International Journal of Surgery 72 (2019) 16–24

Contents lists available at ScienceDirect

International Journal of Surgery

journal homepage: www.elsevier.com/locate/ijsu

Original Research

Continuous adductor canal block is a better choice compared to single shot after primary total knee arthroplasty: A meta-analysis of randomized controlled trials

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ARTICLE INFO

Keywords:
Total knee arthroplasty
Single shot adductor canal block
Continuous adductor canal block
Pain control

ABSTRACT

Background: The advantages of continuous adductor canal block (CACB) over single shot ACB (SACB) are still debatable for pain management after total knee arthroplasty (TKA). The aim of this study was to investigate which ACB method provides better pain relief after TKA.

Methods: MEDLINE, EMBASE, Cochrane Central Register of Controlled Trials, and Web of Science were searched without any language restrictions. Only randomised clinical trials (RCTs) were included in this meta-analysis. The primary outcome was pain score, whereas the secondary outcomes included opioid consumption, postoperative complication, and length of stay.

Results: Eight RCTs with a total of 642 patients were included. The overall evidence for outcomes was moderate. The pooled data indicated that the use of CACB after TKA surgery was associated with lower pain score at rest or movement ($P < 0.00001$), cumulative morphine consumption ($P = 0.003$), and length of hospital stay ($P = 0.03$) compared with SACB, with no difference in nausea or vomiting rate ($P = 0.55$).

Conclusions: Compared with SACB, CACB provides better analgesia after TKA. Therefore, CACB is recommended as an analgesic method for early postoperative pain treatment after TKA.

1. Introduction

TKA is known to be a painful orthopedic procedure and moderate to severe pain is common, especially immediately postoperatively and during active motion. Poorly controlled pain can result in poor function with physical therapy, prolonged hospitalization, and reduced patient satisfaction [1]. The proportion of patients complaining of chronic pain after TKA is as much as 34%, and the intensity of early postoperative pain is associated with increased chronic pain after TKA [2]. Therefore, adequate analgesia following TKA continues to be a topic of interest.

In recent years, continuous femoral nerve block (FNB) has been recommended as a clinical analgesic after TKA. However, continuous blockade of the femoral nerve may result in weakness of quadriceps muscle strength and therefore increases the risk of falling during early ambulation [3,4]. Adductor canal block (ACB) has emerged as an alternative to FNB, with the advantage of sparing the motor nerve supply to most of the quadriceps muscle and thus may lead to a reduction in falls after surgery [5]. However, the optimal duration to maintain ACB is unknown. Some hospitals use a single shot ACB (SACB), while others choose a continuous block using epidural catheter and infusion (CACB) after surgery. The advantages of continuous infusion over a single injection are debatable.

Several more RCTs on this subject have been published without conclusive results. Furthermore, Zhang et al. [6] conducted a recent meta-analysis of RCTs showing that SACB technique provides similar analgesia in the 24-h following TKA compared with CACB, while the CACB method **is** better over 48-h. However, it contained some methodological shortcomings, inaccurate data extraction, limited sample size, and high heterogeneity. Considering all these issues, we undertook a further meta-analysis to evaluate whether CACB is superior to SACB with respect to: (1) pain score at rest or mobilization; (2) opioid consumption; (3) functional outcome; (4) length of hospital stay; and (5) complications.

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https://doi.org/10.1016/j.ijsu.2019.10.012
Received 7 July 2019; Received in revised form 23 August 2019; Accepted 8 October 2019
Available online 12 October 2019
1743-9191/

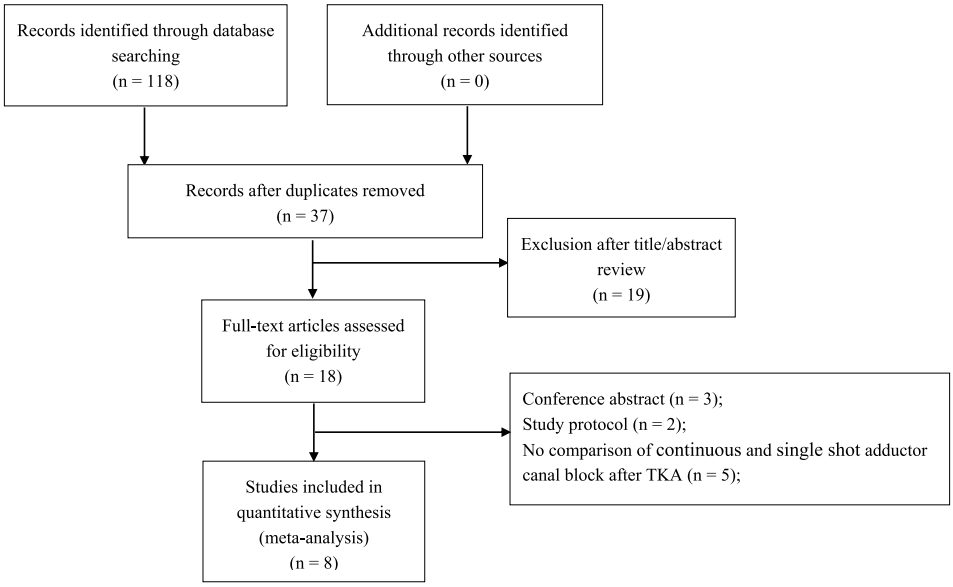


Fig. 1. PRISMA Flow diagram describing the selection process for relevant clinical trials used in this meta-analysis.

2. Materials and methods

2.1. Selection of studies

This study was conducted according to the PRISMA (Preferred Reporting Items for Systematic Review and Meta-Analysis) [7] and AMSTAR (Assessing the methodological quality of systematic reviews) guidelines. We did not publish a prior protocol for this review. The online literature was searched using the following combination of medical subject heading terms: “adductor canal block” OR “saphenous nerve block” OR “peripheral nerve block” AND “total knee arthroplasty” OR “total knee replacement” AND “random” OR “blind.” MEDLINE (PubMed), EMBASE (OVID), Cochrane Central Register of Controlled Trials (CENTRAL), and Web of Science (ISI database) were searched without any language restrictions. The reference lists of the included studies were also checked for additional studies that were not identified with the database search.

2.2. Eligibility criteria

Study included in our meta-analysis had to meet all the following inclusion criteria in the PICOS (patients, interventions, comparators, outcomes, and studies) order. These targets included (P) patients undergoing primary TKA, (I) continuous ACB, (C) single shot ACB, (O) postoperative pain relief, opioid consumption, functional outcome, length of stay, and post-operative complication, and (S) RCTs. We excluded unpublished reports and studies that examined SACB or CACB only, without a comparator group. Duplicate reports and conference abstracts were excluded. Case reports, biochemical trials, letters, and reviews were also eliminated.

2.3. Study selection and data extraction

Articles were exported to EndNote, and duplicates removed. Two independent authors screened the titles and abstracts of potentially relevant studies to determine their eligibility based on the criteria. Disagreements were resolved through a discussion with a third review author.

A standard data extraction form was used independently by two reviewers to retrieve the relevant data from the articles. These variables included authors, study design, sample size, publishing date, population, type of interventions, dosages, type of anesthesia, follow-up, and outcomes. The primary outcome was pain score, whereas the secondary outcomes included opioid consumption, post-operative complication, and length of stay. Data extraction was performed independently, and any conflict was resolved before final analysis. If data (eg, SDs and SEs) were not presented in the original article, corresponding authors were contacted to acquire the missing data. Otherwise, the results were extracted manually from the published figures. If necessary, we would abandon the extraction of incomplete data.

2.4. Study quality assessment

Two independent reviewers assessed the risk of bias of included studies using the parameters defined by the *Cochrane Handbook for Systematic Reviews of Interventions* criteria [8]. The quality of RCTs was assessed by using **the** following 7 items: random sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome assessment, incomplete outcome data, selective reporting, and other bias. Disagreement was resolved through discussion and consensus between the reviewers. Kappa values were used to measure the degree of agreement between the 2 reviewers and were rated as follows: fair, 0.40 to 0.59; good, 0.60 to 0.74; and excellent, 0.75 or more. Based on the information provided from included studies, each item was recorded as low risk of bias, high risk of bias, or unclear (lack of information or unknown risk of bias).

2.5. Data analysis

The present study was performed by Review Manager Software (RevMan Version 5.3, The Cochrane Collaboration, Copenhagen, Denmark). Mean differences (MD) with a 95% confidence interval were assessed for continuous outcomes. $P < 0.05$ was set as the significance level. We examined heterogeneity graphically using forest plots and statistically by calculating the I^2 statistic, which describes the percentage of the variability in effect estimates that is due to heterogeneity rather than sampling error (chance). We considered an I^2 statistic greater than 50% to be substantially heterogeneous. All outcomes were pooled on random-effect model. The Z test was used to assess the overall effect. A meta-analysis was conducted when 4 or more trials reported an outcome of interest. Subgroup analyses were planned by different follow-up periods. We also conducted the sensitivity analysis to evaluate whether any single study had the weight to skew on the overall estimate and data. Begg's funnel plot was used to assess

Table 1
Characteristics of the included studies.

Study	Study Design	Sample size (CACB/SACB)	Anesthesia	Composition of SACB	Composition of CACB	Follow-Up	Outcome Measures
Canbek 2019	RCT	63/60	Spinal anesthesia	30 ml of 0.25% bupivacaine;	125 ml of 0.125% bupivacaine; 5 ml/h for 24 h;	2 days	VAS/LOS/Nausea or vomiting
Elkassabany 2019	RCT	52/53	Spinal or general anesthesia	20 ml of 0.5% ropivacaine;	18 ml of 0.5% ropivacaine;	2 days	VAS/Opioid/LOS/Nausea or vomiting
Kim 2019	RCT	22/22	Spinal anesthesia	20 ml of 0.5% ropivacaine;	20 ml of 0.5% ropivacaine;	4 days	VAS/Opioid/Nausea or vomiting
Lee 2018	RCT	57/60	Spinal anesthesia	20 ml of 0.5% ropivacaine;	20 mL of 0.5% ropivacaine; 5 ml/h for 48 h;	2 days	VAS/Opioid/LOS
Turner 2018	RCT	30/30	Spinal anesthesia	20 ml of 0.25% bupivacaine, 2.5 mcg/ml of epinephrine;	20 ml of 0.25% bupivacaine, 2.5 mcg/mL epinephrine;	2 days	VAS/Opioid/LOS/Nausea or vomiting
Zhang 2018	RCT	23/25	Spinal anesthesia	20 ml of 0.5% ropivacaine;	20 ml of 0.5% ropivacaine;	3 days	VAS/Opioid/LOS/Nausea or vomiting
Li 2017	RCT	30/30	General anesthesia	Ropivacaine 30 ml of 0.25%, adrenaline 0.1 mg;	Ropivacaine 30 ml of 0.25%, adrenaline 0.1 mg; 8 ml/h for 48 h;	3 days	VAS/LOS/Nausea or vomiting
Shah 2015	RCT	46/39	Spinal anesthesia	30 ml of 0.75% ropivacaine;	30 ml of 0.75% ropivacaine; 30 ml of 0.25% ropivacaine, 5 ml/h for 24 h;	3 days	VAS/LOS/Nausea or vomiting

RCT, randomized clinical trial; ACB, adductor canal block; VAS, visual analog scale; LOS, length of stay.

publication bias. If publication bias exists, the Begg's funnel plot is asymmetric.

3. Results

3.1. Studies search and characteristics

The initial search criteria captured 118 citations. A total of 81 articles were evaluated after duplicates from each database were excluded. Of these, 19 articles were excluded by title and abstract. After reading the full text of all remaining articles in detail, 10 studies that did not meet the inclusion criteria were excluded. A total of 8 articles [9–16] met our eligibility criteria (Fig. 1). Briefly, 8 RCTs with a total of 642 patients were included. The sample size of each study ranged from 44 to 123. All 8 included studies were published between 2015 and 2019. Mean follow-up period ranged from 2 days to 4 days. All included studies assessed pain using the visual analog scale. A detailed description of all included studies can be found in Table 1.

3.2. Risk of bias in included studies

All included studies clearly described the methods of randomization. Only 4 studies [10,12,13,16] used appropriate and feasible methods to describe concealment of allocation. There was no blinding of the participants and personnel in all 8 studies. Blinding of outcome assessors was mentioned in 3 studies [9,12,16]. The proportion of patients lost to follow-up was less than 20% in all studies, indicating low attrition bias. All **8** studies showed that all main outcomes were presented in the protocol and were considered at low risk of reporting bias. No other bias was detected. A standardized assessment of the risk of bias in the 8 RCTs was summarized in Table 2. The overall kappa value regarding the evaluation of risk of bias was 0.864, meaning an excellent degree of agreement between the two reviewers.

3.3. CACB versus SACB outcomes analysis

3.3.1. Pain scores with rest

When examining the combined pain scores with rest values for each group, quantitative analysis demonstrated greater reduction in pain scores for the CACB group vs the SACB group, and the difference was statistically significant ($P < 0.00001$). When comparing the pain scores of subgroups analyzed at specific periods in time, significant differences were found in the pain score with rest at 4 h, 12 h, 24 h, and 48 h in favor of CACB (Fig. 2).

3.3.2. Pain scores with movement

Similarly, when examining the combined pain scores with movement values for each group, quantitative analysis demonstrated greater reduction in pain scores for the CACB group vs the SACB group, and the difference was statistically significant ($P < 0.00001$). When comparing the pain scores of subgroups analyzed at specific periods in time, significant differences were found in the pain score with movement at 24 h and 48 h in favor of CACB (Fig. 3).

3.3.3. Cumulative opioid consumption

Only 5 studies [10–13,16] compared cumulative opioid consumption (0–48 h) between 184 patients treated with CACB and 190 patients treated with SACB. Significant difference was found in the cumulative opioid consumption within 48 h in favor of CACB (MD for CACB vs SACB group, −13.99; 95% CI, −23.24 to −4.73; $P = 0.003$) (Fig. 4).

3.3.4. Length of hospital stay

Seven studies [9,10,12–16] evaluated length of hospital stay between 301 patients treated with CACB and 297 patients treated with SACB. Significant difference was found in the length of hospital stay in favor of CACB (MD for CACB vs SACB group, −0.15; 95% CI, −0.28 to

Table 2
Methodological assessment according to 6 domains of potential biases (cochrane risk of bias tool).

RCT Study = 8	Sequence Generation	Allocation Concealment	Blinding of Participants and Personnel	Blinding of Outcome Assessors	Incomplete Outcome Data	Selective Outcome Reporting	Other Potential Threats to Validity	Overall Bias
RCT Canbek 2019	Low	Unclear	High	Low	Low	Low	Low	Low
RCT Elkassabany 2019	Low	Low	High	High	Low	Low	Low	Moderate
RCT Kim 2019	Low	Unclear	High	High	Low	Low	Low	Moderate
RCT Lee 2018	Low	Low	High	High	Low	Low	Low	Moderate
RCT Turner 2018	Low	Low	High	Low	Low	Low	Low	Low
RCT Zhang 2018	Low	Low	High	Low	Low	Low	Low	Low
RCT Li 2017	Low	Unclear	High	Unclear	Low	Low	Low	Moderate
RCT Shah 2015	Low	Unclear	High	Unclear	Low	Low	Low	Moderate

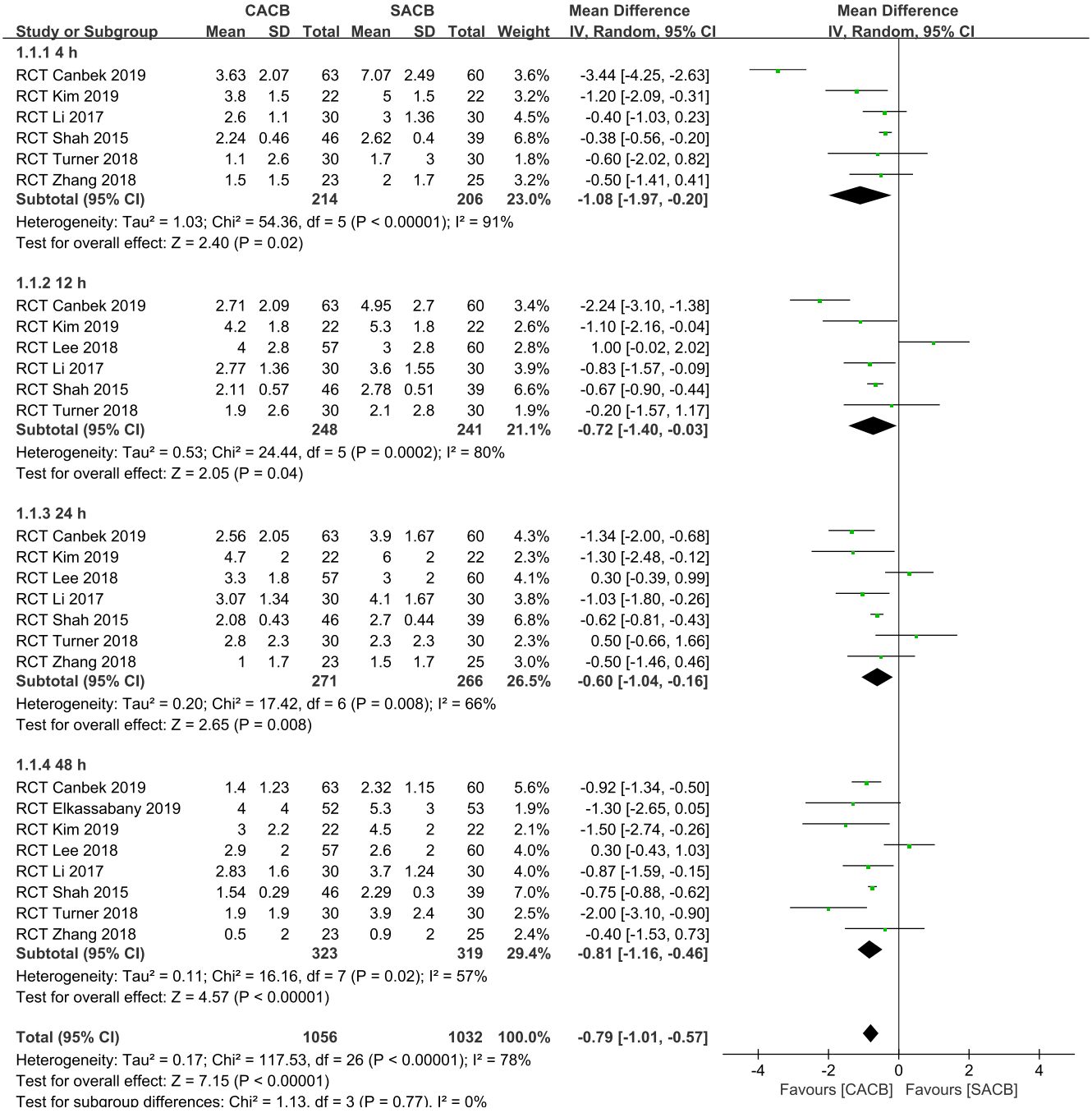


Fig. 2. Forest plots of the pain score with rest between CACB group and SACB group after TKA.

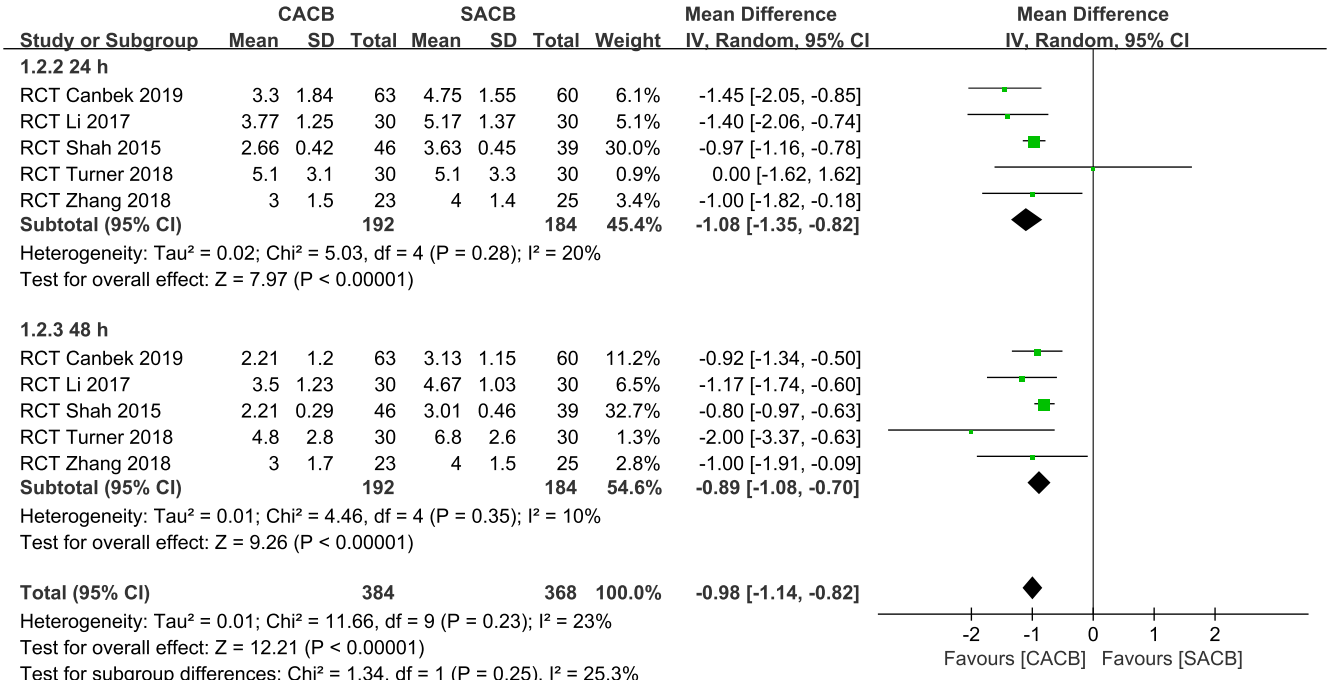


Fig. 3. Forest plots of the pain score with movement between CACB group and SACB group after TKA.

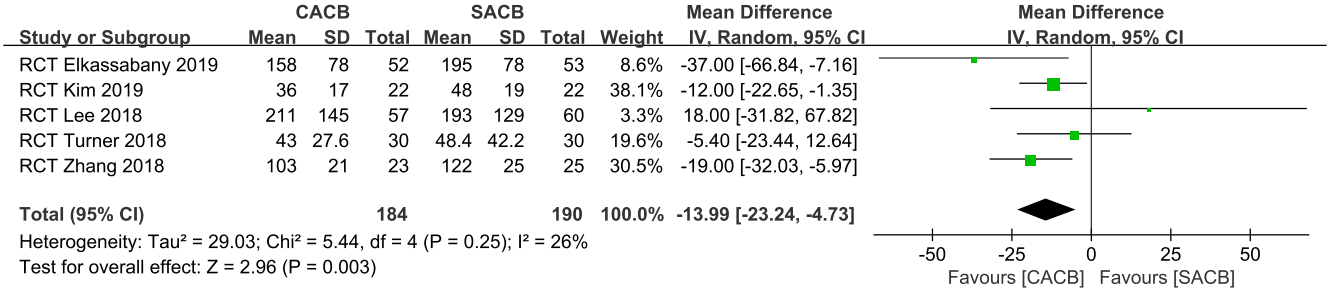


Fig. 4. Forest plots of the cumulative opioid consumption within 48 h between CACB group and SACB group after TKA.

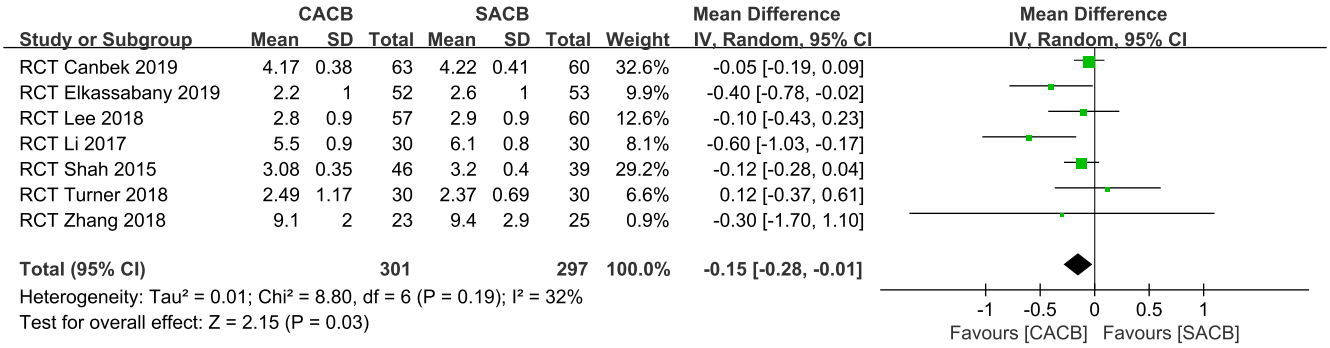


Fig. 5. Forest plots of the length of hospital stay between CACB group and SACB group after TKA.

−0.01; $P = 0.03$) (Fig. 5).

3.3.5. Post-operative nausea or vomiting

Post-operative nausea or vomiting was reported in 7 studies [9–12,14–16] involving 525 patients. Nineteen of the 266 patients (7.1%) in the CACB group and 16 of the 259 patients (6.2%) in the SACB group had nausea or vomiting. The difference was not significant (RR for CACB vs SACB group, 1.22; 95% CI, 0.64 to 2.31; $P = 0.55$) (Fig. 6).

3.4. Quality of evidence

The GRADE system was used to evaluate the quality of outcomes in this study. The overall evidence for outcomes was moderate. The details of the results are summarized in Table 3.

3.5. Sensitivity analysis and publication bias

Owing to the significant heterogeneity in pain score with rest at 4 h

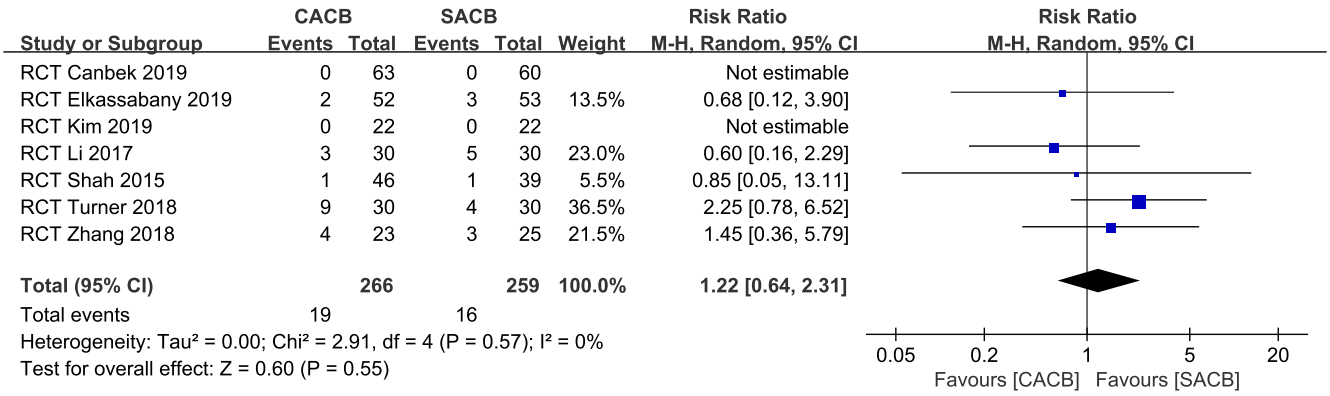


Fig. 6. Forest plots of the nausea or vomiting between CACB group and SACB group after TKA.

Table 3
Results of meta-analysis.

Outcomes and Demographics	Number of Studies	Number of CACB	Number of SACB	MD (95% CI)	*P*-Value	Heterogeneity	Level of Evidence
Pain scores with rest at 4 h	6	214	206	−1.08 (−1.97 to −0.20)	**0.02**	91% (R)	Moderate (2, 3, 4)
Pain scores with rest at 12 h	6	248	241	−0.72 (−1.40 to −0.03)	**0.04**	80% (R)	Moderate (2, 3, 4)
Pain scores with rest at 24 h	7	271	266	−0.60 (−1.04 to −0.16)	**0.008**	66% (R)	Moderate (2, 3, 4)
Pain scores with rest at 48 h	8	323	319	−0.81 (−1.16 to −0.46)	< **0.00001**	57% (R)	Moderate (2, 3, 4)
Pain scores with movement at 24 h	5	192	184	−1.08 (−1.35 to −0.82)	< **0.00001**	20% (R)	Moderate (2, 3, 7)
Pain scores with movement at 48 h	5	192	184	−0.89 (−1.08 to −0.70)	< **0.00001**	10% (R)	Moderate (2, 3, 7)
Cumulative opioid consumption	5	184	190	−13.99 (−23.24 to −4.73)	**0.003**	26% (R)	Moderate (2, 3, 7)
Length of hospital stay	7	301	297	−0.15 (−0.28 to −0.01)	**0.03**	32% (R)	High (2, 3)
Post-operative nausea or vomiting	7	266	259	1.22 (0.64–2.31)	0.55	0% (R)	Moderate (2)

CACB, continuous adductor canal blocks; SACB, single-injection adductor canal blocks; MD, mean differences; (R), random effects model was used.
Bold indicates a statistically significant *P*-value.
1, no details of randomization; 2, no concealment; 3, effect is stable; 4, result is inconsistent; 5, indirect data; 6, inconsistent follow-up time point; 7, limited sample size.

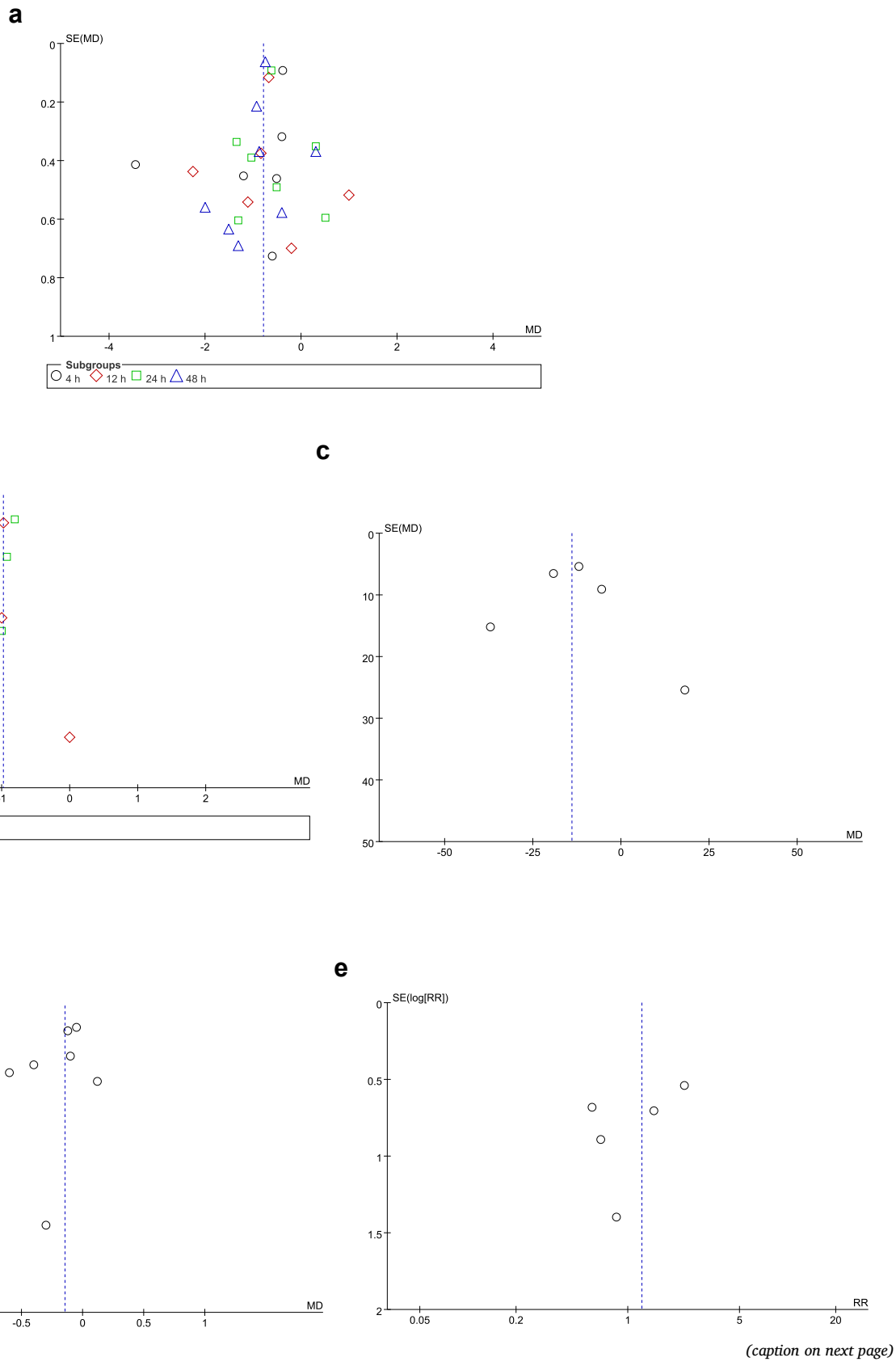
(I^2 = 91%), 12 h (I^2 = 80%), 24 h (I^2 = 66%), and 48 h (I^2 = 57%), the sensitivity analysis was performed in our meta-analysis to investigate the source of heterogeneity. Sensitivity analysis was performed by excluding one trial at a time and recalculating the pooled MD for the remaining trials, which showed that none of the studies affected the results. The funnel plots of all outcomes were symmetrical, indicating a low risk of publication bias in this study (Fig. 7A-E).

4. Discussion

ACB is commonly integrated into a multimodal pain protocol to improve pain management after TKA [17]. An ideal regimen for ACB to provide optimum pain relief and concomitantly promote early patient mobilization following TKA needs to be defined. Critics argue that similar analgesia can be achieved with **S**ACB, especially as the duration of the SACB can be extended over 12 h in some patients, while the insertion and maintenance of continuous catheters is resource- and labour-intensive. Another argument against continuous infusion is that longer blocks may adversely affect physiotherapy and delay patient rehabilitation after surgery [18]. The aim of the present meta-analysis was to compare the efficacy of CACB and SACB in postoperative pain control after TKA. Our study demonstrated that the use of CACB after TKA surgery was associated with lower pain score at rest or movement, cumulative morphine consumption, and length of hospital stay compared with SACB, with no difference in nausea or vomiting rate. The level of evidence, which was undermined by heterogeneity and study design limitations, was moderate, indicating that the degree of benefit must be studied although the benefit is conclusive.

The primary outcome evaluated in the present study was the pain score at different periods. All the included studies used the visual analogue scale. The pooled data indicated that CACB was found to be more effective than SACB in postoperative analgesia following TKA and the pain scores at all the measured time-points were determined to be lower in the CACB group patients than in the SACB group. We think that, with single shot technique only saphenous nerve is blocked, however the delivery of larger quantity of local anesthetic spreading to adductor canal with continuous infusion may lead to blockade of nerves at the proximal and distal region of the adductor canal such as nerve to vastus medialis and deep nerve plexus and providing better pain relief. Total morphine consumption was also considered a reasonable indicator for assessing the analgesic effect. Our study showed that the CACB group had lower cumulative morphine consumption in the first and second 24-h periods than the SACB group, which indirectly verified the aforementioned outcomes of pain scores between the 2 groups. Interestingly, in our included studies, Lee et al. [13] found higher pain scores and opioid consumption in the CACB group patients compared to the SACB group. The poor results in the CACB group can be explained by secondary block failure and catheter displacement in their study. Additionally, Turner et al., Zhang et al., and Elkassabany et al. found similar pain scores and morphine consumption after TKA with the SACB and CACB techniques [10,12,16]. However, the authors in the 3 studies performed a periarticular local infiltration to all patients after ACB, that may have influenced the results. In future studies, a clearer analysis could be done to compare the efficacy of the CACB and SACB methods by eliminating the effects of other analgesic techniques.

With reduced opioid consumption, patients in the CACB group can mitigate potential adverse events such as respiratory depression, nausea, and vomiting [19]. However, the findings of present study revealed a similar rate of nausea or vomiting between the CACB and SACB methods. The length of hospital stay was associated with postoperative pain. As previous results revealed that the 2 groups had significant different pain scores, the length of stay was forecasted to be significant



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different as well. This prediction was then confirmed by our meta-analysis as statistical difference was found after pooling the results, with shorter duration of hospital stay in the CACB group. From this perspective, CACB is a more cost-effective alternative than SACB for pain management.

Adverse events from opioids and increased pain levels generally have an impact on functional outcomes, resulting in delayed ambulation postoperatively. Because early ambulation has been found to

Fig. 7. A. Funnel plot of publication bias for the pain score with rest between CACB group and SACB group after TKA. There was symmetry, suggesting that there was not a significant publication bias;
B. Funnel plot of publication bias for the pain score with movement between CACB group and SACB group after TKA. There was symmetry, suggesting that there was not a significant publication bias;
C. Funnel plot of publication bias for the cumulative opioid consumption within 48 h between CACB group and SACB group after TKA. There was symmetry, suggesting that there was not a significant publication bias;
D. Funnel plot of publication bias for the length of hospital stay between CACB group and SACB group after TKA. There was symmetry, suggesting that there was not a significant publication bias;
E. Funnel plot of publication bias for the nausea or vomiting between CACB group and SACB group after TKA. There was symmetry, suggesting that there was not a significant publication bias.

reduce length of hospital stay and enhance muscle strength and range of motion, increased pain levels or adverse events could prevent these outcomes [20]. An examination of the functional outcomes of the included studies have a weak but similar trend in favor of CACB. A meta-analysis could not be performed on these outcomes due to insufficient and heterogenous data; however, the functional outcomes of the included studies will be noted here. Shah et al. [15] found no differences between groups when examining ambulation ability assessed by TUG test, 10-m walk test and 30-s chair test. Zhang et al. [16] only examined knee range of motion, with no statistically significant differences between groups. Elkassabany et al. [10] found ambulation ability to be superior with the CACB group compared to the SACB group, but there was no significant difference. Li et al. [14] found knee range of motion was significantly better in the CACB group compared to the SACB group. Canbek et al. [9] showed that CACB group displayed better functional results than SACB group with respect to active straight-leg rise time, 6-min walking test, and knee range of motion. Turner et al. [12] found a trend of improved straight leg raise ability in the SACB group compared to the CACB group, but there was no significant difference. Kim et al., and Lee et al. did not use any outcome measures examining functional status of participants [11,13].

The findings of our meta-analysis are not in line with the results and conclusions of a recent meta-analysis conducted by Zhang et al. [6]. These differences result from limited studies included in their analysis. In their study, the SACB group had similar efficacy compared with the CACB group in terms of morphine consumption, time to first opioid request, range of motion, and pain scores at 24-h at rest and movement, with no differences in complications and length of stay. Therefore, the authors concluded that the SACB technique provided a similar analgesia in the 24-h following TKA compared with CACB, while the CACB method was better over 48-h. However, compared to 642 patients in our study, relatively small sample size (322 patients) was included in their meta-analysis. In addition, no sensitivity analysis was performed to investigate the source of heterogeneity in their study.

Several limitations should be considered before interpreting these findings. First, in order to increase the credibility of the results, a meta-analysis was performed only when 4 or more trials reported an outcome of interest. Therefore, functional outcomes such as range of motion, timed up and go test, and 30-s chair stand test were not compared due to limited data. Second, studies often showed a high risk or unclear risk of bias, which may have led to overestimations or underestimations of the reported effects. However, we assessed the quality of evidence through a validated tool and considered the level of certainty of evidence for each outcome. Third, heterogeneity among the included studies was unavoidable due to the different regimens of ACB used. Heterogeneity was also caused by a variety of other factors, such as racial differences, tourniquet use, age differences, and mode of anesthesia. Fourth, some other minor factors such as differences in technique, concentration, amount and assessment techniques may affect the quality of results. To some extent, these factors were inevitable.

5. Conclusion

Although the overall quality of the evidence can be considered "moderate", we objectively assessed the benefits and **risks** of CACB and SACB. Based on this meta-analysis of all currently published RCTs, the findings have important implications for the medical community, namely that CACB following TKA surgery is associated with lower pain score at rest or movement, cumulative morphine consumption, and length of hospital stay compared with SACB, with no difference in nausea or vomiting rate. Therefore, CACB is recommended as an analgesic method for early postoperative pain treatment after TKA.

Ethical approval

Ethical approval was not necessary because the present meta-analysis was performed on the basis of previous published studies.

Funding

None.

Author contribution

Chen Wang: first author, whole study: collection, data analysis writing. First reviewer of the included studies.

Zhengjie Chen: collection. Did a pre-review of the full body of text. Rewrote a significant and important part of the study.

Xinlong Ma: (corresponding author): supervised the whole study.

Trial registry number

https://www.researchregistry.com/Reviewregistry718.

Guarantor

Xinlong Ma.

Provenance and peer review

Not commissioned, externally per reviewed.

Declaration of competing interest

None.

Acknowledgments

We would like to show sincere appreciation to the editors and anonymous reviewers for their many useful comments on the early version of the manuscript.

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