Comparison of two different volumes of 0.5%, ropivacaine used in ultrasound-guided adductor canal block after knee arthroplasty: A randomized, blinded, controlled noninferiority trial

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Abstract

Background and Aims: The aim of this study was to establish noninferiority of 10 mL of 0.5% ropivacaine as compared to 20 mL of 0.5% ropivacaine; for choosing right dose in adductor canal block (ACB) after knee arthroplasty (KA), this trial was conducted.
Material and Methods: Forty patients undergoing bilateral KA with postoperative ultrasound-aided ACB were randomized: Group A patients received 20 mL 0.5% ropivacaine in the right limb and 10 mL 0.5% ropivacaine in the left limb. Group B patients received 10 mL of 0.5% ropivacaine in the right limb and 20 mL of 0.5% ropivacaine in the left limb. Catheter is positioned for intermittent boluses every 12-h up to 48 h.
Results: In the final analysis (excluding six patients) based on split-body design between Group I (comprising 34 limbs which received 20 mL of 0.5% ropivacaine) and Group II (comprising 34 limbs which received 10 mL of 0.5% ropivacaine), baseline demographic data were collected. Length of the limb from anterior superior iliac spine (ASIS) to the base of the patella was comparable between two groups: Group I (in cm; 149 ± 1.63) versus Group II (in cm; 149.5 ± 1.51) ($P = 0.49$, 95% CI of − 1.98 to 0.98). Primary outcomes, that is, quadriceps muscle strength, show a significant difference ($P < 0.025$) at various timeline. Secondary outcome pain scores and degree of knee flexion at various time intervals showed no significant difference. There was zero incidence of fall of the patient and no significant complication due to catheter was reported leading to discontinuation of catheter use in both groups.
Conclusion: 10 mL of 0.5% ropivacaine is noninferior to 20 mL of 0.5% ropivacaine in providing postoperative analgesia with preserved quadriceps muscle strength.

Keywords: Acute pain management, adductor canal block, optimum dose, ropivacaine, split body study

Introduction

A pragmatic multimodal approach for early ambulation, rehabilitation, and adequate pain management after knee arthroplasty (KA) requires adductor canal blocks (ACB) or other regional techniques. Choosing the right dose of local anesthetic agent (LA) in ACB for pain management in KA is an important patient-centric decision.[1,2]

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Inadequate volume or concentration may lead to inadequate analgesia, increase opioid consumption, and related morbidity. An excess of the local anesthetic in the adductor canal may spread to femoral triangle leading to quadriceps femoris weakness. Postoperative rehabilitation protocol for achieving early ambulation and a full range of movements of knees fundamentally depends on the quadriceps muscle strength and its recovery from motor weakness.[3,4]

Till now, dose selection of LA in ACB was done based on studies where young healthy volunteers were enrolled. In clinical practice, patients undergoing arthroplasty are elderly with decreased limb length and muscle mass. We hypothesized that injecting 10 mL of 0.5% ropivacaine in ACB is adequate to anaesthetize the nerves in the adductor canal without spilling into the femoral triangle, thus preserving muscle strength. For establishing the noninferiority of 10 mL of 0.5% ropivacaine as compared to 20 mL of 0.5% ropivacaine in ACB, we conducted this trial.

Material and Methods

Ethical approval for this study was obtained from the All India Institute of Medical Sciences (AIIMS), Rishikesh India (Protocol no. AIIMS/IEC/19/763 dated 12 April, 2019). This was a randomized, double-blinded, parallel-arm group study based on split-body design. Permission to conduct this trial was taken from the ethical committee of the institute (letter number AIIMS/IEC/19/763, dated 12/04/2019) and is registered on Clinical Trial Registry India (CTRI/2019/05/019183 [Registered on 16/05/2019])] The study was conducted for 4 months (June 2019–September 2019) in a government-aided teaching tertiary care institute as per Helsinki declaration on human experimentation. Written and informed consent was taken from all the participants in the study.

Eligible participants included patients undergoing primary bilateral total KA of either sex, age more than 45 years, and ASA class I, II, and III. Surgeries done under general anesthesia or epidural block in combination with subarachnoid block were included in the study. The exclusion criteria of the study were use of any regional block other than ACB for postoperative analgesia, preexisting motor or sensory impairment in the operating limb, presence of coagulation disorder, and patient with cognitive impairment or inability to understand study protocol.

Forty patients undergoing bilateral KA with postoperative ultrasound-aided ACB were randomized into two groups: Group A patients received 20 mL 0.5% ropivacaine in the right limb and 10 mL 0.5% ropivacaine in the left limb.

Group B patients received 10 mL of 0.5% ropivacaine in the right limb and 20 mL of 0.5% ropivacaine in the left limb. Randomization was done by a nurse not involved in the study with computer-generated table of random numbers concealed in a sealed opaque envelope.

Patients were unaware of the volume of the drug in ACB in each limb and were operated by the same orthopedic surgeons. Block was performed by an anesthesiologist who is well versed with the technique but not blinded to the group allotment. Physician in the recovery period collected all the data and was blinded to group allotment. The same general anesthesia or neuraxial block protocols followed in all patients. Following the completion of surgery, ultrasound-aided ACB was performed using a 6–13 MHz linear probe (GE Healthcare, Phoenix, Arizona; Global Ultrasound Probes, Hungary) and SonoPlex STIM 20-G needle of 120 mm length (PAJUNK, Germany) and with catheter (Epi Cath-SFT Romsons, India). Prefilled syringes of 10 mL or 20 mL 0.5% ropivacaine were prepared beforehand in a 20-mL syringe (Original-Perfusor syringe 20 mL, Braun, Germany) covered with opaque tape and is prepared by a trained nurse who was not part of the study.

Needle was inserted in-plane at mid of thigh between the base of the patella and the anterior superior iliac spine (ASIS) level. The required volume of drug was injected between femora artery and sartorius muscle, a catheter was positioned and secured for further boluses (same volume of 0.5% ropivacaine as the initial bolus in each limb) every 12 h up to 48 h. Any incidence of catheter displacement was identified and repositioned under ultrasonography vision. The patient remained in the postanesthesia care unit (PACU) for 24 h, where intravenous morphine 0.05 mg kg^{-1} was given if Numerical Rating Scale (NRS) > = 4. After 24 h, mobilization of the limb was started followed by ambulation. Oral acetaminophen 325 mg and tramadol 37.5 mg drug combination were given twice a day after 24 h until the day of discharge.

Primary outcomes measured were assessment of quadriceps muscle weakness affected by ACB. It was assessed by performing a maximal isometric effort in the sitting state against Dynamometer for 10 s (Isometer, International Design Orthopaedics, UK) before the surgery (baseline) and postoperatively at 24 and 48 h.

Secondary outcomes compared were pain scores (NRS 0 being no pain and 10 as worst imaginable pain) at 0 (immediate postoperative), 1, 6, 12, and 24 h at rest and on measuring flexion of knee and strength of quadriceps muscles at 24 and 48 h. Also measured were degree of knee flexion assessed by goniometer at baseline before surgery and postoperatively at

24 and 48 h and time to ambulation with support and any incidence of fall.

We assumed that using 10 mL instead of 20 mL of 0.5% ropivacaine in ACB will preserve quadriceps muscle strength by effect size of 0.8 (Cohen's *d*).[5] To prove noninferiority, we use one-tailed *t* test at a significance level of 0.025, power of study 90%, and allocation ratio 1. Thirty-four limbs in each group (total 34 patients) will be needed to detect a clinical and statistical difference. To adjust for block failure or any other surgical complication, a total of 40 patients were assessed for inclusion into the study [Figure 1].

Statistical analysis was based on split-body design between two reformed groups: Group I (comprising 34 limbs which received 20 mL of 0.5% ropivacaine) and Group II (comprising 34 limbs which received 10 mL of 0.5% ropivacaine). Statistical tests were conducted on Statistical Package for the Social Sciences (SPSS) software program, version 23.0 (IBM, New York USA). Continuous data were presented as mean (standard deviation [SD]) and discrete numbers were taken as percentages and proportions. Unpaired *t* test was used to compare mean and Chi-square test was used to compare percentages based on the assumption that population at source were equally distributed. Graphs were plotted in Microsoft Word 2016 sheets. A value of $P < 0.025$ was considered statistically significant.

Results

We enrolled 40 patients for the study; six patients were excluded from the final analysis. Four patients were excluded due to documented preexisting neuropathy (two compressive neuropathy and two diabetic neuropathy) in the affected limb and two patients refused after initially getting enrolled in the study. After exclusion, missing data in both groups were zero for all outcomes compared [Figure 2].
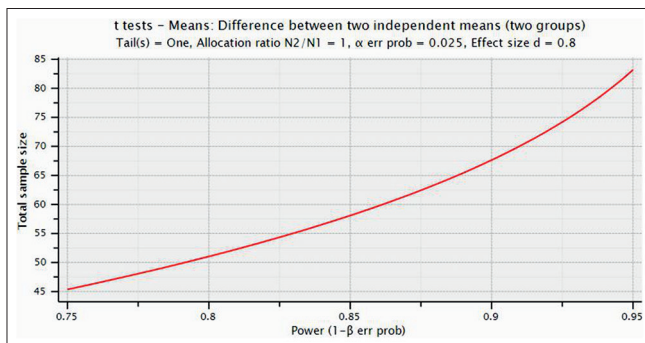

Figure 1: Sample size estimation: on the *y*-axis is total sample size and on the *x*-axis is power (1–β err prob). Effect size *d* = 0.8. Allocation ratio = 1, tail(s) = 1 and α err prob = 0.025

Baseline demographic data are shown in Table 1. Length of the limb from ASIS to base of the patella was comparable between two groups. Group I (in cm; 49 ± 1.63) versus Group II (in cm; 49.5 ± 1.51) had a mean difference of –0.5 ($P = 0.49$, 95% CI of –1.98 to 0.98). Primary outcomes, that is, quadriceps muscle strength, showed a significant difference ($P < 0.025$) at various timeline [Table 2]. Secondary outcomes pain scores at various time intervals and degree of knee flexion showed no significant difference [Tables 2 and 3]. There was zero incidence of fall of the patient during rehabilitation and no significant complication due to catheter was reported leading to discontinuation of catheter use in both groups.

Discussion

Anatomically adductor canal extends from the apex of the femoral triangle proximally to the adductor hiatus distally. It contains the four main neural structures, namely the saphenous nerve, the nerve to vastus medialis, the medial femoral cutaneous nerve, and the terminal end of the posterior division of the obturator nerve.[6] Proximally the adductor canal being in continuity with the femoral triangle houses the common femoral nerve; hence if the minimal volume of drug is not used, the excess drug may reach up into the femoral triangle and anesthetize the femoral nerve thereby affecting the quadriceps muscle.

The review article by Martin Bauer *et al.* pointed out that peripheral nerve blocks are becoming the standard for pain management post-KA.[7] Lumbar epidural analgesia and lumbar plexus block has its own risk and benefit ratio and should be reserved only for some specific orthopedic surgical procedures. Sciatic nerve blocks have also been tried but their use is controversial for pain in the knee. Although FNB is the gold standard for pain management in KA, it results in a higher incidence of post-KA falls due to its higher motor blockade properties. Thus, FNB use is now limited and newer techniques such as ACB and periarticular local infiltration analgesia are being adopted.

The rate of post-TKA falls in patients using FNB ranged from 0.7% to 2.7%.[8,9] Falls after TKA can result in prolongation of hospital stays with higher incidences of postoperative periprosthetic fracture. Thus, an ideal peripheral nerve block must provide effective analgesia and accelerate rehabilitation and early mobilization by preserving motor function. Studies concluded that ACBs in this regard provide comparable analgesia to FNBs preserving the quadriceps strength. The study on multimodal pain management after total KA by D Li highlighted that intraoperative neuraxial anesthesia combined with a continuous ACBs and a timed round the clock analgesic
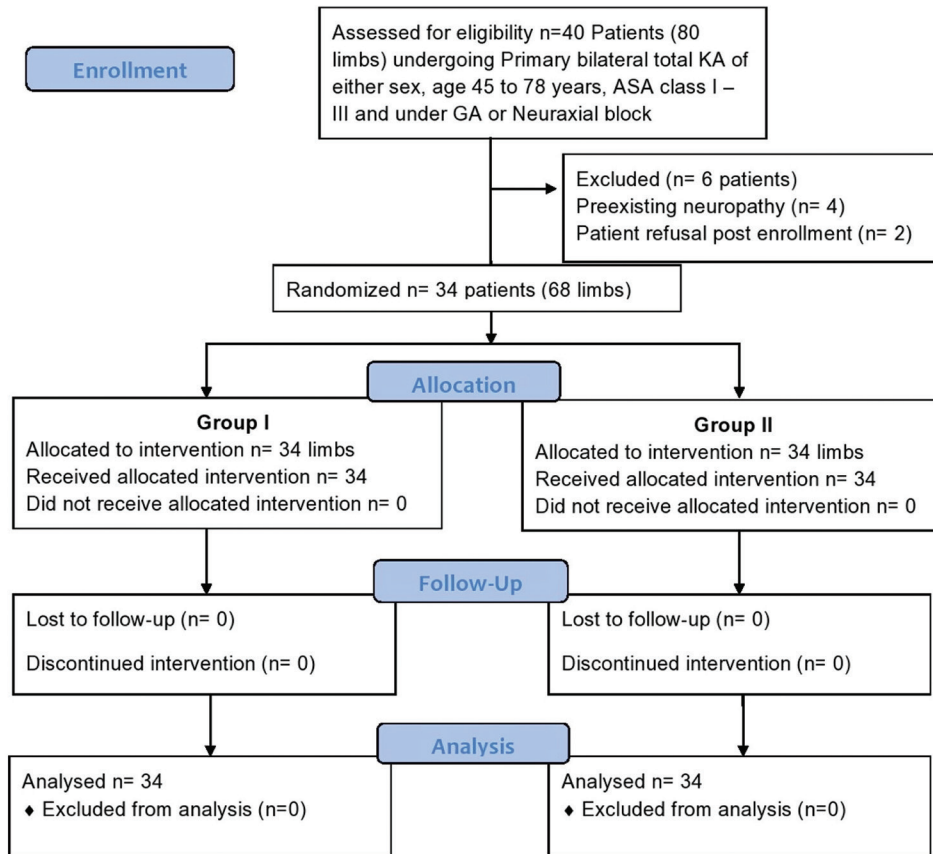
Figure 2: Consort flow diagram

Table 1: Baseline demographic variables	
Parameter	**Number of enrolled subjects=34**
Age (in years) mean (SD)	62.11±8.19
Male *n* (%)	19 (55.88)
Female *n* (%)	15 (44.12)
ASA I *n* (%)	10
ASA II *n* (%)	22
ASA III *n* (%)	2
Weight	73±7.88
Height	162.35±8.75
BMI (kg/m²) mean (SD)	26.71±2.49
Concurrent analgesic use *n* (%)	
WHO ladder I	14 (41.18)
WHO ladder II	20 (58.82)
Duration of surgery (in hours) mean (SD)	121.5±9.76
Total morphine consumption in 24 h (in mg) mean (SD)	11.20±3.0
Incidence of catheter displacement	4 (11.76)

ASA=American Society of Anesthesiologists functional class, BMI=body mass index, NRS=Numerical Rating Scale, WHO=World Health Organization. Data were presented as mean (SD) or number n (%)

medication regimen is the best protocol for postoperative pain control after knee arthroplasties.[10]

If given in adequate dose, ACBs being pure sensory nerve block (obturator nerve) preserve the quadriceps control in contrast to FNBs and thereby add to the benefits of adequate analgesia, resulting in good postoperative pain control with early mobility.[11] Pain following bilateral TKA remains a challenging task to address, especially in resource-limited healthcare settings. Faster recovery from pain, early ambulation, and adequate rehabilitation, preventing postoperative complications such as deep venous thrombosis

Table 2: Comparison of maximal voluntary isometric contraction and degree of flexion

Parameter	Group I Mean (SD)	Group II Mean (SD)	Mean difference (95% confidence interval of difference)	*P*
Preoperative MVIC	3.42±0.37	3.49±0.27	0.07 (-0.23 to 0.09)	0.38
Postoperative MVIC 24th h	1.59±0.26	2.81±0.25	1.22 (-1.34 to -1.09)	0.00
Reduction in percent from baseline at 24th h	53.50	19.48		0.00
Postoperative MVIC 48th h	1.68±0.25	2.90±0.27	1.22 (-1.34 to -1.09)	0.00
Reduction in percent from baseline at 48th h	50.88	16.91		0.00
Preoperative DOF baseline	78.97±9.03	80.44±9.95	-1.47 (-6.07 to 3.13)	0.58
Postoperative DOF 24th h	83.25±5.76	86.91±5.66	-3.6 (-6.43 to -0.89)	0.01
Increase in percent from baseline at 24th h	5.42	8.04		0.39
Postoperative DOF 48th h	103.75±7.73	105.45±7.70	-0.17 (-5.43 to 2.04)	0.37
increase in percent from baseline at 48th h	31.38	31.09		0.96

MVIC=maximal voluntary isometric contraction, DOF=degree of flexion. Data were presented as mean (SD). P<0.025 was considered statistically significant for noninferiority

Table 3: Comparison of postoperative pain scores (NRS)

Parameter	Group I Mean (SD)	Group II Mean (SD)	Mean difference (95% confidence interval of difference)	*P*
Preoperative NRS	7.60±0.66	7.38±0.90	0.22 [-0.16 to 0.60]	0.25
Postoperative 0 h	3.40±0.66	3.10±0.75	0.30 [-0.04 to 0.64]	0.08
Postoperative 1st h	2.45±0.59	3.04±0.79	-0.59 [0.92 to -0.25]	0.00
Postoperative 6th h	3.10±0.63	3.03±0.67	0.07 [-0.24 to 0.38]	0.73
Postoperative 12th h	3.15±0.57	2.86±0.64	0.29 [-0.01 to 0.58]	0.05
Postoperative 24th hour rest	3.20±0.68	3.10±0.61	0.1 [-2.1 to 0.41]	0.52
Postoperative 24th h movement	3.85±0.65	3.86±0.35	-0.01 [-0.26 to 0.24]	0.93
Postoperative 36th h	3.90±0.44	3.76±0.43	0.14 [-0.07 to 0.35]	0.19
Postoperative 48th h	3.30±0.46	3.14±0.47	0.16 [-0.07 to 0.39]	0.16

NRS=Numerical Rating Scale. Data were presented as mean (SD). P<0.025 was considered statistically significant for noninferiority

or chest infections, decreases the duration of hospital stay and increases the quality of life. Effective and ideal analgesia after knee arthroplasties should be the one that control the postoperative pain, and decrease opioids usage and results in early ambulation.

Several studies have been done in the past using two different drug volumes for peripheral nerve blocks. The study by Nakayama *et al.* for determining the dose of anesthetic agents and the effective interval from block procedure to skin incision for ultrasound-guided supraclavicular brachial plexus block, on 255 patients undergoing upper limb surgeries concluded that changing the different drug volumes and its concentration did not affect the analgesia but changes the onset time of block procedure to skin incision.[12] There are only very few studies dealing with the drug volumes for effective ACB and that too are conducted on healthy volunteers.[13]

The study by Anderson *et al.* on 15 unembalmed cadavers indicated that 15 mL of dye was sufficient to spread throughout the adductor canal and beyond both proximally and distally.[14] Also, the previous case report by Davis *et al.* suggested that 15 mL of drugs adequately filled the canal in cadavers.[15] Another important study by Jaeger *et al.*

helped in determining the optimal volume of local anesthetic for ACBs.[16] They used a continual assessment method with the help of MRI for measuring the minimal effective dose (ED_{95}) for anesthetic effect in 95% of individuals. They concluded that 20 mL of 1% lignocaine was enough in 40 healthy individuals to fill the canal distally and proximal spread was detected in 0/4 (0%), 7/12 (58%), 4/8 (50%), and 8/16 (50%) with 5, 10, 15, and 20 mL of drug by MRI. Thus, it helped us designing our study and using 10 and 20 mL of drug volume in study groups.

Study on matched healthy volunteers had been done in the past and quadriceps strength affection has been determined after giving different volumes of local anesthetics in ACB.[13,16] But no correlation between the volume and muscle weakness was found. Jaeger *et al.* in their comparative, randomized, blinded trial used 10 mL of 0.1% ropivacaine in one group and in the other group they used 30 mL of the same drug.[13] They concluded that changing the volume of the drug between the subjects from 30 to 10 mL did not have any clinically significant or statistically relevant effect on the quadriceps weakness. This finding is very well consistent with our study using 10 mL versus 20 mL of 0.5% ropivacaine for postoperative analgesia in the respective groups.

The cadaveric studies suggesting 15 mL of drug is adequate for filling up the adductor canal can also be questioned.[14] This is because firstly, the cadaveric tissues lose its elasticity and secondly, the femurs were cut open close to the femoral triangle which might have caused pressure alterations thereby affecting the injectate volume and its proximal extent. This may result in a profound bias for our results as we also tried to extrapolate the 10 mL drug volume usage from a cadaveric study to our study on human subjects. Again, the volume of 20 mL as an effective volume for ACB has been tested in healthy volunteers in the previous study cannot also be extrapolated for our study group among geriatric patients as they differ in the BMI as well as their physiology. [13] So, we did expect an extravasation of 20 mL drug into femoral triangle in these patients and a substantial quadriceps muscle weakness because of the reduced tissue elasticity. Although there are evidence of weaknesses of quadriceps muscle published in the literature, we did not observe any patients with such consequences affecting their postoperative rehabilitation.[17] This may be explained, by the fact that the quadriceps muscle weakness was not significant enough and moreover the weakness in one limb is often being compensated because of the fair quadriceps power in the contralateral limb, masking the overall muscle weakness. Also, during the course of the study period, there have been no cases of postoperative falls in the immediate rehabilitation phase.

Limitations

There had been also studies focusing on continuous basal infusion versus automated repeated bolus doses of anesthetic agents for ACBs by Monahan *et al.* and they suggested that either of the ways are sufficient and equally effective for cutaneous anesthesia in cases of ACBs using perineural catheter.[18] Hence following this we also conducted the study using intermittent bolus doses of drugs for adequate and effective analgesia. However, as also pointed out in the study by Jaeger *et al.* fixed pressure should be advocated for drug injection.[13] We also feel that a predetermined pressure for drug injection should have made our study even stronger, and this is one of our limitations. The fact that we tried to establish the result using a decreased drug volume whether it leads to better preservation of quadriceps control, without affecting the sensory anesthesia after ACBs it forms one important pillar for our study. Total drug dose forms an important aspect for the pharmacodynamics of local anesthetics, and this had been addressed properly in our study, using two different drug volumes for studying the effectiveness of ACB.[19] Apart from using a fixed pressure for injections during ACBs, the smaller sample size of patients enrolled in our study forms the limitations for our study.

Conclusion

Both the volumes of drugs used are equally effective in providing adequate postoperative analgesia without hampering the quadriceps muscle strength. There is no requirement of any more increase in drug volume for distal spread and the cutaneous block of medial femoral cutaneous nerve or obturator nerve. There is also minimal proximal spread into the femoral triangle and femoral nerve blockade chances, using both the aforementioned drug volumes for ACBs.

Conflicts of interest

There are no conflicts of interest.

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