JB&JS OPEN ACCESS

Continuous Femoral Nerve Block Reduces the Need for Manipulation Following Total Knee Arthroplasty

David M. Freccero, MD, Peter Van Steyn, MD, Patrick M.N. Joslin, MS, Claire E. Robbins, DPT, Xinning Li, MD, Kristian Efremov, MD, Pinak Shukla, MD, Carl T. Talmo, MD, and James V. Bono, MD

Investigation performed at Boston Medical Center, Boston, and New England Baptist Hospital, Boston, Massachusetts

Background: Peripheral nerve blocks improve both pain control and functional outcomes following total knee arthroplasty (TKA). However, few studies have examined the effects of different peripheral nerve block protocols on postoperative range of motion. The present study assessed the impact of a single-shot femoral nerve block (SFNB) versus continuous femoral nerve block (CFNB) on postoperative range of motion and the need for subsequent manipulation following TKA.

Methods: We retrospective reviewed patient charts to identify patients who had undergone primary elective unilateral TKA by 2 surgeons at a high-volume orthopaedic specialty hospital over a 3-year period. A total of 1,091 patients received either SFNB or CFNB and were included in the data analysis. Identical surgical techniques, postoperative oral analgesic regimens, and rehabilitation protocols were used for all patients. Patients with <90° of flexion at 6 weeks postoperatively underwent closed manipulation under anesthesia (MUA).

Results: Overall, 608 patients (55.7%) received CFNB and 483 patients (44.3%) received SFNB. Overall, 94 patients (8.6%) required postoperative manipulation for stiffness, including 36 (5.9%) in the CFNB group and 58 (12%) in the SFNB group. The 50% reduction in the need for manipulation in the CFNB group was independent of primary surgeon ($p > 0.05$). No significant differences were observed between the groups in terms of postoperative range of motion, either at the time of discharge or at 6 weeks postoperatively. A history of knee surgery, decreased preoperative range of motion, and decreased range of motion at the time of discharge were significantly associated with the need for further MUA ($p = 0.0002$, $p < 0.0001$, and $p < 0.0001$, respectively).

Conclusions: Despite similar final postoperative range of motion between patients in both groups, our results suggest that CFNB may be superior to SFNB for reducing the need for postoperative manipulation after primary TKA. Furthermore, a history of ipsilateral knee surgery, decreased preoperative range of motion, and decreased range of motion at the time of discharge were identified as independent risk factors for postoperative stiffness requiring MUA after primary TKA.

Level of Evidence: Therapeutic Level III. See Instructions for Authors for a complete description of levels of evidence.

Postoperative knee stiffness, defined as inadequate range of motion and persistent pain that affects activities of daily living, can be a debilitating complication of total knee arthroplasty (TKA)[1,2]. Despite advances in implants, surgical technique, and postoperative rehabilitation protocols, postoperative stiffness remains a common problem; the reported incidence ranges from 1.3% to 12%[1-9]. Postoperative stiffness leads to worse outcomes and may limit activities of daily living. Previously identified risk factors include limited preoperative flexion range of motion, a history of ipsilateral knee surgery, and low Knee Society scores[10,11]. Intraoperative risk factors include improper gap balancing, malpositioning of the femoral or tibial component, inadequate resection, and excessive joint line elevation[3]. Among arthroplasty specialists, there currently is no clear consensus on the specific criteria that define postoperative knee stiffness or when to intervene to treat it. Both the criteria for diagnosing knee stiffness after TKA and the timing of therapeutic intervention vary among surgeons[1,7-10,12]. Early identification of pathologic knee stiffness after TKA is paramount to preventing poor postoperative range of motion as closed manipulation is most successful within 3 months after the index procedure[13]. It is essential to recognize pathologic knee stiffness after TKA and to adequately address both the intrinsic and extrinsic causes[3]. Symptomatic stiffness at 3 months postoperatively may require the morbidity of

Disclosure: The **Disclosure of Potential Conflicts of Interest** forms are provided with the online version of the article (http://links.lww.com/JBJSOA/A407).

additional surgical procedures such as open or arthroscopic lysis of adhesions or revision TKA[3].

After TKA, optimizing postoperative pain control may hasten recovery and improve performance at physical therapy, ultimately resulting in superior knee range of motion. Peripheral nerve blocks are an integral part of perioperative pain management, along with narcotics, anti-inflammatory medications, and neuromodulators. Multimodal approaches have been shown to improve analgesia and to decrease opioid use, thereby minimizing the side effects of their use such as nausea, pruritus, and sedation[14-20]. Failure to control postoperative pain has also been associated with prolonged hospital stays, increased health-care costs, downregulation of the immune system, and chronic postoperative pain[21]. The 2 main modalities of peripheral nerve block—that is, single-shot femoral nerve block (SFNB) and continuous femoral nerve block (CFNB) delivered via an indwelling catheter—differ in terms of the duration of action. Both techniques are known to improve analgesia and to decrease opioid consumption, postoperative nausea, and vomiting[20,22-25]. Peripheral nerve blocks are further known to promote early knee range of motion and improved functional outcomes after TKA[16,26]. Despite these results, few studies have compared the effects of different peripheral nerve block protocols, including their influence on postoperative knee range of motion. The goal of the present study was to compare postoperative range of motion and the subsequent need for additional closed knee manipulation after TKA in patients receiving SFNB or CFNB.

Materials and Methods

Institutional review board approval for this retrospective study was obtained. The study population included consecutive patients <70 years of age who had undergone primary elective unilateral TKA for degenerative joint disease. All procedures had been performed by 2 surgeons at a high-volume orthopaedic specialty hospital over a 3-year period. Both attending surgeons had utilized a median parapatellar arthrotomy, identical surgical steps, and joint implants from the same company. All patients had engaged in the same postoperative physical therapy protocol. All patients had been examined clinically at 6 weeks and 1 year postoperatively for range of motion. The 2 senior authors (C.T.T. and J.V.B.) defined pathologic stiffness that required manipulation under anesthesia (MUA) as <90° of flexion at 6 weeks postoperatively. All patients with <90° of flexion at the 6-week postoperative visit underwent MUA. Patient charts were reviewed, and patient demographics, preoperative diagnosis, history of knee surgery, history of diabetes mellitus, tourniquet use and time, complications, preoperative and postoperative range of motion, and follow-up range of motion were recorded.

A multimodal pain-management protocol was utilized for all patients, including an oral medication regimen consisting of oxycodone (10 mg), acetaminophen (975 mg), and celecoxib (200 mg, unless contraindicated due to allergy). Intraoperatively, patients underwent posterior capsular injection prior to cementing. The posterior capsular injection solution consisted of 0.25% bupivacaine, ketorolac (30 mg), and morphine (5 mg, unless medically contraindicated secondary to renal insufficiency or allergy). Postoperatively, patients received either SFNB or CFNB. For the SFNB group, a nerve stimulator was used to identify the correct injection location[27]. The choice of SFNB or CFNB was based on the anesthesiologist preference during each procedure.

The SFNB solution consisted of 30 mL of 0.375% bupivacaine with 1:400,000 epinephrine and was administered with ultrasound guidance. CFNB was performed by insertion of an indwelling catheter under ultrasound guidance, followed by (1) an initial bolus of 20 mL of 0.375% bupivacaine with 1:400,000 epinephrine and then (2) a continuous infusion of 0.0625% bupivacaine with 1:400,000 epinephrine at rate of 3 mL/hr[28]. The catheters were removed 36 hours postoperatively. All patients also received a multimodal postoperative pain regimen consisting of oxycodone (5 to 15 mg) or hydromorphone (2 to 4 mg), acetaminophen (975 mg), celecoxib (200 mg), pregabalin (50 mg), and intravenous hydromorphone (1 to 2 mg) as needed for breakthrough pain unless otherwise contraindicated due to allergy.

Summary statistics for categorical variables consisted of frequencies and proportions. Continuous variables were reported in terms of means and standard deviations. Univariate analysis was performed with use of a chi-square test and analysis of variance for multiple comparisons. The level of significance was set at $p < 0.05$.

TABLE I Demographic Data

	CFNB (N = 608)	SFNB (N = 483)	P Value
Preoperative range of motion*	107.3°	100.7°	<0.05
BMI* *(kg/m²)*	33.8	33.1	0.275
History of knee surgery	42.5%	41.9%	0.913
History of diabetes mellitus	18.1%	14.7%	0.441
Tourniquet time* *(min)*	93.7	94.6	0.598
Intraoperative posterior capsular injection	69.7%	65.3%	0.355

*The values are given as the mean.

TABLE II Range of Motion at Discharge and 6 Weeks Postoperatively*

	CFNB	SFNB	P Value
Discharge	79.6°	78.4°	0.366
6 weeks	105.4°	103.6°	0.457

*The values are given as the mean.

Source of Funding
No external funds were received.

Results

Overall, 608 patients (55.7%) received CFNB and 483 patients (44.3%) received SFNB. The mean age was 62 years in the CFNB group (63% female) and 64 years in the SFNB group (61% female). There were no significant differences seen between the groups with regard to body mass index (BMI), history of knee surgery, history of diabetes mellitus, intraoperative tourniquet time, or intraoperative posterior capsular injection (Table I). The preoperative range of motion was 107.3° in the CFNB group and 100.7° in the SFNB group ($p < 0.05$).

A total of 94 patients (8.6% of the total sample) had postoperative stiffness (<90° of flexion at 6 weeks after surgery) requiring manipulation. This group comprised 58 patients from the SFNB group (representing 12% of the patients in the SFNB group and 61.7% of the patients who required MUA) and 36 patients from the CFNB group (representing 5.9% of the patients in the CFNB group and 38.3% of the patients who required MUA). There was an approximately 50% reduction in the need for postoperative manipulation following TKA when the CFNB group was compared with the SFNB group (12% versus 6%, respectively). This finding was independent of primary surgeon ($p > 0.05$). No significant differences were seen between the SFNB and CFNB groups in terms of overall postoperative range of motion at the time of discharge ($p = 0.366$) or at 6 weeks postoperatively ($p = 0.457$) (Table II).

Among the patients who underwent manipulation, there was no significant difference between the SFNB and CFNB groups in terms of overall postoperative range of motion at the time of discharge ($p = 0.394$), 6-week follow-up ($p = 0.356$), or 1-year follow-up ($p = 0.367$) (Table III).

When patients who required MUA were compared with those who did not, a history of knee surgery was significantly associated with the need for postoperative manipulation ($p = 0.0002$) (Table IV). Preoperative range of motion and range of motion at the time of discharge were also significantly associated with the need for postoperative manipulation ($p < 0.0001$). Analysis of multiple patient variables, including BMI, history of diabetes mellitus, tourniquet time, and intraoperative posterior capsular injection, revealed no significant differences between those who underwent manipulation and those who did not (Table IV).

Discussion

The present study showed that patients in the CFNB group required manipulation for the treatment of postoperative stiffness half as often as those who received SFNB. Prior knee surgery and decreased preoperative knee range of motion were further observed to be independent risk factors for postoperative stiffness and the secondary need for manipulation. In contrast, a history of diabetes mellitus, tourniquet time, and BMI were not predictive of postoperative stiffness or the need for manipulation.

Prior studies have shown that femoral nerve block provides superior analgesic benefit compared with patient-controlled analgesia (PCA) or systemic analgesia[18,22,24,26]. Despite these findings, few studies have directly compared the benefits of single-injection versus continuous femoral nerve block, especially as related to postoperative range of motion and the need for manipulation. Hirst et al. randomized 33 patients undergoing TKA to receive no femoral nerve block, SFNB, or CFNB with use of bupivacaine and found no significant differences in analgesic effect between the SFNB and CFNB groups at any time point[29]. In contrast, Salinas et al. demonstrated reduced pain scores and reduced opioid consumption in patients who were randomized to receive CFNB compared with SFNB with use of ropivacaine, although there were no differences between the 2 groups in terms of the length of hospital stay or long-term functional outcomes (knee flexion at 12 weeks, 117° in the CFNB versus 113° in the SFNB group)[30]. The results reported by Salinas et al. were supported by those of 2 other studies comparing SFNB to CFNB with use of ropivacaine[31,32]. Both studies showed significantly lower use of pain medications in the CFNB group, particularly in the first 48 hours postoperatively, but demonstrated no significant differences in functional outcomes[31,32]. Those findings were consistent with the results of a recent Cochrane review by Chan et al., who concluded that continuous blockade provided improved pain scores and reduced opioid consumption at 24 and 48 hours after TKA when compared with single-injection blockade[26]. However, Chan et al. were not able to make any conclusions regarding the effect on functional outcome between the CFNB and SFNB groups because of heterogeneity of the pooled data[26]. More recently, a meta-analysis and systematic review by Ma et al. was unable to demonstrate significant differences in the efficacy of SFNB versus CFNB with regard to pain control or hospital length of stay[33]. Wyatt et al., in a prospective, double-blinded, randomized, placebo-controlled trial, and Dixit et al., in a

TABLE III Range of Motion for Patients Who Underwent Postoperative Manipulation*

	CFNB	SFNB	P Value
Discharge	70.2°	74.4°	0.394
6 weeks postop. (prior to manipulation)	73.8°	79.0°	0.356
1 year post-manipulation	107°	111°	0.367

*The values are given as the mean.

TABLE IV Comparison of Patients Who Underwent Postoperative Manipulation and Those Who Did Not

	Manipulation	No Manipulation	P Value
BMI* *(kg/m²)*	33.5	33.4	0.994
History of prior knee surgery	66%	38.4%	0.0002
History of diabetes mellitus	26.4%	16%	0.72
Tourniquet time* *(min)*	98.0	93.7	0.109
Intraoperative posterior capsular injection	70.4%	68.1%	0.736
Range of motion*			
Preop.	91.9°	105.5°	<0.0001
Discharge	73.4°	80.2°	<0.0001
6 weeks postop.	76.9°	109.0°	<0.0001

*The values are given as the mean.

double-blinded, randomized trial, found no significant differences between CFNB and SFNB with regard to pain scores, opioid use, side effects, length of hospital stay, motor block, or functional outcomes[34,35]. However, they did not examine the rate of MUA between the 2 groups in their study populations. Wyatt et al. did measure the postoperative range of motion but did not observe any significant differences[35]. In contrast, our study showed that the CFNB group had a 50% reduction in the need for postoperative closed knee manipulation after TKA compared with the SFNB group.

To our knowledge, the present study represents the largest cohort analysis comparing these 2 methods, with >1,000 patients; previous studies, with sample sizes ranging from 36 to 133 patients, may have been underpowered to demonstrate the possible clinical and functional outcomes between these 2 peripheral nerve block modalities. Another possible explanation for these disparate findings may be the type of anesthetic used; while most studies in the literature have utilized ropivacaine as the anesthetic, our study, along with the study by Hirst et al., utilized bupivacaine[29]. The duration of action and toxicity profile differ between the 2 anesthetics[24]. As our study used only 1 type of anesthetic for the nerve blocks, it remains unclear how the use of different anesthetics may influence how SFNB and CFNB affect postoperative range of motion and the need for manipulation after TKA.

Long-term functional outcomes and postoperative mobility also have not been adequately investigated in the context of CFNB versus SFNB[32]. If we assume that better or longer reductions in postoperative pain allow for greater patient compliance with protocols and improved performance during physical therapy, then this may help to explain the decreased need for MUA in the CFNB group compared with the SFNB group. Our study largely supports this hypothesis, with the CFNB group showing a 50% reduction in the need for postoperative manipulation. Additionally, at 1 year postoperatively, we found no significant difference between the SFNB and CFNB groups when comparing range of motion in the patients who required manipulation, suggesting that CFNB resulted in no adverse long-term effects compared with SFNB in patients who required manipulation. In the present study, we could not assess how the preoperative difference in range of motion between the SFNB and CFNB groups impacted the lack of difference in range of motion observed at 1 year after surgery.

Recent literature also has suggested that prior knee surgery has negative ultimate impacts on postoperative knee range of motion[36-43]. In the study by Haslam et al., 40 patients who underwent TKA after high tibial osteotomy (HTO) were compared with a matched control cohort who underwent primary TKA[37]. At an average of 12.6 years of follow-up, the HTO group had significantly less flexion capacity compared with the control group (91° versus 106°, respectively). In a recent study involving the PearlDiver Patient Records database, Werner et al. identified 3,051 patients who underwent arthroscopy within 2 years before undergoing ipsilateral TKA. The investigators found that arthroscopy within a 6-month period prior to TKA was associated with a twofold increase in the 90-day risk of postoperative arthrofibrosis[43]. Similarly, our study showed a significant association between history of knee surgery and the need for postoperative manipulation. The rate of prior knee surgery was 66% among patients who required manipulation after TKA, compared with 38% among those who did not. Concordant with our findings, in a retrospective review of 1,729 TKAs that had been performed at a single center, Newman et al. found that the rate of prior knee surgery was 59.7% among patients who required manipulation, compared with only 40.4% among those who did not[44].

Preoperative range of motion is another known predictor of postoperative range of motion[1,35,45-46]. Lizaur et al., in a study of 74 patients, found that a postoperative range of motion of >90° was achieved by 91.3% of patients who had had preoperative range of motion of >90° but only 71.4% of those who had had a preoperative range of motion of <90°[47]. Gandhi et al. also found that preoperative, intraoperative, 6-week, and 6-month flexion were all predictive of knee stiffness at 1 year postoperatively[6]. These findings are consistent with the results of our study, with preoperative range of motion significantly associated with the need for postoperative manipulation. These findings suggest that maximizing preoperative range of motion should be an important part of patient management to help prevent the need for postoperative manipulation. In another investigation, Livbjerg et al. demonstrated that preoperative patient education regarding postoperative rehabilitation and expectations can likely decrease the risk of arthrofibrosis after TKA[48].

The strengths of our study include a large sample size and the analysis of functional outcomes, which has not been widely done in previous studies. Because our study evaluated procedures performed by only 2 surgeons, surgeon bias or subtle technique bias may have affected the results; however, we did not find a significant difference in primary outcomes (postoperative range of motion and the need for manipulation) between the groups managed by the 2 attending surgeons. Furthermore, it is important to note that comparing our results with those of prior studies is difficult because of the lack of standardized postoperative multimodal analgesia, rehabilitation protocols, and functional outcome measurements across institutions and studies.

The present study is limited in the scope of its conclusions by its retrospective design. Additionally, the study could have been improved by the addition of a patient pain-level assessment and the need for opioids postoperatively. As the purpose of the present study was to compare the 2 block techniques in terms of postoperative range of motion and the need for manipulation, we could not control for any variations among and between individuals' pain regimens. The use of total range of motion also does not differentiate between patients with extension versus flexion limitations. In addition, preoperative range of motion was different between the 2 groups, and we did not take into account how this factor could have affected the final results. Future investigators should focus on performing randomized controlled trials with standard protocols to evaluate both subjective and objective measures of long-term functional outcome and patient satisfaction. Furthermore, it should be mentioned that adductor canal blocks have become popular as they avoid the complications of motor weakness inherent to the femoral block. Future investigators may consider assessing the differences observed between continuous and single-shot adductor canal block.

Taken together, the results of the present comprehensive study of 1,091 patients who underwent TKA by 2 surgeons using identical surgical techniques, the same types of implants, and the same postoperative rehabilitation protocols showed significant differences between the SFNB and CFNB methods for analgesia. Our study revealed a 50% reduction in the need for postoperative manipulation following the use of CFNB compared with SFNB. Our findings also suggest that a history of knee surgery and decrease in preoperative range of motion are independent risk factors for postoperative stiffness. ■

David M. Freccero, MD[1]
Peter Van Steyn, MD[2]
Patrick M.N. Joslin, MS[1]
Claire E. Robbins, DPT[3]
Xinning Li, MD[1]
Kristian Efremov, MD[1]
Pinak Shukla, MD[3]
Carl T. Talmo, MD[3]
James V. Bono, MD[3]

[1]Boston University School of Medicine, Boston, Massachusetts

[2]Madigan Medical Center, Tacoma, Washington

[3]New England Baptist Hospital, Boston, Massachusetts

Email for corresponding author: Xinning.li@gmail.com

References

1. Fox JL, Poss R. The role of manipulation following total knee replacement. J Bone Joint Surg Am. 1981 Mar;63(3):357-62.

2. Schiavone Panni A, Cerciello S, Vasso M, Tartarone M. Stiffness in total knee arthroplasty. J Orthop Traumatol. 2009 Sep;10(3):111-8.

3. Bong MR, Di Cesare PE. Stiffness after total knee arthroplasty. J Am Acad Orthop Surg. 2004 May-Jun;12(3):164-71.

4. Desai AS, Karmegam A, Dramis A, Board TN, Raut V. Manipulation for stiffness following total knee arthroplasty: when and how often to do it? Eur J Orthop Surg Traumatol. 2014 Oct;24(7):1291-5.

5. Esler CN, Lock K, Harper WM, Gregg PJ. Manipulation of total knee replacements. Is the flexion gained retained? J Bone Joint Surg Br. 1999 Jan;81(1):27-9.

6. Gandhi R, de Beer J, Leone J, Petruccelli D, Winemaker M, Adili A. Predictive risk factors for stiff knees in total knee arthroplasty. J Arthroplasty. 2006 Jan;21(1):46-52.

7. Kim J, Nelson CL, Lotke PA. Stiffness after total knee arthroplasty. Prevalence of the complication and outcomes of revision. J Bone Joint Surg Am. 2004 Jul;86(7):1479-84.

8. Scranton PE Jr. Management of knee pain and stiffness after total knee arthroplasty. J Arthroplasty. 2001 Jun;16(4):428-35.

9. Yercan HS, Sugun TS, Bussiere C, Ait Si Selmi T, Davies A, Neyret P. Stiffness after total knee arthroplasty: prevalence, management and outcomes. Knee. 2006 Mar;13(2):111-7.

10. Christensen CP, Crawford JJ, Olin MD, Vail TP. Revision of the stiff total knee arthroplasty. J Arthroplasty. 2002 Jun;17(4):409-15.

11. Erkan S, Yercan HS, Okcu G, Ozalp RT. [Factors causing stiff knee after total knee arthroplasty]. Eklem Hastalik Cerrahisi. 2011;22(1):16-21.

12. Nicholls DW, Dorr LD. Revision surgery for stiff total knee arthroplasty. J Arthroplasty. 1990;5(Suppl):S73-7.

13. Mamarelis G, Sunil-Kumar KH, Khanduja V. Timing of manipulation under anaesthesia for stiffness after total knee arthroplasty. Ann Transl Med. 2015 Nov;3(20):316.

14. Allen HW, Liu SS, Ware PD, Nairn CS, Owens BD. Peripheral nerve blocks improve analgesia after total knee replacement surgery. Anesth Analg. 1998 Jul;87(1):93-7.

15. Chelly JE, Greger J, Gebhard R, Coupe K, Clyburn TA, Buckle R, Criswell A. Continuous femoral blocks improve recovery and outcome of patients undergoing total knee arthroplasty. J Arthroplasty. 2001 Jun;16(4):436-45.

16. De Ruyter ML, Brueilly KE, Harrison BA, Greengrass RA, Putzke JD, Brodersen MP. A pilot study on continuous femoral perineural catheter for analgesia after total knee arthroplasty: the effect on physical rehabilitation and outcomes. J Arthroplasty. 2006 Dec;21(8):1111-7.

17. Feibel RJ, Dervin GF, Kim PR, Beaulé PE. Major complications associated with femoral nerve catheters for knee arthroplasty: a word of caution. J Arthroplasty. 2009 Sep;24(6)(Suppl):132-7.

18. Fischer HB, Simanski CJ, Sharp C, Bonnet F, Camu F, Neugebauer EA, Rawal N, Joshi GP, Schug SA, Kehlet H; Working Group PROSPECT. A procedure-specific systematic review and consensus recommendations for postoperative analgesia following total knee arthroplasty. Anaesthesia. 2008 Oct;63(10):1105-23.

19. Ganapathy S, Wasserman RA, Watson JT, Bennett J, Armstrong KP, Stockall CA, Chess DG, MacDonald C. Modified continuous femoral three-in-one block for postoperative pain after total knee arthroplasty. Anesth Analg. 1999 Nov;89(5):1197-202.

20. Lareau JM, Robbins CE, Talmo CT, Mehio AK, Puri L, Bono JV. Complications of femoral nerve blockade in total knee arthroplasty and strategies to reduce patient risk. J Arthroplasty. 2012 Apr;27(4):564-8.
21. Moucha CS, Weiser MC, Levin EJ. Current Strategies in Anesthesia and Analgesia for Total Knee Arthroplasty. J Am Acad Orthop Surg. 2016 Feb;24(2):60-73.
22. 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 Jul;91(1):8-15.
23. Liu SS, Salinas FV. Continuous plexus and peripheral nerve blocks for postoperative analgesia. Anesth Analg. 2003 Jan;96(1):263-72.
24. Paul JE, Arya A, Hurlburt L, Cheng J, Thabane L, Tidy A, Murthy Y. Femoral nerve block improves analgesia outcomes after total knee arthroplasty: a meta-analysis of randomized controlled trials. Anesthesiology. 2010 Nov;113(5):1144-62.
25. Wang H, Boctor B, Verner J. The effect of single-injection femoral nerve block on rehabilitation and length of hospital stay after total knee replacement. Reg Anesth Pain Med. 2002 Mar-Apr;27(2):139-44.
26. 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 Apr;28(4):608-13.
27. Forouzan A, Masoumi K, Motamed H, Gousheh MR, Rohani A. Nerve Stimulator versus Ultrasound-Guided Femoral Nerve Block; a Randomized Clinical Trial. Emerg (Tehran). 2017;5(1):e54.
28. Vishwanatha S, Kalappa S. Continuous Femoral Nerve Blockade versus Epidural Analgesia for Postoperative Pain Relief in Knee Surgeries: A Randomized Controlled Study. Anesth Essays Res. 2017 Jul-Sep;11(3):599-605.
29. Hirst GC, Lang SA, Dust WN, Cassidy JD, Yip RW. Femoral nerve block. Single injection versus continuous infusion for total knee arthroplasty. Reg Anesth. 1996 Jul-Aug;21(4):292-7.
30. 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 Apr;102(4):1234-9.
31. Duarte VM, Fallis WM, Slonowsky D, Kwarteng K, Yeung CK. Effectiveness of femoral nerve blockade for pain control after total knee arthroplasty. J Perianesth Nurs. 2006 Oct;21(5):311-6.
32. Albrecht E, Morfey D, Chan V, Gandhi R, Koshkin A, Chin KJ, Robinson S, Frascarolo P, Brull R. Single-injection or continuous femoral nerve block for total knee arthroplasty? Clin Orthop Relat Res. 2014 May;472(5):1384-93.
33. 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 Feb 24;21(1):121.
34. Dixit V, Fathima S, Walsh SM, Seviciu A, Schwendt I, Spittler KH, Briggs D. Effectiveness of continuous versus single injection femoral nerve block for total knee arthroplasty: A double blinded, randomized trial. Knee. 2018 Aug;25(4):623-30.
35. Wyatt MC, Wright T, Locker J, Stout K, Chapple C, Theis JC. Femoral nerve infusion after primary total knee arthroplasty: a prospective, double-blind, randomised and placebo-controlled trial. Bone Joint Res. 2015 Feb;4(2):11-6.
36. Harvey IA, Barry K, Kirby SP, Johnson R, Elloy MA. Factors affecting the range of movement of total knee arthroplasty. J Bone Joint Surg Br. 1993 Nov;75(6):950-5.
37. Haslam P, Armstrong M, Geutjens G, Wilton TJ. Total knee arthroplasty after failed high tibial osteotomy long-term follow-up of matched groups. J Arthroplasty. 2007 Feb;22(2):245-50.
38. Katz BP, Freund DA, Heck DA, Dittus RS, Paul JE, Wright J, Coyte P, Holleman E, Hawker G. Demographic variation in the rate of knee replacement: a multi-year analysis. Health Serv Res. 1996 Jun;31(2):125-40.
39. Gill T, Schemitsch EH, Brick GW, Thornhill TS. Revision total knee arthroplasty after failed unicompartmental knee arthroplasty or high tibial osteotomy. Clin Orthop Relat Res. 1995 Dec;(321):10-8.
40. McAuley JP, Engh GA, Ammeen DJ. Revision of failed unicompartmental knee arthroplasty. Clin Orthop Relat Res. 2001 Nov;(392):279-82.
41. van Raaij TM, Reijman M, Furlan AD, Verhaar JA. Total knee arthroplasty after high tibial osteotomy. A systematic review. BMC Musculoskelet Disord. 2009 Jul 20;10:88.
42. Rothermich MA, Nam D, Brophy RH, Li KK, Barrack RL, Nunley RM. The Impact of Prior Surgery after Total Knee Arthroplasty. J Knee Surg. 2017 Jan;30(1):57-62.
43. Werner BC, Burrus MT, Novicoff WM, Browne JA. Total Knee Arthroplasty Within Six Months After Knee Arthroscopy Is Associated With Increased Postoperative Complications. J Arthroplasty. 2015 Aug;30(8):1313-6.
44. Newman ET, Herschmiller TA, Attarian DE, Vail TP, Bolognesi MP, Wellman SS. Risk Factors, Outcomes, and Timing of Manipulation Under Anesthesia After Total Knee Arthroplasty. J Arthroplasty. 2018 Jan;33(1):245-249.
45. Parsley BS, Engh GA, Dwyer KA. Preoperative flexion. Does it influence postoperative flexion after posterior-cruciate-retaining total knee arthroplasty? Clin Orthop Relat Res. 1992 Feb;(275):204-10.
46. Schurman DJ, Parker JN, Ornstein D. Total condylar knee replacement. A study of factors influencing range of motion as late as two years after arthroplasty. J Bone Joint Surg Am. 1985 Sep;67(7):1006-14.
47. Lizaur A, Marco L, Cebrian R. Preoperative factors influencing the range of movement after total knee arthroplasty for severe osteoarthritis. J Bone Joint Surg Br. 1997 Jul;79(4):626-9.
48. Livbjerg AE, Froekjaer S, Simonsen O, Rathleff MS. Pre-operative patient education is associated with decreased risk of arthrofibrosis after total knee arthroplasty: a case control study. J Arthroplasty. 2013 Sep;28(8):1282-5.