IPACK (Interspace between the Popliteal Artery and the Capsule of the Posterior Knee) Block Combined with SACB (Single Adductor Canal Block) Versus SACB for Analgesia after Total Knee Arthroplasty

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Objectives: To evaluate the combination of the infiltration between the popliteal artery and the posterior capsule of the knee (iPACK) block and single adductor canal block (SACB) versus SACB for motor-sparing knee analgesia effects after total knee arthroplasty (TKA).

Methods: PubMed, Ovid, Cochrane Library, and other databases were searched from the inception to January 2021. Randomized controlled trials (RCTs) comparing patients receiving iPACK plus SACB with patients receiving SACB after TKA were included. The included studies were assessed by two reviewers according to the Cochrane risk of bias criteria. Meta-analysis was performed with STATA 13.0 software, the risk ratios (RR) and mean differences (MD) were used to compare dichotomous and continuous variables. The primary outcome was ambulation pain and secondary outcomes were rest pain, opioid consumption, function ability, clinical outcomes, and complications.

Results: Seven RCTs (304 knees in iPACK + SACB group; 305 knees in SACB group) were included. The follow-up periods ranged from 2 days to 3 months. Pooled data indicated lower pain scores at ambulation (p < 0.0001) for iPACK + SACB. When comparing the pain scores of subgroups analyzed at specific periods, lower scores in subgroups within 12 h (at rest and ambulation) and after 48 h (at ambulation) were observed in the iPACK + SACB group. Analysis demonstrated greater reduction in morphine consumption (p = 0.007) in the iPACK + SACB group. The iPACK + SACB group is also superior to the SACB group regarding function ability, which included range of motion (ROM) (p = 0.001), time up to go (TUG) test (p = 0.030), and ambulation distance (p < 0.0001). No difference was found in clinical outcomes or complications.

Conclusions: With the iPACK added to SACB, pain scores, morphine consumption, functional ability were improved. Additional high-quality studies are required to further address this topic.

Key words: IPACK (interspace between the popliteal artery and posterior capsule of the knee) block; Randomized controlled trials; SACB (single adductor canal block); Systematic review and meta-analysis; Total knee arthroplasty

Introduction

Total knee arthroplasty (TKA) is regarded as an effective treatment that provides pain relief, deformity correction, and function reconstruction for patients with end-stage knee arthritis.¹ The rate of patients who experienced moderate to severe postoperative pain was reported from 23% to 54%.¹⁻³

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Received 5 February 2021; accepted 21 March 2022
Effective analgesia is of paramount importance for post-TKA patients because it could decrease pain scores, facilitate recovery, and reduce the rates of immobility-related complications.\textsuperscript{4} The adductor canal block (ACB) is a widely accepted motor-sparing ultrasound-guided modality and could provide a blockade of the saphenous nerve and vastus medialis nerve with greater preservation of the quadriceps muscle strength than the femoral nerve block (FNB).\textsuperscript{1,2,5-8} ACB can be administered as single or continuous form (administered in the form of repeated boluses at specific predetermined intervals).\textsuperscript{6} Single-shot ACB (SACB) has shown efficacy in pain control.\textsuperscript{3} However, the anteromedial part of the knee could be covered by SACB while the posterior knee pain still troubles patients. To compensate for this, SACB is usually combined with sciatic nerve block or multimodal drug peri-articular injection (PAI).\textsuperscript{7,8,17-20} Recently, a procedure using ultrasound-guided local anesthetic infiltration between the popliteal artery and the capsule of the knee (iPACK) has been shown to provide promising motor-sparing posterior knee analgesia with a lower probability of nerve or vascular injury.\textsuperscript{9-14} This novel approach anesthetizes terminal branches of genicular nerves and popliteal plexus that innervate the posterior capsule of the knee joint without affecting the main trunks of the tibial and common peroneal nerves (CPN).\textsuperscript{8,15}

Several randomized controlled trials (RCT) have compared SACB combined with iPACK block with SACB.\textsuperscript{5,16-21} Many of these trials contained relatively small cohorts and demonstrated inconsistent outcomes. This uncertainty leads to the determination of which method to adopt by the surgeons. The purpose of this meta-analysis was to elucidate whether iPACK plus SACB is superior to SACB with respect to pain score, morphine consumption, function ability, clinical outcomes, and complications.

Methods

This meta-analysis was performed in accordance with the Cochrane Handbook for Systematic Reviews of Interventions and the PRISMA Checklist guidelines (Appendix S1).\textsuperscript{22,23}

Search Strategy

A search was conducted in January 2021, in the PubMed, Ovid, Cochrane Library, and other databases. The search terms were as follows: (iPACK OR “interspace between the popliteal artery and posterior capsule of the knee”) AND (total knee arthroplasty OR knee arthroplasty OR total knee replacement OR knee replacement OR TKA OR TKR) AND ((randomize* control* trial*) OR RCT). The manual search was used to identify proper results in published studies (Appendix S2).

Eligibility Criteria

The titles and abstracts were initially appraised by two reviewers when met inclusions. The full text was checked, and any disagreement was settled by discussion among the research team. The inclusion criteria followed PICO principle: P, participant; I, intervention; C, comparison; O, outcome. Participants were people undergoing TKA without age limitations; intervention was the regional anesthesia utilized iPACK + SACB; comparison was the regional anesthesia utilized SACB; and outcomes were pain scores, opioid consumption, function ability, clinical outcomes, and complications. Articles were excluded if they (i) used a continuous nerve block, (ii) were studies of basic or animal science, or economics, (iii) abstracts without full text.

Quality Assessment

Methodology quality was independently evaluated by two reviewers using the Cochrane Collaboration’s tool for assessing risk of bias in randomized trials.\textsuperscript{24} It is a validated and reliable scoring tool used to assess the quality of RCT. The risk of bias included random sequence generation, allocation concealment, blinding of participants and personnel, blinding of assessors, incomplete outcome data, selective reporting, and other bias. The overall quality could be evaluated as “low risk of bias”, “high risk of bias”, or “unclear risk of bias”.

Data Extraction

Data were independently extracted by two authors via a standardized spreadsheet, including: first author, publication year, number of knees in each treatment arm, age, women percentage, body mass index, inclusion and exclusion criteria, conclusions. Anesthesia modality (types, dosages of anesthesia drugs, rescue anesthesia method, perioperative analgesia protocols), surgeons, prosthesis, surgical approach, follow-up duration, and the number of patients lost to follow were also collected. We also attempted to contact study authors by email for additional information if needed. Data in other forms (e.g. median, confidence intervals, or range of values) were converted to mean and standard deviation based on Cochrane Handbook.

Outcomes

The primary outcome was ambulation pain score as measured by visual analogue scale (VAS) (scale 0–10, 0 = no pain and 10 = worst imaginable pain) and secondary outcomes included (i) pain score at rest; (ii) morphine consumption (oral); (iii) function ability: range of motion (ROM), time up to go test (TUG), quadriceps muscle strength (QMS), ambulation distance; (iv) clinical outcomes: length of hospital stay, surgery time; and (v) complications: risk of falls, vomiting, and nausea, etc.

Statistical Analysis

In our study, STATA 13.0 (StataCorp, College Station, Texas, US) was used for data synthesizes. Subgroup analysis based on follow-up time points were used in our analysis. Mean difference (MD) for continuous variables and risk ratios (RR) for dichotomous variables with 95% confidence intervals (95% CIs) was reported. A $p$-value of 0.05 was
considered statistically significant. Data was pooled by random-effects model. Statistical heterogeneity was detected by both Q statistics and $I^2$ statistics, and $p$-value of 0.10 or $I^2 > 60\%$ was considered substantially heterogenous. Sensitivity analysis was applied to compare the effect of deleting either single study on the overall results. To assess publication bias, the funnel plots were used (number of studies >10) and the Egger test was performed when observed asymmetry in funnel plots. When $p < 0.01$ in the Egger test, the trim and filling method will be used to assess the stability of the results.

Results

Search Results
Our search yielded 165 results after duplicates. After title and abstract screening, 17 relevant papers remained for full-text selection. Ultimately, seven RCTs were included for qualitative analysis with the remainder excluded for various reasons as outlined in the PRISMA flow diagram (Figure 1).

Study Characteristics
Seven trials presented data from 609 patients (304 in iPACK + SACB group; 305 in SACB group). All included RCTs were published between 2018 and 2020 with the follow-up periods ranging from 2 days to 3 months. There was no difference in age, sex, and BMI between two groups. Detailed study characteristics of included studies were presented in Table 1. Five studies enrolled patients with osteoarthritis (OA), one study enrolled traumatic arthritis and rheumatoid arthritis patients. The type of analgesia drug used was variable, with six studies using ropivacaine, two using epinephrine, and one using methylprednisolone and bupivacaine. TKA was performed under general anesthesia in four studies and spinal anesthesia in two studies. One study used combined spinal and epidural anesthesia. The detailed interventions in each group can be seen in Table 2.

Risk of Bias
The random sequence generation was described fairly well in five studies, and allocation concealment in five studies; in the remainder, this risk of bias was high or unclear. Three studies described the blinding of participants and personnel explicitly, and the blinding method was not described in one study. The dropout rate was lower than 20% in all studies and we did not find any other apparent bias. In general, the risk of bias in five studies was low, one study was unclear, and one study was high (Figures 2 and 3). Funnel plots were
| Study (year) | Patients (no) | Age | Women | BMI | Outcomes | Infusion | Exclusion | Conclusions |
|-------------|---------------|-----|-------|-----|----------|----------|-----------|-------------|
| El-Emam (2020) | N/A 28 | 28 | 54 (3) | 8 (28.57%) | 9 (32.14%) | 29.1 (2.7) | 28.5 (3) | (1) VAS (2 weeks, 4 weeks, 8 weeks, 12 weeks); (2) WOMAC Index. |
| Hu (2020) | N/A 40 | 40 | 73.9 (4.9) | N/A | N/A | 21.2 (1.9) | 20 (4.2) | (1) VAS at rest, 2 h, 6 h, 12 h, 24 h, 48 h; ambulation VAS at 2 h, 6 h, 12 h, 24 h, 48 h; (2) Time to rescue analgesic treatment and frequency; (3) Muscle strength; Daily walking distance; (4) Time for initial mobilization; (5) Complications (Pain, vomiting, bleeding, infection, falls etc.). |
| Li (2019) | 2017.11-2018.04 30 | 30 | 66 (6) | 69 (6) | 21 (70%) | 21.9 (2.2) | 21.7 (2) | (1) Release morphine consumption (IV, mg); (2) NRS (0-10) N/A; (3) Walking distance at POD 1 and POD 2; (4) ROM; (5) Complications (narcotic intoxication, hematoma, infection, muscle weakness, falls) |
| Li (2020) | 2018.05-2019.04 50 | 50 | 66.82 (6.17) | 65.56 (6.34) | 40 (80%) | 31 (62%) | 24.68 (2.60) | 24.97 (3.18) | (1) VAS at rest, 2 h, 8 h, 12 h, 24 h, 48 h, and discharge; VAS at ambulation, 2 h, 8 h, 12 h, 24 h, 48 h, and discharge; (2) Opioid consumption (within 24 h, 24-48 h, 48h discharge), number of patients with no morphine requirement; (3) Knee flexion and extension at 24 h, 48 h, and discharge; (4) Quadriceps strength, mobilization distance at 24 h, 48 h, and discharge; (5) TUG, KSS, WOMAC at discharge and 3 months; (6) Complications. |
| Li (2020) | N/A 28 | 28 | 54 (3) | 8 (28.57%) | 9 (32.14%) | 29.1 (2.7) | 28.5 (3) | (1) VAS (2 weeks, 4 weeks, 8 weeks, 12 weeks); (2) WOMAC Index. |

**TABLE 1 The basic information of included studies**

- **El-Emam (2020)**: Study focused on the effectiveness of SACB combined with iPACK block in the elderly patients, compared to the SACB alone.
- **Hu (2020)**: Study compared the analgesic efficacy of SACB combined with iPACK block to the SACB alone.
- **Li (2019)**: Study evaluated the analgesic effect of SACB combined with iPACK block to the SACB alone.
- **Li (2020)**: Study investigated the analgesic effect of SACB combined with iPACK block to the SACB alone.
| Study | Time Period | Included Patients | Included Females | Mean Age (SD) | Mean ASA | Mean BMI (SD) | Pain Assessment | Other Assessments | Exclusion Criteria |
|-------|-------------|-------------------|------------------|---------------|----------|---------------|----------------|------------------|-----------------|
| Sankineani (2018) | 2016.09-2017.03 | 60 | 60 | 61 | 38 (63.33%) | 42 (70%) | 29.36 | 28.88 | N/A (1) VAS at 8 h, on POD1, and on POD2; (2) ROM; (3) ambulation distance; (4) Patients undergoing bilateral or revision TKA, with history of bleeding diathesis or prior vascular surgery on femoral vessels on operated site, severe renal insufficiency, arrhythmia or seizures, sepsis, preexisting lower extremity neurological abnormalities, and difficulties in comprehending VAS pain scores, were excluded from the study. |
| Tak (2020) | 2019.03-2019.06 | 56 | 57 | 65.5 | 64.1 | 29 (51.8%) | 37 (63.8%) | 26 | 26.6 | (1) Unilateral tricompartmental TKA for primary OA; (2) age between 45 and 80 years with an ASA of I-II; |
| Wang (2020) | 2019.01-2020.01 | 40 | 40 | 65.3 (7.11) | 64.1 (8.01) | 14 (30%) | 9 (22.5%) | 25.1 (3.4) | 25.6 (3.9) | (1) VAS (at rest, 2 h, 8 h, 12 h, 24 h, 48 h, 72 h; at ambulation, 12 h, 24 h, 48 h, 72 h); (2) ROM; (3) muscle strength; (4) daily walking distance; (5) complications (nausea, vomiting, swelling, bleeding, delayed healing of wound, VTE, neurovascular injury, infection, MI). |

SACB + iPACK is a promising technique that offers improved pain management in the immediate postoperative period without affecting the motor function around the knee joint, resulting in better ROM and ambulation compared to SACB alone.

The addition technique of iPACK to SACB may not add any additional benefit in postoperative pain control, ambulation, opioid consumption or rehabilitation compared to SACB alone.

SACB combined with iPACK block is more effective than SACB on analgesia after TKA.

Abbreviations: ASA, American Society of Anesthesiologists; iPACK, interspace between the popliteal artery and the capsule of the posterior knee; KSS, Knee Society Score; NRS, Numeric Rating Scales; OA, osteoarthritis; POD, postoperative day; ROM, range of motion; SACB, single adductor canal block; TKA, total knee arthroplasty; TUG, Time up and go test; VAS, Visual Analog Scale; WOMAC, Western Ontario and McMaster Universities Arthritis Index.

† The data was presented as mean and standard difference; ‡ The data was presented as number and percentages; I represented intervention group (iPACK + SACB); C represented control group (SACB);
| Author          | ASA  | Diseases                                      | I          | C                  | Rescue Method | Anesthesia | Pre-operative | Intraoperative | Postoperative | Surgeons | Approach | Prosthesis | Follow-up |
|-----------------|------|-----------------------------------------------|------------|--------------------|---------------|------------|---------------|----------------|---------------|-----------|----------|------------|------------|
| El-Emam (2020)  | I/II | OA (KL II, III)                               | (3) IPACK: 30 mL of 12.5% ropivacaine + 40 mg methylprednisolone; (2) SACB: 30 mL of 12.5% ropivacaine + 40 mg methylprednisolone. | N/A         | General         | N/A         | N/A            | N/A            | N/A         | N/A       | N/A       | N/A        | 12 weeks   |
| Hu (2020)       | I/II | OA 25/39/16                                   | (3) IPACK: 15 mL of 0.2% ropivacaine; (2) SACB: 20 mL of 0.2% ropivacaine. | N/A         | General         | N/A         | (1) Propofol 3–5 mg/kg; (2) Remifentanil 10–15 μg/ml/h; (3) other medications were given by patients' situation. | N/A            | N/A         | N/A       | N/A       | N/A        | 2 days     |
| Li (2019)       | I/II | OA 39; Traumatic arthritis 16; RA5.           | (3) IPACK: 30 mL of 0.33% ropivacaine; (2) SACB: 20 mL of 0.33% ropivacaine. | N/A         | General         | N/A         | Transacetic acid first dose of 20 mg/kg IV used during surgery; another dose used 8 h later; Elastic bandage was used to reduce the blood loss. | N/A            | N/A         | Senior surgeons | N/A       | 2 days     |
| Li (2020)       | I/II | OA 22/43/35                                   | (3) IPACK: 20 mL AV; (2) SACB: 20 mL AV: Anesthetic volume, consisted of 0.2% ropivacaine and 2.0 mg/mL of epinephrine. | Mepivacaine hydrochloride (30 mg) was intramuscularly administered with unbearable pain reported by patients. | SACB: 20 mL AV. | Combined spinal and epidural anesthesia (0.5% ropivacaine 1.6–2 mL lidocaine was added as needed). | N/A            | N/A         | Two senior surgeons | N/A       | 3 months   |
| Sankineani (2018) | N/A | N/A                                            | (3) IPACK: 35 mL of 0.2% ropivacaine; (2) SACB: 20 mL of 0.2% ropivacaine. | Mepivacaine hydrochloride (30 mg) was intramuscularly administered with unbearable pain reported by patients. | SACB: 20 mL of 0.2% ropivacaine. | Spinal (2.5 mL of 0.5% hyperbaric bupivacaine) | N/A            | N/A         | N/A       | Senior stabilized knee prosthesis | Posterior stabilized knee prosthesis | 2 days     |
| Tak (2020)      | II/II| OA 306/8                                      | (3) IPACK: 20 mL of 0.2% ropivacaine; (2) SACB: 20 mL of 0.2% ropivacaine. | Oxycodone immediate release tablets (oral); morphine (IV). | SACB: 20 mL of 0.2% ropivacaine. | Spinal | Oral oxycodone 200 mg and Gabapentin 300 mg were given 12 h before the surgery. | N/A            | N/A         | Two surgeons | Medical parapetellar approach | Posterior stabilized knee prosthesis | 2 days     |
| Wang (2020)     | I/II | OA 3/48/20                                    | (3) IPACK: 20 mL of mixed analgesic drugs (0.2% ropivacaine + 2.0 μg/mL epinephrine); (2) SACB: 20 mL of mixed analgesic drugs (0.2% ropivacaine + 2.0 μg/mL epinephrine); | Mepivacaine hydrochloride (30 mg, IV) | SACB: 20 mL of 0.2% ropivacaine. | Morphine hydrochloride (30 mg, IV) | Oral oxycodone (200 mg, bid) | N/A            | N/A         | One surgeon | Medical parapetellar approach | Posterior stabilized knee prosthesis | 3 days     |

C represented control group (SACB); I represented intervention group (IPACK + SACB).; Abbreviations: ASA, American Society of Anesthesiologists; interspace between the popliteal artery and the capsule of the posterior knee; KL, Kellgren-Lawrence Classification; NRS, Numeric Rating Scales; OA, osteoarthritis; RA, Rheumatoid Arthritis; SACB, single adductor canal block; VAS, Visual Analog Scale.
applied on the VAS score at rest and ambulation. The asymmetrical distribution of funnel plots was observed. The Egger test showed $p < 0.01$, thus we did the trim and filling test, and the results were not changed (Appendix S3).

**Sensitivity Analysis**
To validate our results, the sensitivity analysis was performed by excluding one trial at a time and recalculating the pooled MD for the remaining trials, which showed that the conclusions remained unchanged in all outcomes, suggesting the stability of our meta-analysis (Appendix S4).

**Primary Outcome**

**Pain at Ambulation**
When comparing the ambulation VAS scores of subgroups analyzed at specific periods in time, there was a trend toward lower VAS scores in the iPACK + SACB group in subgroups of 0–6 h, 8–12 h, 48 h, and after 72 h (Figure 4).

**Secondary Outcomes**

**Pain at Rest**
We examined the combined VAS scores for each group, it demonstrated more reduction in VAS scores for the iPACK + SACB group versus the SACB group, and the difference was statistically significant ($p < 0.001$). Considering that the duration of follow-up may be the origin of heterogeneity, subgroup analysis was conducted based on different follow-up times. The iPACK + SACB group had lower VAS scores at 8 h ($p = 0.002$) and 12 h ($p = 0.001$) postoperatively (Figure 5).

**Morphine Consumption**
Data on 354 patients from 4 trials were analyzed for morphine consumption. A significant difference was identified and the result showed decreased morphine usage in the iPACK + SACB group (MD = −0.451, $p = 0.007$) (Table 3.).

**Function Ability**

**Range of Motion**
ROM refers to the main movement when the knees are flexion and extension. When knee movement is limited, it causes pain, impairs function, and makes us predisposed to knee injuries. Data on 440 patients were analyzed and the results favored the iPACK + SACB group (MD = 2.686, $p = 0.001$).

**Time Up and Go Test**
TUG test is a simple evaluative test by measuring the time a patient takes to stand up from a chair, walk a distance of...
three meters without any support, and return to the chair. It could be used to estimate the risk of falling and the ability to maintain balance while walking. Data on 540 patients were pooled and the result suggested that the iPACK + SACB group performed better (MD = 0.247, p = 0.030).

**Quadriceps Muscle Strength**

The strength of the quadriceps muscle determined the ability of mobilization and could reduce falling. Pooled results showed that the SACB group was better in quadriceps muscle strength recovering (MD = −0.225, p = 0.009).

**Ambulation Distance**

Data on 774 patients suggested that patients with iPACK block had longer ambulation distances (MD = 0.296, p < 0.0001). Subgroup analysis showed similar benefits on postoperative day 1 (POD1) and on POD 2 while there was no difference on POD 3.
Clinical Outcomes
Data on 475 primary TKAs were pooled from 5 trials for the surgery time and 240 patients from three trials for hospital length. The difference was not statistically significant between the two groups.

Complications
Only three studies reported complications, therefore, limited data can be used for analysis. The nausea rate was similar between the two groups (RR = 0.760, p = 0.089).

Discussion

Key Findings
The key findings of this meta-analysis were that iPACK plus SACB provided better results in terms of pain control, morphine use, and function recovery when compared with SACB. The results of pain scores (at rest, at ambulation) reached the minimally clinical importance (MCID) within 12 h. However, the other results lacked clinical importance.
The ideal analgesia regime should balance optimal pain control and best early recovery in fast-track TKA management. ACB is an effective peripheral nerve block, which could replace FNB with better motor preservation ability and adequate analgesic effect. By block- ing the saphenous nerve and the posterior branch of the obturator nerve, SACB provided satisfying analgesic effects on the anteromedial part of the knee. However, the posterior part was not covered. Ultrasound-guided iPACK was introduced in 2012 as an alternative analgesic method for sciatic nerve block on the posterior part without causing any common peroneal nerve damage, foot drop, or numbness.

Several RCTs that compared SACB plus iPACK to SACB found inconclusive outcomes in terms of pain scores. Therefore, our study was performed to assess whether iPACK plus SACB had superiority over SACB after TKA.

Our results showed that iPACK plus SACB was better than SACB regarding rest pain, activity pain, and morphine consumption. A significant difference was observed in pain relief after surgery and the results of pain scores (at rest and at ambulation) measured within 12 h all reached the MCID. Though high heterogeneity was found, the results were not changed by sensitivity analysis. Factors such as patient characteristics (sex, weight, height), local anesthetic formulation (dosing, volume), surgeon techniques (nerves or muscle damage, tourniquet use, and length), prosthesis (cement, type), anesthesiologist techniques, and perioperative protocols (rehabilitation, analgesia, blood management, sleep, and

Discussion over Results

TKA is associated with moderate-to-severe postoperative knee pain. The poor management of pain usually results in prolonged rehabilitation time, increased complications, and diminished patient satisfaction. Effective analgesia is of paramount importance. The ideal analgesia regime should balance optimal pain control and best early recovery in fast-track TKA management. ACB is an effective peripheral nerve block, which could replace FNB with better motor preservation ability and adequate analgesia effect. ACB could also reduce the risk of quadriceps weakness and falling risk. ACB had both single and continuous techniques, but the advantages of each technique are debatable. By blocking the saphenous nerve and the posterior branch of the obturator nerve, SACB provided satisfying analgesic effects on the anteromedial part of the knee. However, the posterior part was not covered. Ultrasound-guided iPACK was introduced in 2012 as an alternative analgesic method for sciatic
emotion management) may explain for the stubborn heterogeneity. The rising demand for TKA also mandates strategies to minimize opioid consumption and prevent patients from adverse events such as nausea, vomiting, respiratory depression, or chronic opioid dependency. Rescue opioids were used for breakthrough pain in several studies and we found decreased opioids use with the addition of iPACK. The incidence of postoperative nausea or vomiting was low without significant difference in our review. This is most likely due to the effective blockade that reduced morphine consumption and minimized associated side effects. None of the included studies reported severe complications such as death, intoxication, puncture, or injury, and proved the safety of both interventions. However, it is important to closely monitor patients after administration of the anesthetic. As for function ability, we adopted four indicators (ROM, TUG test, ambulation distances, and quadriceps muscle strength) for assessment. There were significantly better outcomes in the iPACK plus SACB group comparing with the SACB group. However, these results all lack MCID and the interpretation must be made with caution due to the relatively small sample size and other confounding factors. However, the outcome of quadriceps muscle strength was better in the SACB group, which we cannot explain now. For clinical outcomes, multiple factors could affect the length of hospital stay or surgery time, for instance, sex, age, and physiological status. Prolonged hospitalization may lead to several complications, including deep vein thrombosis, muscle atrophy, and increased cost. No difference was found with hospital stay or surgery time and this may reveal the possibility of applying iPACK as it did not increase time–cost.

Recently, many researchers designed different trials by the combinations of AOB and iPACK. And the results were consistent with ours. Kertkiatkachorn et al. found iPACK plus SACB block may be a suitable alternative to CACB plus periarticular injection (PAI) under the condition that the surgeons cannot perform PAI. However, iPACK is more complicated, requiring the regional anesthesiologist with expertise. Kim et al. found the iPACK plus SACB significantly improved analgesia and reduced opioid consumption compared to PAI and strongly supported it within the multimodal analgesic pathway. Jung et al. reported that iPACK plus SACB may be a better option than PAI for controlling acute phase pain. Similarly, Eccles et al. found iPACK plus SACB demonstrated improved early ambulation with decreased opioid use, and shortened length of stay compared with FNB plus sciatic nerve block.

The strengths of our study are that we adhere to the strict inclusion and exclusion criteria and only selected SACB plus iPACK with SACB for analysis to make sure the precision of our results.

Limitations

The review also has several limitations. First, the heterogeneous of several outcomes cannot be solved by subgroup analysis, however, we did sensitivity analysis and the results were not changed. Second, the included studies only had a small number of participants and short-term follow-up lengths, which indicates the paucity of large population and long-term reports. Third, as the analgesic effects of iPACK mainly influence the posterior part pain, the assessment of pain on different knee parts should be specified in future studies. Further high quality and multicentral studies should be undertaken to refine the technique (ie, optimal place, injection pressure, anesthetic formulation and et al.).

Conclusions

With the iPACK added to SACB, pain scores, morphine consumption, function ability were improved. Additional high-quality studies are required to further address this topic.

Abbreviations

iPACK: Intersosseous popliteal artery to capsule of the knee (iPACK); Single adductor canal block (SACB); Total Knee Arthroplasty (TKA); Randomized controlled trials (RCTs); Femoral nerve block (FNB); risk ratio (RR); mean difference (MD); Visual analog scale (VAS); 95% confidence interval (95% CI); PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses); Periarticular injection (PAI); Range of motion (ROM); Time up to go test (TUG); Quadriceps muscle strength (QMS); Postoperative day (POD); Common peroneal nerve (CPN); Postoperative day (POD); minimally clinical importance (MCID).

Declarations

Funding (information that explains whether and by whom the research was supported)

Supported by

1. West China Nursing Discipline Development Special Fund Project, Sichuan University (HXHL20003)
2. 1.3.5 project for disciplines of excellence, West China Hospital, Sichuan University (ZYJC18040)
3. The Key Research & Development program of Science & Technology Department of Sichuan Province 2021YFS0167
4. Post-Doctor Research Project, West China Hospital, Sichuan University (2020HXBH080)
5. Sichuan University Postdoctoral Interdisciplinary Innovation Fund

Conflicts of interest/Competing interests (include appropriate disclosures)

The authors declare no competing interests.

Availability of data and material

All data are fully available without restriction.
This meta-analysis and all the included studies meet all the ethical standards described in the declaration of Helsinki. No ethical committee approval was required for this study.

Ethical approval

Consent to participate (include appropriate statements)

Consent for publication (include appropriate statements)

Availability of data and material (data transparency)

Supporting Information

Additional Supporting Information may be found in the online version of this article on the publisher’s web-site:

Appendix S1. Supplementary Tables.
Appendix S2. Supporting Information.

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