Original Article

Adductor canal block for post-operative analgesia after simultaneous bilateral total knee replacement: A randomised controlled trial to study the effect of addition of dexmedetomidine to ropivacaine

Address for correspondence:
Dr. Rakhee Goyal, Department of Anaesthesia and Critical Care, Army Hospital (Research and Referral), New Delhi, India.
E-mail: rakheegoyalkumar@gmail.com

Rakhee Goyal, Gaurav Mittal[1], Arun Kumar Yadav[2], Rishab Sethi, Animesh Chattopadhyay

Departments of Anaesthesia and Critical Care and [1]Orthopaedics, Army Hospital (Research and Referral), [2]Department of Community Medicine, All India Institute of Medical Sciences, New Delhi, India

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ABSTRACT

Background and Aims: Knee replacement surgery causes tremendous post-operative pain and adductor canal block (ACB) is used for post-operative analgesia. This is a randomised, controlled, three-arm parallel group study using different doses of dexmedetomidine added to ropiavcaine for ACB. **Methods:** A total of 150 patients aged 18–75 years, scheduled for simultaneous bilateral total knee replacement, received ultrasound-guided ACB. They were randomised into three groups -Group A received ACB with plain ropivacaine; Groups B and C received ACB with ropivacaine and addition of dexmedetomidine 0.25 μg/kg and 0.50 μg/kg, respectively, on each side of ACB. The primary outcome was the duration of analgesia. Total opioid consumption, success of early ambulation, and level of patient satisfaction were also assessed. **Results:** The patient characteristics and block success rates were comparable in all groups. Group C patients had longer duration of analgesia (Group C 18.4 h ± 7.4; Group B 14.6 ± 7.1; Group A 10.8 ± 7; $P < 0.001$); lesser tramadol consumption (Group C 43.8 mg ± 53.2; Group B 76.4 ± 49.6; Group A 93.9 mg ± 58.3; $P < 0.001$) and lesser pain on movement ($P < 0.001$). The patients in Group B and C walked more steps than in Group A ($P < 0.002$). The level of patient satisfaction was highest in Group C ($P < 0.001$). **Conclusions:** The addition of dexmedetomidine to ropivacaine resulted in longer duration of analgesia after adductor canal block for simultaneous bilateral total knee replacement surgery.

Key words: Arthroplasty, replacement, knee, dexmedetomidine, diagnostic imaging, nerve block, ropivacaine

INTRODUCTION

Total knee replacement (TKR) surgery is associated with severe post-operative pain. Multimodal analgesia facilitates early ambulation and rehabilitation, reduced hospital stay and cost of treatment and increased patient satisfaction. Studies in the recent past have shown promising results of adductor canal block (ACB) in volunteers, and in patients after various surgeries on the knee.[1,2] They have demonstrated good post-operative analgesia and significantly better quadriceps muscle strength compared to femoral nerve block and psoas compartment block.

The present study was designed to evaluate the duration of analgesia after ACB for simultaneous bilateral TKR (SBTKR) surgery.

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METHODS

The study was a randomised, controlled, three-arm parallel group study and conducted in a high volume joint replacement centre in New Delhi, India. The institutional ethics committee of the hospital approved it. The study was conducted from April 2016 to March 2017 and was compiled in accordance with the consolidated standards of reporting trials CONSORT guidelines.

All the patients, aged 18–75 years, body mass index 20–35 kg/m^2, in the American Society of Anesthesiologists' I–II, scheduled for SBTKR were enrolled in the study. The exclusion criteria included known allergy to any of the study drugs; patients on recent oral opioids in the last 3 months; pregnancy; patients in whom the nerve block could not be performed as per the methodology; and any cognitive dysfunction. After explaining the study preoperatively in detail, a research assistant took written consent from all the patients.

The patients received oral paracetamol 500 mg, pregabalin 75 mg and etoricoxib 90 mg, on the night before surgery. After overnight fasting, all the patients were given a subarachnoid block for the surgery with 2.5 ml 0.5% hyperbaric bupivacaine and 25 μg fentanyl. They received 8 mg intravenous (IV) dexamethasone as per institutional protocol. General anaesthesia was given in those patients where subarachnoid block was contraindicated, or who either had the inadequate effect of subarachnoid block or the surgery extended beyond the duration of the block. Fentanyl 2 μg/kg IV was used for analgesia in these cases. The same team of orthopaedic surgeons performed all the surgeries. IV paracetamol 15 mg/kg was given at the end of the surgery and then orally, thrice a day postoperatively. After the completion of surgery, the patients were shifted to the block-procedure room. The attending anaesthesiologist who had an experience of minimum 25 such blocks gave the ACB.

An independent researcher generated the randomisation code on the basis of a computer-generated randomisation table using www.graphpad.com. Each patient allocation was put in a serially numbered opaque sealed envelope and handed over by the research assistant to the procedure room anaesthesiologist. The anaesthesiologist incharge of the case who performed the block was blinded to the group allocated. The assessor was the nurse and the physiotherapist of the ward, both blinded to the study groups. The patient and the surgeon were also blinded to the study group allocation. Data analysis was independent of treatment allocation.

The block solution was made in a 20 ml syringe for each group. Each syringe had 10 ml ropivacaine 7.5 mg/ml. In addition, in Group A, the syringe contained 10 ml saline; Group B and Group C had 0.25 μg/kg DEX and 0.5 μg/kg DEX, respectively. The required amount of saline was added in Group B and C syringes to make the volume of 20 ml. One syringe was used for each side. The anaesthesiologist incharge of the procedure room was given the study group allocation in a sealed envelope, and he or she prepared the drugs according to the study protocol. Each 20 ml syringe was labelled with the patient number, date and surgery, but not the designated group.

The patient was positioned with both lower limbs slightly abducted at the hips and flexed at the knees. At the level of mid-thigh, an ultrasound-guided ACB was performed successively on both operated sites. The block sites were prepped with chlorhexidine. Local lignocaine infiltration was used for surgeries that were done under general anaesthesia. A linear ultrasound probe (7 L4P, 5–10 MHz; Mindray Z 6, Shenzhen Mindray Biomedical Electronics Ltd, Shenzhen, China), covered in a sterile dressing was transversely placed to visualise the adductor canal. As shown in Figure 1, these structures were identified on the ultrasound-boat shaped sartorius muscle, femoral artery (pulsatile) and femoral vein (compressible by the probe), the latter two also confirmed on Doppler mode. A 21-gauge 10 cm short bevel needle (Stimuplex, B Braun Medical Inc., USA) was used in plane with the

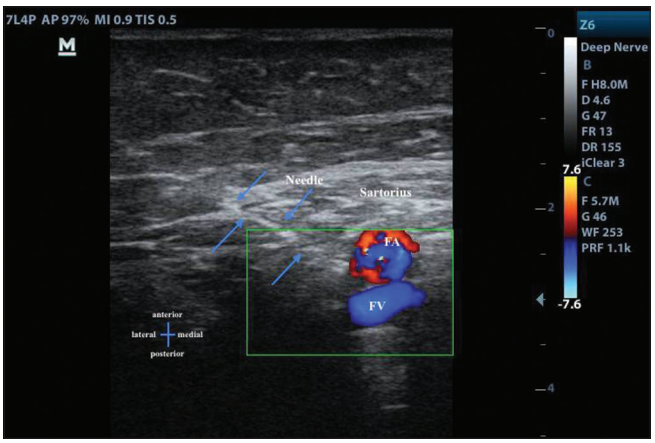

Figure 1: Ultrasound image showing important landmarks for the adductor canal block. FA – Femoral artery; FV – Femoral vein

transducer, from lateral to medial, with the needle tip targeted anterolateral to the femoral artery and below the sartorius. A bolus of 2 ml of normal saline was used to confirm the location of needle tip. A volume of 20 ml of block solution was injected in 5 ml aliquots through the injection port of the needle after a careful negative aspiration. The spread of the drug between the sartorius and the femoral artery was seen real time on ultrasound [Figure 2].

The patients were observed by the anaesthesia resident for 60 min in the procedure room. Heart rate (HR), arterial blood pressure (BP) and SpO_2 were monitored continuously and noted at 15 min interval for the 1st h after the block, and then 6-hourly for the next 24 h.

As a part of multimodal analgesia, pregabalin 75 mg, etoricoxib 90 mg, and ranitidine 150 mg were given orally to all the patients on the evening after surgery and then repeated twice a day for the next two days. Numeric Rating Scale (1–10, 1 being the least and 10 being the worst pain described by the patient) was used to assess pain at 6, 12, 18 and 24 h during the post-operative period. If the patient complained of pain and demanded relief, IV tramadol 100 mg was administered. Ondansetron 4 mg was added intravenously if tramadol was used. Time to first rescue analgesia and the total tramadol consumption in 24 h were noted.

The ward nurse collected the data in the post-operative period such as HR, BP and SpO_2. Bradycardia and hypotension were defined as 20% decreases from the baseline HR and mean arterial pressure and were treated with atropine and IV fluids, respectively. Any adverse event such as nausea, vomiting, shivering, giddiness, local pain, paraesthesia, or signs of local anaesthetic systemic toxicity were noted. A physiotherapist assessed quadriceps motor strength by straight leg raise on a 0–5 scale pre-operatively and then at 24 h after the block as per the Medical Research Council Scale[3] (0 = no voluntary contraction possible, 1 = muscle flicker, but no movement of limb, 2 = active movement only with gravity eliminated, 3 = movement against gravity but without resistance, 4 = movement possible against some resistance and 5 = normal motor strength against resistance). The patients were assisted to ambulate with support by the physiotherapist when motor strength was ≥ 2 at 24 h. The ward nurse noted the time of ambulation and the number of steps that the patient could walk. She also noted the patient satisfaction score at 72 h postoperatively; 1 - not satisfied, 2 – satisfied and 3 - better than expected. At this time, the patients were also asked about any paraesthesia, numbness or pain in the thigh. Both the nurse and the physiotherapist were blinded to the study groups.

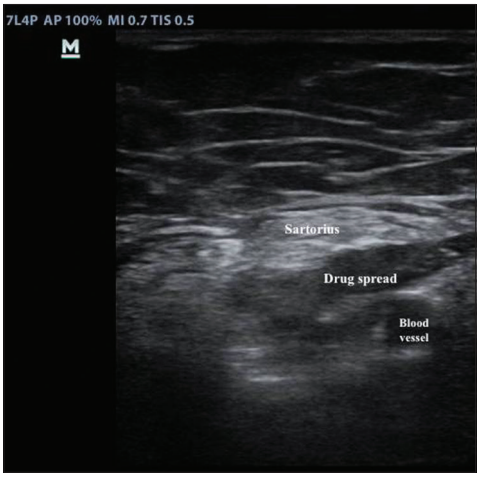

Figure 2: Ultrasound image showing the spread of drug below the sartorius and lateral to femoral vessels

The primary outcome of the study was the duration of analgesia. The secondary outcomes included total 24 h opioid consumption, success of early ambulation, level of patient satisfaction and any adverse effects following the study intervention.

The sample size was calculated on the assumption that addition of dexmedetomidine (DEX) will increase the duration of analgesia by 50%, level of significance as 0.05, power as 80% and error (within-group variance) as 70 for a mean contrast comparing means of the first two groups, assuming equal group sizes. Total sample size was calculated as 135 i.e. 45 in each group. However, 200 cases were enrolled to cover for any dropouts. The results were analysed using STATA version 13 IC (StataCorp. 2013. Stata Statistical Software: Release 13. College Station, TX: StataCorp LP). The level of statistical significance was taken at 0.05.

Baseline difference among three groups was analysed by univariate analysis of variance (ANOVA) for a continuous variable, Kruskal–Wallis test for non-parametric data, or by Chi-square test for a categorical variable. Intention to treat was used to analyse efficacy parameters. ANOVA was done to assess the difference between the duration of analgesia and average step walked after 24 h, and Bonferroni test

was applied for the difference between two groups if ANOVA was significant.

RESULTS

Enrolment of participants was carried out between April 2016 and March 2017. A detail of flow of the participants is shown in Figure 3. The basic characteristics of the parameters of the participants are shown in Table 1. A subarachnoid block was given to all patients except in two cases (patient refusal) in Group A, three cases (two-patient refusal; one-general anaesthesia given because subarachnoid block was inadequate during surgery) in Group B, and one patient (patient refusal) in Group C. The duration of surgery was 97 ± 15 min. ACB was successfully given as per protocol in all the cases. The duration of analgesia (time between the block and rescue analgesia) was highest in Group C (mean 18.4 h ± 7.4). Bonferroni test showed a statistically significant difference between Group A and C ($P < 0.001$) and comparable results between Group A and B ($P < 0.023$); and B and C groups ($P < 0.028$). The number of patients who required rescue analgesic [Table 1] and the total amount of opioid consumed in 24 h was lowest in Group C.

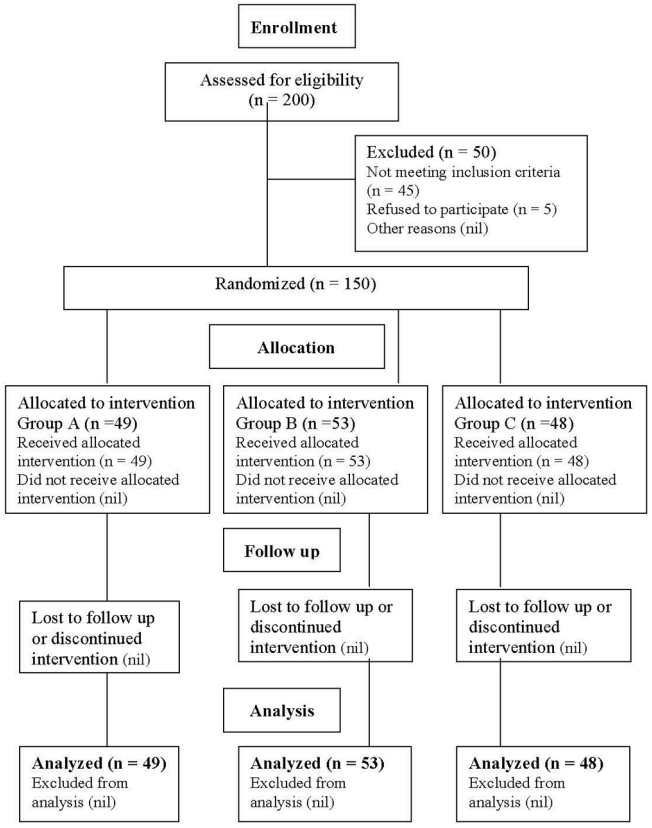

Figure 3: CONSORT diagram showing the flow of patients in the study

Patients in Group C experienced lesser pain both at rest and on movement as compared to the other groups during the first 24 h in the post-operative period [Table 2]. There was statistically significant difference among three groups for pain rest (left) and pain movement (right and left) ($P = 0.002$, <0.001 and <0.001, respectively). The pain score was consistently higher in Group A as compared to Group B and Group C.

The motor strength of quadriceps was comparable on both sides in all the groups 24 h after the block. All the patients were able to walk on the post-operative day 1 morning. The number of steps walked by the patients was more in Group C as compared to Group A ($P = 0.002$). The difference between Group A and B was also statistically significant but not between Group B and C ($P = 0.9$). Figure 4 shows a graphical representation of the duration of analgesia, amount of tramadol used and number of steps walked in Group A, B and C.

The HR, BP, SpO_2 and post-operative adverse effects were comparable among all the three groups. There was no local anaesthetic systemic toxicity in any of the groups.

No patient reported any paraesthesia or pain in the thigh following ACB during 72 h postoperatively. *Post hoc* analysis showed statistically significant number of patients with a level of satisfaction 1 ($P = 0.002$) in Group A, and level of satisfaction 3 in Group C ($P = 0.005$) as shown in Table 1.

DISCUSSION

The study shows that first, ACB could be successfully given in all cases with technical ease using ultrasound guidance; second, early ambulation is possible with ACB after bilateral TKR surgery; and third, ambulation is better with better pain relief (Group C > B > A). The study also shows that the addition of DEX to ropivacaine in ACB up to 1 μg/kg does not affect the HR, blood pressure and SpO_2.

The patients who require bilateral knee replacement either undergo staged surgery i.e. two surgeries, one in each knee, at two separate occasions in one hospital admission; or simultaneous bilateral surgery under one anaesthesia. The SBTKR involves single anaesthesia exposure, single rehabilitation period, single hospital stay and reduced overall cost.[4] This is likely to lead to

Table 1: Basic characteristics of the participants and post-operative outcomes

Characteristic	Group A (*n*=49)	Group B (*n*=53)	Group C (*n*=48)	*P*
Age (years), mean (SD)	66.6 (8.4)	63.5 (8.7)	65 (7.9)	0.2*
Sex female, *n* (%)	32 (65.3)	29 (54.7)	27 (56.25)	0.5**
BMI, mean (SD)	25.7 (3)	25.7 (2.9)	25 (2.6)	0.4*
ASA (I/II/III)	32/17	34/19	35/13	0.6**
Baseline HR	66.9 (11)	66.4 (8.7)	67.8 (10)	0.8*
Baseline MAP	115 (12.8)	113 (11.6)	114 (12.4)	0.9*
Spinal/GA	47/2	50/3	47/1	0.8****
Motor strength (left)				
Mean (SD)	2.5 (0.5)	2.8 (0.7)	2.8 (0.6)	0.05***
Median (IQR)	2 (2-3)	3 (2-3)	3 (2-3)	
Motor strength (right)				
Mean (SD)	2.7 (0.7)	2.8 (0.7)	2.7 (0.6)	0.6***
Median (IQR)	3 (2-3)	3 (2-3)	3 (2-3)	
Patients with opioid requirement postoperatively, *n* (%)	40 (81.6)	40 (75.5)	21 (43.8)	<0.001**
Level of satisfaction, *n* (%)				
1	12 (24.5)	3 (5.7)	4 (8.3)	<0.001**
2	34 (69.4)	31 (58.5)	23 (47.9)	
3	3 (6.1)	19 (35.8)	21 (43.8)	
Post-operative nausea and vomiting, *n* (%)	4 (8.1)	3 (5.7)	1 (2)	0.7***

*ANOVA; **Chi-square test; ***Kruskal-Wallis test; ****Fisher exact test. IQR – Inter quartile range; HR – Heart rate; MAP – Mean arterial pressure; GA – General anaesthesia; SD – Standard deviation, ANOVA – Analysis of variance; BMI – Body mass index; ASA – American Society of Anesthesiologists

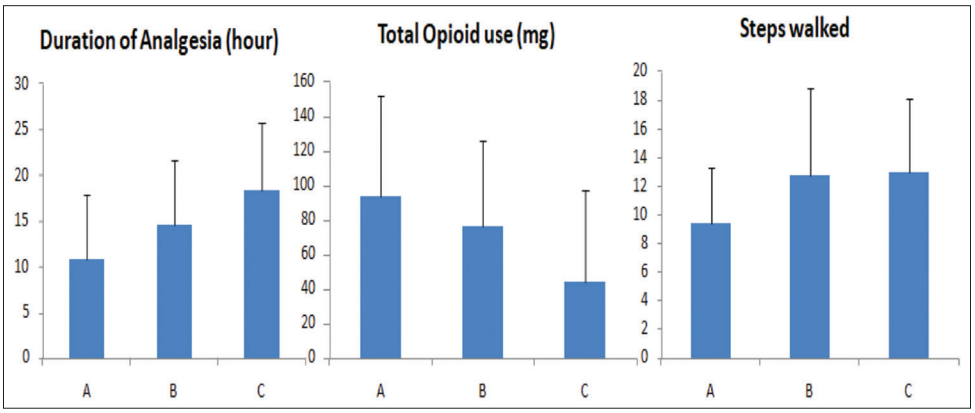

Figure 4: Bar diagrams showing duration of analgesia, amount of opioid (tramadol) administered and number of steps walked on first postoperative day

better patient satisfaction and lower treatment costs, therefore, better outcome.[5-7]

In a multi-centric feasibility study to assess the clinical and functional outcomes of SBTKR, 123 patients who were operated in five different centres over a period of 7 years.[8] There was no increased risk established for unilateral TKR as compared to the rates published in the literature. However, in another study a number of patient-related risk factors were identified for major morbidity and mortality following bilateral TKR and it was suggested that these factors be used as criteria for patient selection.[9] Several studies have shown good analgesia and better quadriceps strength with ACB for unilateral TKR.[10-16] Unlike the previous studies, the present study was designed to assess the duration of analgesia with ACB following SBTKR using ropivacaine and two different doses of dexmedetomidine.

The saphenous nerve, primarily a sensory nerve, is the main nerve that is blocked in the adductor canal at the level of mid-thigh. It is postulated that some other nerves such as nerve to vastus medialis, medial femoral cutaneous nerve, obturator nerve (articular branches) and medial retinacular nerve also traverse through the adductor canal and will have a motor component.[17] Ropivacaine is less lipophilic than bupivacaine and less likely to penetrate large myelinated motor fibres.[18] Theoretically, ropivacaine will have a lesser motor blockade in ACB, and therefore, we hypothesised that there would be better ambulation after surgery. In a similar study, 100 mg ropivacaine was used in ACB along

Table 2: Post-operative clinical parameters

Parameter	Group	Baseline	15 min	30 min	45 min	60 min	6 h	12 h	18 h	24 h	*P*	Partial *et al*[2]
HR	A N=49	66.9 (11)	66.5 (11.3)	68.9 (8.9)	70.5 (7.3)	71.8 (6.8)	72.6 (6.9)	74.7 (6.4)	74.7 (5.4)	75.5 (6.2)	0.9	0.001
	B N=53	66.4 (8.7)	66.2 (9.1)	67.7 (8.2)	69.8 (8.3)	71.9 (8)	74.4 (6.1)	74.5 (6)	75.7 (5.4)	75.9 (4.9)		
	C N=48	67.8 (9.6)	67.5 (9.1)	68.6 (6.6)	70 (5.3)	71.2 (5.7)	71.3 (5.7)	74.3 (6.4)	74.3 (5.8)	73.8 (5.2)		
MAP	A N=49	115 (12.8)	116 (13.8)	116 (12.2)	120 (12.1)	120 (11.5)	121 (11.2)	122 (14.4)	122 (12.7)	120 (12.3)	0.9	0.002
	B N=53	113 (12.6)	100 (12.1)	101 (13.5)	100 (11.7)	98 (11.7)	116 (13.2)	115 (13.2)	116 (10.8)	118 (12.1)		
	C N=48	114 (11.4)	100 (16.4)	100 (15.2)	101 (12.6)	98 (13.8)	104 (12.5)	106 (10.9)	110 (12.5)	120 (12.8)		
Pain rest (right)	A N=49	-	-	-	-	-	4.2 (1.2)	3.7 (1)	3.4 (0.8)	3.6 (1.1)	0.3	0.06
	B N=53	-	-	-	-	-	3.5 (1.4)	3.7 (1.2)	3.3 (0.9)	3.3 (1)		
	C N=48	-	-	-	-	-	2.8 (1.4)	3.4 (1.3)	3.5 (1.2)	3.6 (1)		
Pain rest (left)	A N=49	-	-	-	-	-	4.5 (1.2)	3.7 (0.9)	3.5 (0.7)	3.6 (1)	0.002	0.13
	B N=53	-	-	-	-	-	3.7 (1.3)	3.7 (1.2)	3.3 (0.9)	3.4 (1)		
	C N=48	-	-	-	-	-	3.1 (1.4)	3.4 (1.2)	3.4 (1)	3.5 (1.1)		
Pain on movement (right)	A N=49	-	-	-	-	-	5.8 (1.1)	5.2 (1.1)	4.5 (0.8)	4.7 (0.9)	<0.001	0.28
	B N=53	-	-	-	-	-	5.2 (1.5)	4.9 (1.3)	4.3 (0.8)	4.5 (0.8)		
	C N=48	-	-	-	-	-	4.5 (1.7)	4.5 (1.2)	4.3 (0.9)	4.5 (0.8)		
Pain on movement (left)	A N=49	-	-	-	-	-	6.3 (1.3)	5.1 (1)	4.5 (0.8)	4.7 (0.9)	<0.001	0.17
	B N=53	-	-	-	-	-	5.1 (1.6)	5.2 (1.3)	4.3 (0.8)	4.4 (0.9)		
	C N=48	-	-	-	-	-	4.6 (1.9)	4.5 (1.5)	4.3 (0.9)	4.4 (0.9)		

Data expressed as mean (SD). SD – Standard deviation; HR – Heart rate; MAP – Mean arterial pressure

with local infiltration analgesia (300 mg ropivacaine) for unilateral TKR. They found better analgesia and greater distance walked as compared to the continuous femoral nerve block. The rate of home discharge was also higher in the patients who received ACB.[19]

DEX has been used in many studies as an additive to local anaesthetics for peripheral nerve blocks with good results.[20-22] In this study, longer duration of analgesia and lesser opioid consumption was seen with DEX. Better analgesia, lower opioid consumption, better ambulation and minimal adverse effects are the possible contributory factors for higher satisfaction. Further studies with larger sample size may be required to establish the safety of ACB with additives like DEX for bilateral blocks.

It is likely that the haemodynamic parameters and pain in the early post-operative period may have been affected in cases where general anaesthesia was given. This may be considered as a limitation of the study.

CONCLUSIONS

The addition of dexmedetomidine to ropivacaine results in longer duration of analgesia after adductor canal block for simultaneous bilateral total knee replacement surgery.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/

her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Nil.

Conflicts of interest

There are no conflicts of interest.

REFERENCES

1. Jaeger P, Nielsen ZJ, Henningsen MH, Hilsted KL, Mathiesen O, Dahl JB, *et al.* Adductor canal block versus femoral nerve block and quadriceps strength: A randomized, double-blind, placebo-controlled, crossover study in healthy volunteers. Anesthesiology 2013;118:409-15.
2. Abdallah FW, Whelan DB, Chan VW, Prasad GA, Endersby RV, Theodoropolous J, *et al.* Adductor canal block provides noninferior analgesia and superior quadriceps strength compared with femoral nerve block in anterior cruciate ligament reconstruction. Anesthesiology 2016;124:1053-64.
3. Compston A. Aids to the investigation of peripheral nerve injuries. Medical Research Council: Nerve Injuries Research Committee. His Majesty's Stationery Office: 1942; pp 48 (iii) and 74 figures and 7 diagrams; with aids to the examination of the peripheral nervous system. By Michael O'Brien for the Guarantors of Brain. Saunders Elsevier: 2010; pp. [8] 64 and 94 figures. Brain 2010;133:2838-44.
4. Bohm ER, Molodianovitsh K, Dragan A, Zhu N, Webster G, Masri B, *et al.* Outcomes of unilateral and bilateral total knee arthroplasty in 238,373 patients. Acta Orthop 2016;87 Suppl 1:24-30.
5. Fu D, Li G, Chen K, Zeng H, Zhang X, Cai Z, *et al.* Comparison of clinical outcome between simultaneous-bilateral and staged-bilateral total knee arthroplasty: A systematic review of retrospective studies. J Arthroplasty 2013;28:1141-7.
6. Odum SM, Troyer JL, Kelly MP, Dedini RD, Bozic KJ. A cost-utility analysis comparing the cost-effectiveness of simultaneous and staged bilateral total knee arthroplasty. J Bone Joint Surg Am 2013;95:1441-9.
7. Macario A, Schilling P, Rubio R, Goodman S. Economics of one-stage versus two-stage bilateral total knee arthroplasties. Clin Orthop Relat Res 2003;414:149-56.
8. Jenny JY, Trojani C, Prudhon JL, Vielpeau C, Saragaglia D, Houillon C, *et al.* Simultaneous bilateral total knee arthroplasty. A multicenter feasibility study. Orthop Traumatol Surg Res 2013;99:191-5.
9. Memtsoudis SG, Ma Y, Chiu YL, Poultsides L, Gonzalez Della Valle A, Mazumdar M, *et al.* Bilateral total knee arthroplasty: Risk factors for major morbidity and mortality. Anesth Analg 2011;113:784-90.
10. Kim DH, Lin Y, Goytizolo EA, Kahn RL, Maalouf DB, Manohar A, *et al.* Adductor canal block versus femoral nerve block for total knee arthroplasty: A prospective, randomized, controlled trial. Anesthesiology 2014;120:540-50.
11. Patterson ME, Bland KS, Thomas LC, Elliott CE, Soberon JR Jr., Nossaman BD, *et al.* The adductor canal block provides effective analgesia similar to a femoral nerve block in patients undergoing total knee arthroplasty – A retrospective study. J Clin Anesth 2015;27:39-44.
12. Grevstad U, Mathiesen O, Valentiner LS, Jaeger P, Hilsted KL, Dahl JB, *et al.* Effect of adductor canal block versus femoral nerve block on quadriceps strength, mobilization, and pain after total knee arthroplasty: A randomized, blinded study. Reg Anesth Pain Med 2015;40:3-10.
13. Jaeger P, Grevstad U, Henningsen MH, Gottschau B, Mathiesen O, Dahl JB, *et al.* Effect of adductor-canal-blockade on established, severe post-operative pain after total knee arthroplasty: A randomised study. Acta Anaesthesiol Scand 2012;56:1013-9.
14. Jæger P, Zaric D, Fomsgaard JS, Hilsted KL, Bjerregaard J, Gyrn J, *et al.* Adductor canal block versus femoral nerve block for analgesia after total knee arthroplasty: A randomized, double-blind study. Reg Anesth Pain Med 2013;38:526-32.
15. Hanson NA, Allen CJ, Hostetter LS, Nagy R, Derby RE, Slee AE, *et al.* Continuous ultrasound-guided adductor canal block for total knee arthroplasty: A randomized, double-blind trial. Anesth Analg 2014;118:1370-7.
16. Jenstrup MT, Jæger P, Lund J, Fomsgaard JS, Bache S, Mathiesen O, *et al.* Effects of adductor-canal-blockade on pain and ambulation after total knee arthroplasty: A randomized study. Acta Anaesthesiol Scand 2012;56:357-64.
17. Lund J, Jenstrup MT, Jaeger P, Sørensen AM, Dahl JB. Continuous adductor-canal-blockade for adjuvant post-operative analgesia after major knee surgery: Preliminary results. Acta Anaesthesiol Scand 2011;55:14-9.
18. Kuthiala G, Chaudhary G. Ropivacaine: A review of its pharmacology and clinical use. Indian J Anaesth 2011;55:104-10.
19. Perlas A, Kirkham KR, Billing R, Tse C, Brull R, Gandhi R, *et al.* The impact of analgesic modality on early ambulation following total knee arthroplasty. Reg Anesth Pain Med 2013;38:334-9.
20. Das A, Majumdar S, Halder S, Chattopadhyay S, Pal S, Kundu R, *et al.* Effect of dexmedetomidine as adjuvant in ropivacaine-induced supraclavicular brachial plexus block: A prospective, double-blinded and randomized controlled study. Saudi J Anaesth 2014;8:S72-7.
21. Marhofer P, Brummett CM. Safety and efficiency of dexmedetomidine as adjuvant to local anesthetics. Curr Opin Anaesthesiol 2016;29:632-7.
22. Marhofer D, Kettner SC, Marhofer P, Pils S, Weber M, Zeitlinger M, *et al.* Dexmedetomidine as an adjuvant to ropivacaine prolongs peripheral nerve block: A volunteer study. Br J Anaesth 2013;110:438-42.