest that ACB should be taken into account as part of a contemporary multimodal approach to pain control after TKA. However, more detailed neural components inside the adductor canal and analgesic effects of each neural component following ACB should be defined, and the optimal type and amount of local anesthetics and mode of infusion should be determined, to enable wide use of ACB as an adjunctive analgesic modality in pain management after TKA.

ACB, which offers almost pure sensory blockade, seems to be a reasonable alternative to FNB that leads to substantial reduction in quadriceps muscle strength, as part of a current TKA pain control protocol. All studies included in final analyses in this review showed comparable analgesic efficacy in terms of pain level and opioid consumption between ACB and FNB[21-32,39-44]. In addition, most studies documented superior quadriceps strength and mobilization ability during the first 24 hours after TKA for ACB compared with FNB[22,27,28,30-32,40-44]. Moreover, ACB catheters required fewer provider interventions per patient, thus decreasing the workload compared with FNB catheters[23]. The findings of this study suggest that ACB is a more appropriate analgesic modality than FNB in patients undergoing current multimodal perioperative protocols after TKA. However, superior functional recovery in ACB groups was limited to the 24–48-hour period after TKA. In addition, although ACB offered comparable pain relief with preserved motor strength, patient satisfaction did not differ[21,25,43,44]. Moreover, there was no evidence that ACB reduced the risk for postoperative falls, which may be a fatal complication of FNB[22,30-32,42], or LOS[30,39,42] compared with FNB. Heterogeneity among studies in reporting outcome variables made uniform comparison difficult, and further studies are needed to determine whether ACB provides superior functional recovery compared with FNB. In addition, the clinical relevance of motor strength during the immediate postoperative period (within 24 hours after TKA) should be determined. Further studies with realistic sample sizes and consistent outcome variables are required to determine whether ACB provides clinically relevant functional recovery compared with FNB.

## Conclusions

Current evidence supports that ACB provides comparable analgesic efficacy and facilitates earlier mobilization by sparing quadriceps strength compared with FNB. Based on current trends in perioperative protocols toward early rehabilitation following TKA, ACB may be a reasonable alternative to FNB as part of a contemporary multimodal pain management protocol after TKA. However, more detailed definition of the neural anatomy inside the adductor canal and determination of the optimal ACB infiltration technique are needed. In addition, further studies with realistic sample sizes are required to determine whether ACB could provide clinically relevant functional recovery in patients undergoing TKA compared with FNB.

## Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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