ORIGINAL ARTICLE

Safety and Efficacy of Magnesium Sulfate Added to Levobupivacaine in Ultrasound-Guided Adductor Canal Block for Post-operative Analgesia in Patient Subjected to Total Knee Arthroplasty

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ABSTRACT

Background: Total knee arthroplasty (TKA) which is among the most frequent procedures performed by orthopedic surgeons, usually carried out in more advanced age groups and severe pain occurs postoperatively which is difficult to be controlled with oral analgesics. Adding adjuvant to local anesthesia as magnesium in adductor canal block (ACB) could be a method to prolong the duration of the block. The aim of the study was to study the analgesic efficacy magnesium added to levobupivacaine in ultrasound-guided ACB for patients undergoing elective TKA. **Materials and Methods:** Sixty patients (American Society of Anesthesia [ASA] II-III) of either sex were scheduled for elective TKA surgeries under subarachnoid block using heavy bupivacaine 15 mg. Patients were randomly allocated into three groups (20 patients each), to receive subarachnoid block using heavy bupivacaine fentanyl 25 mic Group C, ultrasound-guided adductor canal block using levobupivacaine 0.25% in 20 ml volume Group L, or levobupivacaine 0.25% in 18 ml added to plus 2 ml magnesium sulfate 10% (200 mg) Group ML. Post-operative pain was assessed over 24 h using numerical rating scale (NRS) scale plus time of first analgesic request and overall post-operative analgesics consumption was recorded. The intra and post-operative hazard ratio (HR) and mean arterial blood (MAP) were recorded. Any concomitant complications were observed postoperatively. **Results:** As regard patient demographic data and ASA grades, we found that there were no significant changes between the two groups. Patient hemodynamic parameters intraoperative were comparable in the three groups ($P = 0.47$) but post-operative HR and MAP were optimized in both L and LM groups ($P = 0.0.03$*). There was a significant decrease in NRS pain scores in Group LM during the 1st day post-operative ($P = 0.000$*) and post-operative analgesic consumption much more decreased in Group LM in comparison to Group C ($P = 0.000$*). We found that the time of the 1st request of analgesia in Group C was 6.13 ± 1.008 h while it was 9.27 ± 0.9 and 15.35 ± 0.4 h in Group L and Group LM, respectively, the analgesic consumption between the three groups was significant being the lowest in Group LM ($P < 0.000$*). **Conclusion:** Ultrasound-guided femoral nerve block improves post-operative analgesia and the addition of fentanyl to levobupivacaine in femoral nerve block prolonged the duration of block and decreased analgesic requirements in patient subjected to total knee replacement surgery.

Key words: Acute post-operative pain, Adductor canal block, Levobupivacaine, Magnesium sulfate, Numerical rating scale score, Total knee arthroplasty

INTRODUCTION

Total knee arthroplasty (TKA) which is among the most frequent procedures performed by orthopedic surgeons, usually carried out in more advanced age groups and severe pain occurs postoperatively which is difficult to be controlled with oral analgesics. Under managed pain prevents early mobilization of the knee joint that can be both physically and psychologically stressful for patients and can lead to serious cardiac, pulmonary, and renal

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problems due to endocrine, metabolic, and inflammatory responses.[1-4]

This is why early ambulation and physical therapy are essential for functional recovery and long-term functional outcome after TKA as well as for reducing the immobility-related complications. Many methods used to control post-operative pain as integrated multimodal analgesic protocols, preemptive analgesia using nonsteroidal anti-inflammatory drugs (NSAIDs), or opioid and local anesthetic infiltration or peripheral nerve block.[5-7]

The neural innervation of the knee joint is highly complex and according to Hilton's law which states that a joint is innervated by the articular branches of the muscles which move the joint so, the articular nerves are derived from the femoral (mainly), obturator, tibial, common peroneal, and recurrent peroneal nerves.[8]

Adductor canal block (ACB) blocks the main sensory contributions from the femoral nerve to the knee, namely, the saphenous nerve and the nerve to vastus medialis while they pass through the adductor canal and because of the small size and the absence of motor component, the conventional nerve localization techniques such as nerve stimulation have inconsistent success.[9,10]

Levobupivacaine which is the levorotatory isomers of bupivacaine has a safer pharmacological profile with less cardiac and neurologic adverse effects.[11]

Magnesium (Mg), a naturally occurring cation in the body and N-methyl-D-aspartate (NMDA) receptor antagonist, Mg sulfate has analgesic effect due to antinociceptive effect which is mediated by control of calcium influx into the cell.[12]

The aim of this prospective study was to evaluate safety and efficacy of Mg sulfate added to levobupivacaine in ultrasound-guided ACB in patients subjected to TKA.

TKAs mostly performed under neuro-axial anesthesia as the patient being often elderly with multiple medical co-morbidities with the following advantages over general anesthesia; less hemodynamic and respiratory instability, better postoperative pain control, and less nausea and vomiting. But the challenges in neuro-axial anaesthesia is how to titrate local anaesthetic (LA) to provide sufficient anaesthesia during surgery while avoiding a dosage that is too low and results in the need for supplemental intravenous opioids or conversion to general anaesthesia.[7-9]

The adductor canal is a pyramidal, musculoaponeurotic tunnel from the apex of the femoral triangle to the adductor hiatus, running between the vastus medialis muscle anterolaterally and the adductor longus and adductor magnus muscles posteromedially. It is roofed in its entire length by the vastoadductor membrane [Figure 1]. The contents of the adductor canal include the superficial artery and vein, saphenous nerve, the nerve to vastus medialis, the posterior branch of the obturator nerve, and in some cases, the medial cutaneous nerve and the anterior branch of the obturator nerve.[10-12]

There is now an increasing desire to undertake regional anesthetic techniques which provide adequate analgesia and reduce morphine consumption without delaying post-operative physiotherapy and rehabilitation. Fentanyl has been added to local anesthetics, with many advantages, increase the success rate of sensory blockade and prolongation of analgesic effects with minimal systematic side effects.[13,14]

The aim of this study was to study the effects of ultrasound-guided femoral nerve block on the severity of post-operative pain in patients undergoing knee joint arthroplasty.

PATIENTS AND METHODS

This is a prospective randomized clinical trial that was conducted in Assiut University Hospitals, after obtaining local ethical committee approval and written consent from all included patients. Sixty patients (American Society of Anesthesia [ASA] II-III), aged between 18 and 60 years old, were scheduled for total knee replacement surgery under spinal anesthesia, who were enrolled in our study from March 2018 to March 2020.

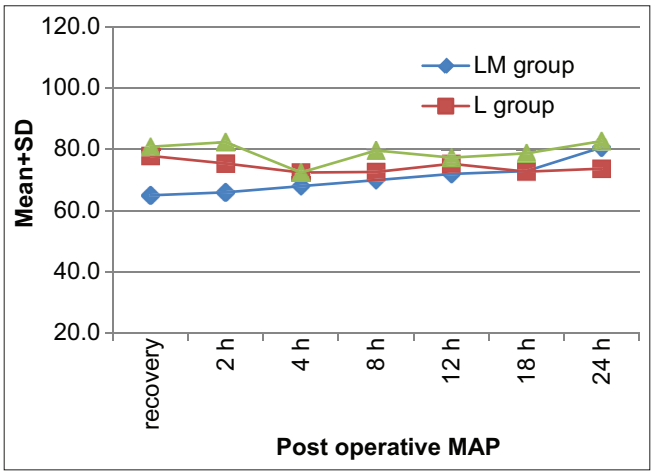

Figure 1: Mean blood pressure changes during post-operative period three studied groups (mmHg). Group LM=Levobupivacaine plus Mg group, Group L =Levobupivacaine group, Group C: Control. Data expressed as Mean ± SD, number and percentage (%). $P < 0.05$ considered statistically significant. Between three groups, there were significant changes regarding patient's MAP being the best optimized in Group ML

The study was conducted in accordance with the principles of the Declarations of Helsinki. The necessary written consents were taken from all participants. Exclusion criteria were patient's refusal, history of allergic reactions to local anesthetics, coagulopathy, and severe cardiac, respiratory, hepatic, or renal disease.

Pre-operative data were collected 2 days before surgery as demographic data, medical, surgical history, physical examination, and routine laboratory investigations. The day before surgery, all patients were taught how to evaluate their own pain intensity using the numerical rating scale (NRS), scored from 0 to 10 (where 0 = no pain and 10=worst pain imaginable).

Two hours before surgery, all patients were informed about pain management strategy after their operation. Moreover, all patients were randomly assigned into three groups (20 patients each) using opaque sealed envelopes containing computer-generated randomization schedule, the opaque sealed envelopes are sequentially numbered that were open before application of anesthetic plan. Patients of all groups were pre-medicated with intravenous midazolam 0.05 mg/kg and ranitidine 50 mg.

After shifting the patient to the induction room, electrocardiogram (ECG), pulse oximeter, and non-invasive blood pressure monitors were attached. Peripheral venous line was established and an infusion of lactated ringers' solution was started.

- Group C (No.=30); subarachnoid anesthesia with 12 mg heavy bupivacaine and 25 mic fentanyl
- Group L (No.=30); ultrasound-guided femoral nerve block was done for each patient using (20 ml of 0.25% levobupivacaine) after subarachnoid anesthesia with 12 mg heavy bupivacaine
- Group ML (No.=30); ultrasound-guided femoral nerve block was done for each patient using (with 0.25% levobupivacaine 18 ml plus 2 ml magnesium sulfate 10% (200 mg) after subarachnoid anesthesia with 12 mg heavy bupivacaine.

Technique of subarachnoid block

Subarachnoid block was performed in all patients in both groups, in the sitting position under complete aseptic technique and infiltration of 2 ml lidocaine 1%, in targeting intervertebral space (L4-L5 or L5-S1). Disposable Quincke-type cutting needle (25 G) was used. The subarachnoid space was identified by spontaneous reflux of CSF, then injected 3 ml of 0.5% hyperbaric bupivacaine. Patients were immediately placed in the supine position without tilting the operating table. Anesthesia was considered satisfactory when there was loss of cold sensitivity from lower limbs to the umbilicus, tested with an alcohol swab. Heart rate, systolic blood pressure, diastolic blood pressure, and mean blood pressure were recorded as following; before femoral nerve block (baseline), after block and before spinal anesthesia, immediately after spinal anesthesia, and every 5 min till end of surgery.

Technique of Ultrasound-Guided ACB

Under complete aseptic technique, the linear ultrasound probe (SonoSite, Inc. USA) was placed at midpoint between the inguinal fold on the anterior aspect of the thigh and the medial condyle of the knee to visualize the adductor canal using in plane technique. The adductor canal is a pyramidal, musculoaponeurotic tunnel from the apex of the femoral triangle to the adductor hiatus, running between the vastus medialis muscle anterolaterally and the adductor longus and adductor magnus muscles posteromedially. The arteria femoralis was visualized in the adductor duct under the sartorius muscle. 1–2 cm lateral to the ultrasound probe, entry was made with 22 G (100 mm ultrasonographic needle) through in plane technique from 1–2 cm lateral of the ultrasound probe then needle was advanced under the sartorius muscle to the lateral of arterial femoralis and the nervus saphenous, and after careful aspiration, 1–2 mL of local anesthetic was injected to confirm the proper needle placement. When injection of the local anesthetic did not appear to result in a spread close to the femoral nerve, additional needle repositions and injections may be necessary.

During injection, the distribution of LA was easily observed under ultrasound. After the administration; ECG, hazard ratio (HR), NIBP, and SpO_2 values were recorded at 10 min intervals in the post-operative care unit for at least 1 h.

Post-operative analgesia for all groups was performed using tramadol (25 mg/ml) through patient-controlled analgesia (PCA) device that was programmed to give a bolus dose 2 ml/dose with a minimal lockout interval of 15 min with no background infusion and the maximum dose of 400 mg in 24 h total doses was calculated and recorded.

The following parameters were recorded in post-operative period:

- NRS for pain measurement at regular intervals and the time to the first analgesic request (primary outcome)
- Total doses of tramadol that given through PCA. The analgesic regimen was adjusted to achieve a visual analog scale (VAS) scores <3.
- HR and mean arterial blood (MAP) were recorded every 4 h, for 24 h
- Any concomitant complications, if happened, as (infections, hematoma, or paresthesia) or side effects.

Statistical analysis

The required sample size was calculated according to a previous study in our department[11] using Epi Info software version 7 (CDC, 2012)®. We used NRS as the

primary outcome, and therefore, it was estimated that minimum sample size of 29 patients in each study group would a chive a power of 80% to detect an effect size of 0.8 in the outcome measures of interest, assuming a type I error of 0.05.

All analyses were performed with the SPSS 21.0® software. Categorical variables were described by number and percent (N, %), where continuous variables described by mean and standard deviation (Mean, SD). Categorical variables were compared using the Chi-square (χ^2) and Fisher's exact tests (if required). To compare between continuous variables, we used *t*-test. *P* value considered significant if <0.05 at confidence interval 95% and the level of significance was accepted if $P < 0.05$.

RESULTS

As regard patient demographic data and ASA grades, we found that there were no significant changes between the two groups [Table 1]. Patient hemodynamic parameters intraoperative were comparable in the three groups ($P = 0.47$) [Tables 2 and 3], but post-operative HR and MAP were optimized in both L and LM groups ($P = 0.0.03$*) [Figures 1 and 2]. There was a significant decrease in NRS pain scores in Group LM during the 1st day post-operative ($P = 0.000$*) and post-operative analgesic consumption much more decreased in Group LM in comparison to Group C ($P = 0.000$*) [Figure 3]. We found that the time of the 1st request of analgesia in Group C was 6.13 ± 1.008 h while it was 9.27 ± 0.9 and 15.35 ± 0.4 h in Group L and Group LM, respectively, the analgesic consumption between the three group was significant being the lowest in Group LM ($P < 0.000$*) [Table 4].

In the current study, no local anesthetic toxicity, no hematoma, or excessive tissue trauma had been developed at the site of injection in both groups this result could probably due the guidance of ultrasonography that enabled better visualization of the adductor canal before injection.

Table 1: Comparison of demographic data among studied two groups

Demographic variable	Group LM (*n*=20)		Group L (*n*=20)		Group C (*n*=20)		*P*-value
	No.	%	No.	%	No.	%	
Age (years)							
<50	7	35.0	11	55.0	6	30.0	0.233
≥50	13	65.0	9	45.0	14	70.0	
Mean±SD	50.90±12.32		45.25±13.95		46.25±10.42		0.309
Weight (Kg)							0.113
Mean±SD	62.20±4.61		64.10±4.22		65.10±6.03		
Range	50–70		55–72		58–75		
ASA score							0.280
ASA III	8	40.0	13	65.0	11	55.0	
ASA II	12	60.0	7	35.0	9	45.0	

Group LM =Levobupivacaine plus Mg group, Group L=Levobupivacaine group. Group C: Control. Data expressed as Mean±SD, number and percentage (%). ASA: American Society of Anesthesiologists. *P*<0.05 considered statistically significant. Between three groups, no significant changes regarding patient's characteristics

Table 2: Comparison of intraoperative HR (beat/minute) parameters among studied groups

HR	Group LM	Group L	Group C	*P*-value
	Mean±SD	Mean±SD	Mean±SD	
Baseline	80.30±12.81	82.60±8.38	79.60±8.46	0.308
After 2 h	78.70±16.09	78.90±9.69	80.20±9.23	0.954
After 4 h	79.50±10.75	83.50±8.91	80.20±7.81	0.076
After 8 h	77.70±9.30	84.60±7.94	78.60±7.17	0.11
After 12 h	79.90±11.15	85.00±9.01	82.90±9.24	0.089
After 18 h	78.10±6.94	86.60±9.69	81.30±8.34	0.169
After 24 h	81.40±6.31	83.60±6.84	80.80±6.42	0.537

Group LM=Levobupivacaine plus Mg group, Group L=Levobupivacaine group. Group C: Control. Data expressed as Mean±SD, number and percentage (%). *P*<0.05 considered statistically significant. Between three groups, there were significant changes regarding patient's HR

Table 3: Mean blood pressure changes during intraoperative period three studied groups (mmHg)

Mean arterial blood	Group LM (*n*=20)	Group L (*n*=20)	Group C (*n*=20)	*P*-value
Baseline	73.00±11.65	72.00±7.68	74.00±4.62	0.643
After 2 h	72.00±9.68	72.00±6.81	74.00±6.81	0.605
After 4 h	72.00±8.01	71.00±7.18	73.00±5.13	0.830
After 8 h	72.00±6.88	71.00±6.49	73.00±8.01	0.626
After 12 h	71.00±9.23	70.00±4.59	72.00±7.68	0.918
After 18 h	71.00±9.40	71.00±3.08	71.00±8.01	0.666
After 24 h	70.00±7.18	70.00±4.59	69.00±5.53	0.207

Group LM=Levobupivacaine plus Mg group, Group L=Levobupivacaine group. Group C: Control. Data expressed as Mean±SD, number and percentage (%). *P*<0.05 considered statistically significant. Between three groups, there were significant changes regarding patient's MAP.

Table 4: Comparison of the 1st tramadol request among studied groups

Mean/SD	Group ML *n*=30	Group L *n*=30	Group V *n*=30	*P*-value
Time of 1st dose request	15.13±1.008	9.27±0.9	6.27±0.9	<0.001**
Total analgesic consumption mg/ 24 h	50.27±0.8	125.18±0.74	300.18±0.74	<0.001**

Group LM=Levobupivacaine plus Mg group, Group L=Levobupivacaine group, Group C: Control. Data expressed as Mean±SD, number and percentage (%). *P*<0.05 considered statistically significant. Between three groups, there were significant changes regarding patient's HR being long pain-free period and low consumption in Group L and the longest pain-free period and least consumption in Group ML.

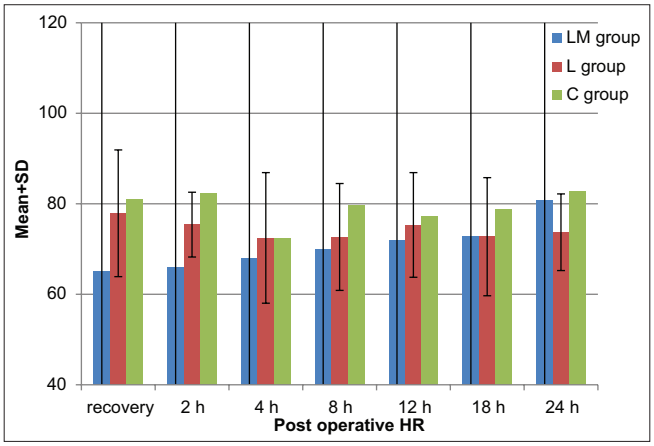

Figure 2: Comparison of post-operative HR (beat/minute) parameters among studied groups, Group LM=Levobupivacaine plus Mg group, Group L =Levobupivacaine group, Group C: Control. Data expressed as Mean ± SD, number and percentage (%). *P* < 0.05 considered statistically significant. Between three groups, there were significant changes regarding patient's HR being the best optimized in Group ML

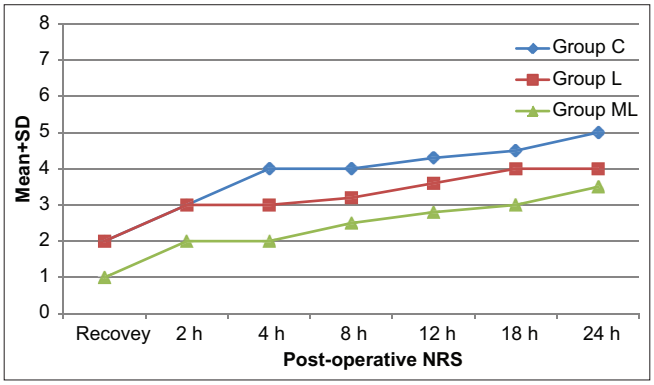

Figure 3: Comparison of post-operative NRS parameters among studied groups. Group L=Levobupivacaine group. Group C: Control. Data expressed as Mean ± SD, number and percentage (%). *P* < 0.05 considered statistically significant. Between three groups, there were significant changes regarding patient's HR being low pain scores in Group L and the lowest pain scores in Group ML

DISCUSSION

Many study concluded that post-operative pain is inadequately treated in more than one-third of all TKA procedures and many clinical trials confirm that a high-quality post-operative pain management must be performed to reduce the risk of post-operative acute adverse effects such as pulmonary dysfunction and chronic adverse effect as delayed recovery, hospital discharge, and chronic pain.[12-14]

Pre-emptive analgesia, systemic analgesics (opioids, acetaminophen, COX-2 inhibitors, and NMDA antagonists), neuraxial techniques, peripheral nerve blocks, and multimodal analgesia methods are used in post-operative pain management.[15]

The pre-emptive administration of opioids and NSAIDs may be helpful for reducing such pain, reducing post-operative analgesic requirements, and accelerate functional recovery.[16] However, the incidence of side effects including sedation, dysphoria, and post-operative nausea and vomiting was increased.[17]

ACB, which is a new technique targeting the sensory fibers mostly, so the following nerves are blocked: the saphenous nerve, the sensory branch of the femoral nerve, in the adductor canal. Also the medial femoral cutaneous nerve, articular branches of the obturator nerve and second largest sensory branch of the femoral nerve (vastus medialis) are blocked.[18]

The main advantage of the ACB is to create sensory blockage without motor block in knee and inferior to knee level surgery. In post-operative analgesia studies, it has been shown to be effective especially in patients with TKA surgery.[19]

Regarding the nerve supply of knee joint, many studies noted the little effect of the sciatic nerve contributing to the pain originating from the knee region after TKA and this pain was relieved dramatically after receiving ketorolac 30 mg as in our study.[20]

The value from using ultrasound in this study as; facilitates more rapid block onset and prolongs block duration, with the added advantages of a decrease in drug dosage and a reduction in the incidence of LA toxicity.[21]

We chose levobupivacaine in our study because of its better pharmacokinetic and less toxic profiles, especially cardiac toxicity.[22] However, previous clinical trial has compared between LAs in terms of their practical potency it compared the analgesic efficacy of ropivacaine and levobupivacaine, and concluded that local tissue infiltration with levobupivacaine was more effective than ropivacaine in reducing the post-operative pain associated with abdominal surgeries.[23]

Agree with our study, a study by Egeler that included ACB is associated with significantly less analgesic consumption after TKA than placebo alone.[23] Furthermore, most studies comparing and femoral nerve block (FNB) have reported similar effects of the two blocks on post-operative analgesic consumption and pain scores after knee surgery. However, the ability to ambulate and maintain quadriceps strength after TKA favors ultrasound-ACB, while FNB is associated with post-operative quadriceps paresis, delayed mobilization, and increased length of stay.[24]

Furthermore, Hanson *et al*.[18] in his study, ACB was performed for multimodal analgesia to patients undergoing medial meniscopathy surgery with general anesthesia and they showed that pain scores and opioid consumption were significantly lower compared to the control group.

Moreover, Akkaya *et al*.[25] in their study performed under general anesthesia to two groups for arthroscopic knee surgery. ACB was administered in addition to one of the groups. They found a significant decrease in VAS scores and opioid consumption during the post-operative period in the ACB applied group.

The mechanism of action of Mg is being NMDA receptor antagonist and also inhibits the central sensitization from peripheral painful stimulus regulated by NMDA receptors.[26] This effect is primarily based on physiological calcium antagonism, through voltage-dependent regulation of calcium influx into the cell, so regardless the route of administration, the actual site of action of Mg is probably at the spinal cord NMDA receptors producing pain relief.[27]

In previous trials, $MgSO_4$ was proved to be an effective adjuvant when added to bupivacaine in TAB block during abdominal cancer surgeries[28] or when added to levobupivacaine in spinal anesthesia during major orthopedic surgeries.[29]

This study has many limitations such as small sample size and short-term follow-up. It was advisable to establish continuous follow-up using survey questionnaires and periodic checking for a longer period.

CONCLUSION

Ultrasound-guided ACB improves post-operative analgesia and reduces analgesic consumption and the addition of MgSO4 to levobupivacaine in ACB prolonged the duration of block and decreased analgesic requirements in patient subjected to total knee arthroplasty.

DECLARATIONS

- Consent for publication was taken from all included patients.
- The study was done after local ethical committee approval of Assiut University Hospitals and written consent from all included patients.
- The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request

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CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

REFERENCES

1. Fischer HB, Simanski CJ, Sharp C, Bonnet F, Camu F, Neugebauer EA, *et al*. A procedure-specific systematic review and consensus recommendations for postoperative analgesia following total knee arthroplasty. Anaesthesia 2008;63:1105-23.

2. Key W, Grayling M. PROSPECT, before and after: Anaesthesia for total knee arthroplasty. Eur J Anaesthesiol 2010;27:217.
3. Mandalia V, Eyres K, Schranz P, Toms AD. Evaluation of patients with a painful total knee replacement. J Bone Joint Surg Br 2008;90:265-71.
4. Choi P, Bhandari M, Scott K, Douketis JD. Epidural analgesia for pain relief following hip or knee replacement. Cochrane Database Syst Rev 2003;3:CD003071.
5. Paul JE, Arya A, Hurlburt L, Cheng J, Thabane L, Tidy A, *et al*. Femoral nerve block improves analgesia outcomes after total knee arthroplasty: A meta-analysis of randomized controlled trials. Anesthesiology 2010;113:1144-62.
6. Albrecht E, Guyen O, Jacot-Guillarmod A, Kirkham KR. The analgesic efficacy of local infiltration analgesia vs femoral nerve block after total knee arthroplasty: A systematic review and meta-analysis. Br J Anaesth 2016;116:597-609.
7. Smith LM, Cozowicz C, Uda Y, Memtsoudis SG, Barrington MJ. Neuraxial and combined neuraxial/general anesthesia compared to general Anesthesia for major truncal and lower limb surgery: A systematic review and meta-analysis. Anesth Analg 2017;125:1931-45.
8. Perlas A, Chan VW, Beattie S. Anesthesia technique and mortality after total hip or knee arthroplasty: A retrospective, propensity score-matched cohort study. Anesthesiology 2016;125:724-31.
9. Carvalho Júnior LH, Temponi EF, Paganini VO, Costa LP, Soares LF, Gonçalves MB. Reducing the length of hospital stay after total knee arthroplasty: Influence of femoral and sciatic nerve block. Rev Assoc Med Bras (1992) 2015;61:40-3.
10. Weinstein AM, Rome BN, Reichmann WM, Collins JE, Burbine SA, Thornhill TS, *et al*. Estimating the burden of total knee replacement in the United States. J Bone Joint Surg Am 2013;95:385-92.
11. Morsy KM, Askar FG, Elzohry AA, Abdelhafeez AM. Effect of adding fentanyl to bupivacaine in femoral nerve block for post-operative pain in patient subjected to total knee replacement guided by ultrasound. Anaesth Pain Med 2019;1:6-11.
12. Chan EY, Fransen M, Parker DA, Assam PN, Chua N. Femoral nerve blocks for acute postoperative pain after knee replacement surgery. Cochrane Database Syst Rev 2014;2014:CD009941.
13. Cappelleri G, Ghisi D, Fanelli A, Albertin A, Somalvico F, Aldegheri G. Does continuous sciatic nerve block improve postoperative analgesia and early rehabilitation after total knee arthroplasty? A prospective, randomized, double-blinded study. Reg Anesth Pain Med 2011;36:489-92.
14. Sahin L, Korkmaz HF, Sahin M, Atalan G. Ultrasound-guided single-injection femoral nerve block provides effective analgesia after total knee arthroplasty up to 48 hours. Agri 2014;26:113-8.
15. Liu SS, Ngeow JE, Yadeau JT. Ultrasound-guided regional anesthesia and analgesia: A qualitative systematic review. Reg Anesth Pain Med 2009;34:47-59.
16. Affas F, Nygårds EB, Stiller CO, Wretenberg P, Olofsson C. Pain control after total knee arthroplasty: A randomized trial comparing local infiltration anesthesia and continuous femoral block. Acta Orthop 2011;82:441-7.
17. Sinha SK, Abrams JH, Arumugam S, D'Alessio J, Freitas DG, Barnett JT, *et al*. Femoral nerve block with selective tibial nerve block provides effective analgesia without foot drop after total knee arthroplasty: A prospective, randomized, observer-blinded study. Anesth Analg 2012;115:202-6.
18. Hanson NA, Derby RE, Auyong DB, Salinas FV, Delucca C, Nagy R, *et al*. Ultrasound-guided adductor canal block for arthroscopic medial meniscectomy: A randomized, double-blind trial. Can J Anaesth 2013;60:874-80.
19. Shah NA, Jain NP. Is continuous adductor canal block better than continuous femoral nerve block after total knee arthroplasty? Effect on ambulation ability, early functional recovery and pain control: A randomized controlled trial. J Arthroplasty 2014;29:2224-9.
20. Andersen KV, Bak M, Christensen BV, Harazuk J, Pedersen NA, Søballe K. A randomized, controlled trial comparing local infiltration analgesia with epidural infusion for total knee arthroplasty. Acta Orthop 2010;81:606-10.
21. American Society of Anesthesiologists Task Force on Acute Pain Management. Practice guidelines for acute pain management in the perioperative setting: An updated report by the American Society of Anesthesiologists Task Force on Acute Pain Management. Anesthesiology 2012;116:248-73.
22. Cassuto J, Sinclair R, Bonderovic M. Anti-inflammatory properties of local anesthetics and their present and potential clinical implications. Acta Anaesthesiol Scand 2006;50:256-82.
23. Furutani K, Ikoma M, Ishii H, Baba H, Kohno T. Bupivacaine inhibits glutamatergic transmission in spinal dorsal horn neurons. Anesthesiology 2010;112:138-43.
24. Egeler C, Jayakumar A, Ford S. Motor-sparing knee block-description of a new technique. Anaesthesia 2013;68:542-3.
25. Akkaya A, Yildiz I, Tekelioglu UY, Demirhan A, Bayir H, Ozlu T, *et al*. Dexamethasone added to levobupivacaine in ultrasound-guided tranversus abdominis plain block increased the duration of postoperative analgesia after caesarean section: A randomized, double blind, controlled trial. Eur Rev Med Pharmacol Sci 2014;18:717-22.
26. Wiesmann T, Piechowiak K, Duderstadt S, Haupt D, Schmitt J, Eschbach D, *et al*. Continuous adductor canal block versus continuous femoral nerve block after total knee arthroplasty for mobilisation capability and pain treatment: A randomised and blinded clinical trial. Arch Orthop Trauma Surg 2016;136:397-406.
27. Arcioni R, Palmisani S, Tigano S, Santorsola C, Sauli V, Romanò S, *et al*. Combined intrathecal and epidural magnesium sulfate supplementation of spinal anesthesia to reduce post-operative analgesic requirements: A prospective, randomized, double-blind, controlled trial in patients undergoing major orthopedic surgery. Acta Anaesthesiol Scand 2007;51:482-9.
28. Ghatak T, Chandra G, Malik A, Singh D, Bhatia VK. Evaluation of the effect of magnesium sulphate vs. clonidine as adjunct to epidural bupivacaine. Indian J Anaesth 2010;54:308-13.
29. Lysakowski C, Dumont L, Czarnetzki C, Tramèr MR. Magnesium as an adjuvant to postoperative analgesia: A systematic review of randomized trials. Anesth Analg 2007;104:1532-9.

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