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RESEARCH

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A novel technique of intraoperative infiltration between posterior capsule and popliteal artery can reduce opioid consumption and blood loss in total knee arthroplasty surgery: an age- and gender-matched study

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Abstract

Purpose Interspace infiltration between the posterior knee capsule and popliteal artery (iPACK) is an effective method for pain control following total knee arthroplasty (TKA). However, this procedure still requires an experienced physician to perform ultrasound-guided injections postoperatively, and the patient will need to undergo additional injections aside from the surgery. This study investigates a novel, simplified intraoperative iPACK (I-iPACK) technique, applied during surgery without the need for ultrasound or an anesthesiologist. We hypothesized that combining I-iPACK with periarticular injection (PAI), comparing with using PAI alone, could reduce postoperative morphine consumption and improve the range of motion (ROM) in patients after TKA.

Methods This retrospective analysis reviewed data from 600 patients who underwent unilateral TKA, selected from an initial pool of 3502. The patients were divided into two groups: 300 received PAI with I-iPACK (Group A), and 300 received PAI alone (Group B). The groups were matched by age and gender. The primary outcome parameters postoperative pain levels (VAS scores) and cumulative morphine consumption at 24, 48, and 72 h. The secondary outcome parameters were maximum tolerated ROM measured by continuous passive motion (CPM) through time and adverse events, such as nausea, dizziness, constipation, and gastrointestinal bleeding, monitored for two weeks post-surgery. The hypothesis is the additional I-iPACK technique is not inferior to the PAI alone. Non-parametric statistical methods were used for analysis, with a significance threshold set at $p < 0.05$.

Results Both groups were comparable in demographics, and no significant differences in surgery time were noted. However, the I-iPACK group had significantly less blood loss. Patients receiving I-iPACK had improved ROM at 24 h, reduced morphine consumption at all measured time points, and had lower rates of complications including constipation and dizziness. The two groups showed no significant differences in other complications or pain scores.

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Conclusion The addition of I-iPACK to PAI during TKA surgery effectively reduces morphine consumption, limits blood loss, and enhances early postoperative ROM without increasing adverse events such as nerve palsy. Similar technique of intra-operative infiltration for pain control could be adopted in diverse surgical settings. However, the lack of blinding might have minor impacts on the patient-reported outcome such as VAS scores.

Level of Evidence Level III, Therapeutic Study.

Keywords IPACK, Infiltration between posterior capsule and popliteal artery, Total knee arthroplasty, Pain control, Morphine consumption

Introduction

Total knee arthroplasty (TKA) is a widely performed orthopedic procedure aimed at alleviating pain and restoring function in patients with end-stage knee osteoarthritis. TKA has proven to be highly effective in improving quality of life, mobility, and long-term joint health for many individuals [1, 2]. However, the procedure is not without challenges, as postoperative pain management remains a significant concern. Effective pain control is crucial for early mobilization, reducing hospital stay, and preventing chronic pain development following TKA [3, 4].

In recent years, the iPACK (interspace between the popliteal artery and capsule of the posterior knee) block has gained attention as a promising technique for postoperative pain management in TKA [5–8]. Unlike traditional nerve blocks, which may affect motor function, the iPACK block provides effective pain relief while preserving quadriceps strength, allowing for early mobilization. Studies have shown that the iPACK block, when combined with other regional anesthesia techniques, results in reduced opioid consumption, lower pain scores, and faster recovery times in TKA patients, making it an advantageous option for enhancing postoperative outcomes [5, 9, 10].

However, this procedure still requires an experienced physician to administer ultrasound-guided injections after the surgery, and the patient will need to receive additional injections in addition to the surgery. Therefore, in this study, we performed our novel technique to do additional intraoperative iPACK (I-iPACK) block without access of ultrasonogram or anesthesiologists. It allows the patient's postoperative pain management to no longer rely on additional equipment in the ward, while also reducing the burden on the anesthesiologist. Our hypothesis is the I-iPACK can avoid the need for additional procedures after surgery, and reduce pain as well as morphine consumption and enhance postoperative motion of knee.

Material and methods

In this study, the prospectively routine practice collected data which was obtained from our hospital's joint replacement registry was retrospectively exploratory analyzed from a series of patients who underwent unilateral TKA in one institute. Ethical approval was obtained from our institutional review broads (2024–07–142AD). The informed consent was obtained from all registered patients. A total of 3502 patients of unilateral TKA were enrolled which were all performed by two surgeons (FYC and YPS). Exclusion criteria of this study are as follow: (1) patients who had undergone a total knee arthroplasty procedure for an inflammatory arthritis (e.g. rheumatoid arthritis, septic arthritis or gouty arthritis); (2) chronic renal impairment (estimated glomerular filtration rate less than 60 ml/min/1.73m^2 on at least 2 occasions 90 days apart); (3) preoperative chronic opioid-dependent patients(exceeding 50 mg oral morphine equivalence per day at time of recruitment); (4) History of coronary artery disease; (5) History of peptic ulcer disease; (6) substance abuse (e.g. alcohol or narcotics); (7) receiving perioperative regional block or spinal anesthesia; (8) receiving patient controlled analgesia for postoperative pain control. After the above selection process, subdivided into 304 TKR using PAI with I-iPACK technique (Group A) and 1259 TKR using PAI without I-iPACK (Group B). To ensure comparability between two groups, the matching was based on the following criteria: (1) Age matching: Patients were matched within one year to minimize confounding effects of age; (2) Gender matching: the proportion of male and female patients was balanced between the two groups to reduce the influence of gender-related differences. As a result, two groups were matched according to gender and age at time of surgery in a 1:1 ratio (Fig. 1).

The surgeries were all conducted using a minimally invasive surgical technique via the mid-vastus approach. A tourniquet was routinely employed, with the pressure set at 120 mmHg above the systolic blood pressure prior to inflation. In Group A, a half of mixture of 20 ml of 0.25% bupivacaine and 20 ml of normal saline was injected to posterior capsule evenly within 1 cm depth along the posteromedial, midline and posterolateral point

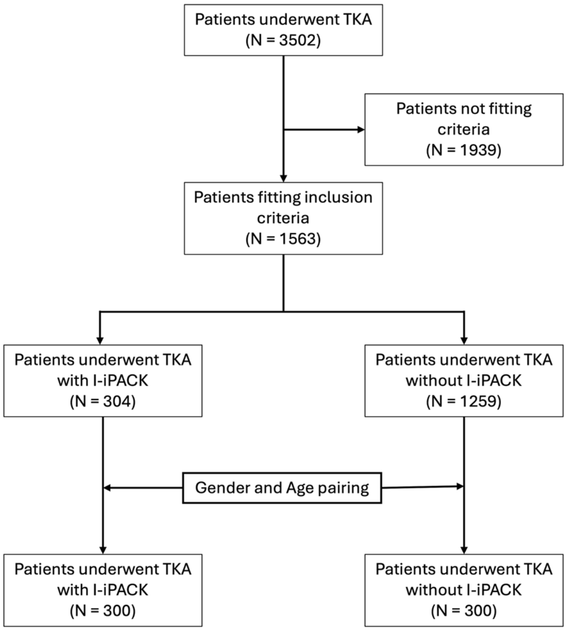

Fig. 1 Flowchart explaining how to group patients. 300 patients were included in each group after gender and age pairing. TKA, Total knee arthroplasty; I-iPACK, Intraoperative interspace between the popliteal artery and capsule of the posterior knee block

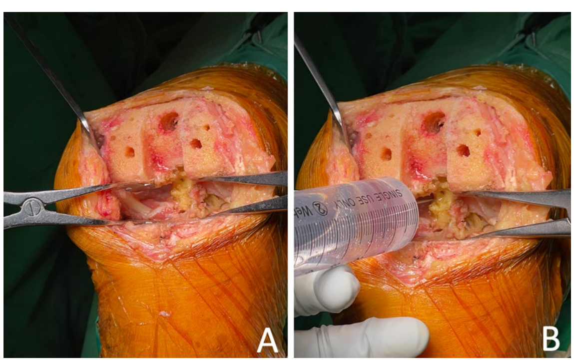

Fig. 2 (**A**) The posterior capsule was exposed when the knee was flexed with the spreader instrument. (**B**) The I-iPACK was performed by injecting to posterior capsule evenly within 1 cm depth after needle aspiration confirmed there was no blood vessel while checking the flexion gap

according to the anatomical study from LaPrade et al. [11] after needle aspiration confirmed there was no blood vessel (Fig. 2). All patients received a cemented posterior-stabilized total knee arthroplasty (NexGen High Flex, Zimmer Inc., Warsaw, USA). After implanting the prosthesis, we deflated the tourniquet, performed a periarticular injection, irrigated the area, inserted a Hemovac® drain (Zimmer, Warsaw, IN, USA), and then closed the wound accordingly.

Before wound closure, the rest of mixture was injected around the knee joint in group A and total mixture was injected in group B. All patients had oral paracetamol 500 mg, 4 times/day and celecoxib 200 mg, 2 times/day after surgery.

A standardized postoperative protocol was provided for all of the patients. We allowed the patients started to ambulate using a walker if necessary and allowed weight-bearing without restrictions as soon as possible. We used continuous passive motion (CPM) device for range of motion training four times a day, followed by ice-packing for 15 minutes. We started from 70 degrees and added 10 degrees each time if the patient was able to tolerate it. The indwelled foley catheter was removed on postoperative day 1. The Hemovac drain was removed on postoperative day 2. The patient was discharged on postoperative day 4 or 5.

Outcome measurements

We measured pain levels at rest and during movement using VAS scores at various postoperative intervals (6, 12, 24, 48, 72, and 96 h). To assess the effectiveness of reducing opioid use, we tracked cumulative morphine consumption (in mg) for both groups at 24, 48, and 72 h after surgery. In theory, the maximum cumulative morphine dosage was the same for both groups. Additionally, we noted the maximum range of motion patients could tolerate under continuous passive motion (CPM) at the same postoperative intervals.

For safety evaluation, we recorded any drug-related adverse effects within the first two weeks post-surgery. These included nausea, vomiting, dry mouth, dizziness, itching or skin rashes, constipation, dyspepsia, gastrointestinal bleeding, cardiovascular issues (such as angina or heart attack), urinary retention, sedation, and cognitive impairment.

Statistical analysis

All data were retrieved in a registry electronic database and analyzed using SPSS software (Version 28.0; SPSS, Inc., Chicago, IL, USA). Categorical data were reported as absolute and relative frequencies, while quantitative data were expressed as medians with interquartile ranges. The Kolmogorov–Smirnov test was conducted to assess the normality of the data distribution. Since the data were not normally distributed, non-parametric statistical methods were utilized: the chi-square test for categorical data and the Mann–Whitney U test for continuous data. A p-value of less than 0.05 was considered statistically significant.

Results

A total of 600 patients who underwent total knee arthroplasty (TKA) were included in the study based on the inclusion and exclusion criteria. Of these, 300 patients received the I-iPACK (intraoperative—interspace between the popliteal artery and capsule of the knee) block during surgery, while 300 did not. Both groups were comprised of 217 females and 83 males. Demographic characteristics, including age ($p=1$), gender ($p=1$), body mass index (BMI) ($p=0.362$), American Society of Anesthesiologists (ASA) classification ($p=0.863$), and Charlson Comorbidity Index (CCI) ($p=0.99$), were comparable between the two groups, with no statistically significant differences observed (Table 1).

Intraoperative outcomes revealed no significant difference in operation time between the two groups. However, patients who received the I-iPACK block had significantly reduced estimated blood loss compared to those who did not ($p<0.0001$).

Postoperative outcomes are summarized in Table 2. The length of hospital stay was similar between the two groups ($p=0.287$). Patients in the I-iPACK group demonstrated significantly better continuous passive motion (CPM) at 24 h post-surgery ($p=0.004$), although no significant difference was observed at 48 or 72 h postoperatively. In addition, patients in the I-iPACK group had significantly reduced morphine consumption at 24, 48, and 72 h postoperatively ($p<0.001$).

Table 1 Demographic Data

	PAI + iPACK (n = 300)	PAI only (n = 300)	*p*-value
Age(year)	73.0 ± 8.0	73.0 ± 8.0	1.0
Gender			
Female	217 (72.3%)	217 (72.3%)	1.0
Male	83 (27.7%)	83 (27.7%)	
Height(cm)	154.5 ± 8.1	154.7 ± 8.1	0.700
Weigh (Kg)	65.3 ± 11.5	64.0 ± 12.2	0.200
BMI(Kg/m2)	27.3 ± 3.9	27.0 ± 4.15	0.362
ASA			
I	188 (62.7%)	193 (64.3%)	0.863
II	102 (34.0%)	96 (32.0%)	
III	10 (3.3%)	11 (3.7%)	
CCI			
1	8 (2.7%)	6 (2.0%)	0.99
2	53 (17.7%)	47 (15.7%)	
3	90 (30%)	91 (30.3%)	
4	83 (27.6%)	83 (27.7%)	
5 or > 5	56 (18.7%)	73 (24.3%)	
Operation time(mins)	47.2 ± 12.4	45.3 ± 13.2	0.07
EBL (ml)	78 ± 8.32	125 ± 11.39	< 0.001

PAI, periarticular injection; BMI, Body Mass Index; CCI, Charlson Comorbidity Index; I-iPACK, intraoperative infiltration of interspace between posterior knee capsule and popliteal artery; EBL, estimated blood loss

Table 2 Postoperative outcome

	PAI + iPACK(n = 300)	PAI only(n = 300)	*p*-value
CPM			
Post-op 24 h	95.2 ± 9.23	97.6 ± 11.2	0.004
Post-op 48 h	110.3 ± 10.72	111.6 ± 9.79	0.121
Post-op 72 h	120.2 ± 11.21	119.2 ± 13.20	0.318
Length of Hospital Stay (Days)	3.5 ± 1.2	3.6 ± 1.1	0.287
Cumulative morphine dosage(mg)			
Post-op 24 h	3.16 ± 2.12	7.3 ± 3.22	< 0.001
Post-op 48 h	6.72 ± 3.11	16.3 ± 5.69	< 0.001
Post-op 72 h	10.52 ± 4.35	20.2 ± 7.92	< 0.001

PAI, periarticular injection; I-iPACK, intraoperative infiltration of interspace between posterior knee capsule and popliteal artery; CPM, continuous passive motion)

Complication rates, presented in Table 3, indicated that the I-iPACK group had a significantly lower incidence of side effects correlated with morphine consumption, including constipation ($p<0.001$) and dizziness ($p=0.001$) compared to the control group. However, no significant differences were found between the groups regarding gastrointestinal (GI) bleeding ($p=0.279$), skin rash ($p=0.132$), or urinary retention ($p=0.247$). The reoperation rate was identical in both groups ($p=1.0$). Notably, other complications often associated with morphine use, such as dry mouth, respiratory depression, and nerve palsy, were not observed in either group.

Regarding pain control, visual analog scale (VAS) pain score of patients within both groups, recorded in multiple time spots after surgery (Fig. 3). VAS for pain reduced from postoperative 6 h to 96 h in both I-iPACK group (from 2.78 to 2.44, $p<0.001$) and PAI-only group (from 2.89 to 2.73, $p<0.001$). However, no significant differences were noted in visual analog scale (VAS) pain scores between two groups at 6, 12, 24, 48, 72, and 96 h postoperatively.

Discussion

This study evaluated the efficacy of adding the novel I-iPACK block to standard analgesia in patients undergoing total knee arthroplasty (TKA). Our findings indicate that the additional I-iPACK block significantly reduces intraoperative blood loss and postoperative opioid consumption, with no increase in major complications. Additionally, patients receiving the I-iPACK block demonstrated better passive motion at 24 h post-surgery and experienced fewer opioid-related side effects, such as constipation and dizziness. While numerous studies

Table 3 Complication within two weeks and reoperation within 90 days

	PAI + iPACK(n = 300)	PAI only(n = 300)	*p*-value
Opioid related- Adverse events			
Constipation	4 (1.3%)	21 (7.0%)	0.001
Dry mouth	0	0	
Dizziness	5 (1.7%)	21 (7.0%)	0.001
Skin rash	0	4 (1.3%)	0.132
Urinary retention	0	3 (1.0%)	0.247
Respiratory depression	0	0	
Sedative	0	1 (0.3%)	1.000
Non Opioid related- Adverse events			
Nerve Palsy	0	0	
Dyspepsia/GI bleeding	9 (3.0%)	5 (1.7%)	0.279
Reoperation	6 (2.0%)	5 (1.7%)	1.000

PAI, periarticular injection; I-iPACK, intraoperative infiltration of interspace between posterior knee capsule and popliteal artery; GI, gastrointestinal

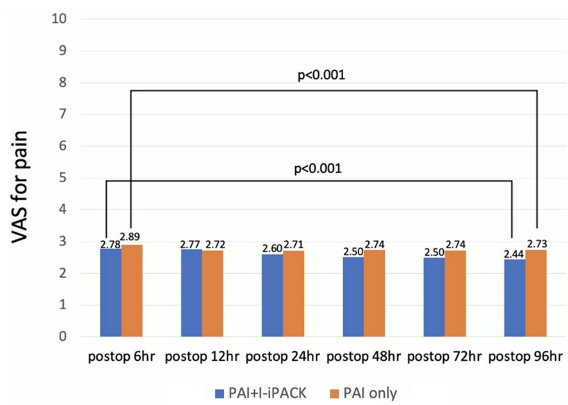

Fig. 3 Visual Analogue Scale (VAS) recorded 6, 12, 24, 48, 72, 96 h after total knee arthroplasty. There was no significant difference between two groups in each time point. PAI, periarticular injection; I-iPACK, Intraoperative interspace between the popliteal artery and capsule of the posterior knee block

focused on the effects of iPACK on patients having TKA, this procedure still requires an experienced physician to perform ultrasound-guided injections postoperatively, and the patient will need to undergo additional injections aside from the surgery. The novel I-iPACK block provides an alternative option in region with limited settings, while reducing unnecessary workforce and time consumption.

According to past studies [9, 12, 13], the use of the iPACK block alone in total knee arthroplasty (TKA) has shown advantages over traditional methods for managing posterior knee pain. Anatomically, the local anesthetic is injected into the space between the popliteal artery and the posterior knee capsule, primarily at the level of the distal femoral condyles. This approach anesthetizes the terminal sensory branches of the tibial nerve, obturator nerve, and occasionally the common peroneal nerve [14]. By sparing the main motor branches of these nerves, the IPACK block provides effective analgesia while preserving motor function, particularly during postoperative rehabilitation. [5, 10, 15–17] Unlike the femoral nerve block (FNB) or sciatic nerve block (SNB), which often result in significant motor impairment, the iPACK block provides effective analgesia for the posterior knee while preserving motor function, making it an attractive option for early mobilization. In comparison to periarticular infiltration (PAI), iPACK offers more targeted relief for posterior pain, which is often inadequately addressed by PAI alone. According to the study from Hussain et al. In the absence of periarticular infiltration (PAI), adding iPACK to ACB reduced pain scores by 1.33 cm on a 10-cm VAS at 6 h postoperatively, with further reductions at 12 and 24 h [16, 18].

When used in combination with other regional anesthesia techniques, such as the adductor canal block (ACB), the benefits of iPACK become more pronounced. Studies have demonstrated that iPACK combined with ACB significantly reduces opioid consumption, enhances early postoperative mobility, and decreases the incidence of opioid-related side effects compared to ACB alone [15, 19]. Moreover, the combination of iPACK with ACB or PAI provides a more comprehensive pain control strategy, addressing both anterior and posterior knee pain without compromising motor function, as can be seen with FNB. Overall, iPACK's ability to complement other techniques within multimodal analgesia protocols has been well-supported, leading to improved pain management and functional recovery in TKA patients [5, 15].

Besides, this region where the iPACK block is administered is close to the geniculate arteries, which supply blood to the knee joint [20, 21]. The presence of these arteries near the injection site raises the possibility that the local anesthetic may influence perioperative blood loss by inducing vasoconstriction in the surrounding vasculature. Several studies have shown that local anesthetics, such as ropivacaine and lidocaine, can cause vasoconstriction when injected near blood vessels, contributing to reduced blood flow and, consequently, diminished intraoperative bleeding [22–24]. This mechanism is supported by findings in our study, where patients who received the I-iPACK block had significantly reduced estimated blood loss compared to those who did not, suggesting that the block may not only provide effective analgesia but also contribute to blood conservation during total knee arthroplasty. By acting on the geniculate arteries and other nearby vessels, the I-iPACK block could offer dual benefits of pain control and blood loss reduction. However, due to lack of direct evidence, the hypothesis still required future research for validation.

The significant reduction in morphine consumption observed in I-iPACK patients on the first postoperative day in our study suggests potential long-term benefits, particularly in reducing the risk of chronic opioid use. Past studies showed that higher opioid use in the immediate postoperative period is associated with increased chances of chronic opioid dependence, leading to worse long-term outcomes [25]. By minimizing early opioid intake through the use of I-iPACK, our approach may reduce the likelihood of prolonged opioid use and improve overall long-term recovery outcomes for TKA patients. Reducing opioid consumption also offers several long-term benefits. One of the key advantages is a lower risk of chronic pain. Long-term opioid use can contribute to opioid-induced hyperalgesia, where pain sensitivity increases. By reducing opioid use, individuals may avoid this cycle, leading to better long-term pain management through alternative therapies. Additionally, cutting down on opioid consumption reduces the risk of opioid dependence and opioid use disorder (OUD), which can have serious physical, mental, and social consequences. Lower opioid use also reduces the risk of cognitive impairment, overdose, and mental health issues such as depression and anxiety, ultimately improving quality of life.

Our study found that the I-iPACK block significantly lowered the incidence of opioid-related side effects, such as constipation and dizziness, which are commonly associated with higher opioid use. By minimizing the need for opioids, I-iPACK not only improves pain management but also enhances patient comfort and reduces the burden of adverse effects. These advantages suggest that I-iPACK plays a crucial role in optimizing early postoperative recovery and may contribute to better patient satisfaction and outcomes in the long term.

In our study, the novel I-iPACK technique can be performed intraoperatively without access of ultrasonogram and anesthesiologist. In addition, there was no transient or permanent nerve injury after the surgery in our series. Such technology can serve as a reference for hospitals that are lacking in equipment or manpower, and it has the potential to reduce healthcare costs. However, the technique still requires experienced surgeon to infiltrate the solution in the proper position for effective nerve blockage.

The I-iPACK technique holds significant potential for influencing clinical guidelines and standard practices for pain management in TKA. It could be used in combination with periarticular injections (PAI) to enhance analgesia in TKA patients without affecting motor function and could also be included in the Enhanced Recovery After Surgery (ERAS) protocol as a key part of the multimodal pain management strategy, contributing to early mobilization and a quicker return to normal function. The reduction in blood loss also aligns with ERAS guidelines, which focus on optimizing intraoperative conditions to improve patient outcomes. In resource-limited settings, the I-iPACK technique provides a way to improve early postoperative recovery without the need for specialized equipment such as ultrasound, or personnel.

This study has several limitations that should be acknowledged. First, although the data is from a registered source, the postoperative pain scores were recorded only at specific time points. As a result, the apparent lack of difference between the two groups may not accurately reflect the patients' pain experiences over time. Second, the administration of morphine varied among patients, meaning that not all individuals received the same form or dosage, which could impact the consistency of pain relief. In addition, the use of non-morphine analgesics also differed between patients, leading to variability in the types and effectiveness of pain management strategies employed. Moreover, the lack of blinding might have minor impacts on the patient-reported outcome such as VAS scores. These limitations may affect the interpretation of the results and suggest the need for further research to better understand the nuances of postoperative pain management. Although both surgeons were very highly experienced and having high volume of surgeries, the potential variability may arise such as subjective anatomical landmarks. However, both high-volume surgeons can minimize variability and standardize the technique between them. Another limitation of this study is the potential lack of generalizability to other populations or healthcare systems, particularly those with differing perioperative care resources. Cultural and systemic factors, such as variations in clinical practice guidelines and patient management strategies, may further limit the transferability of these findings. Future studies are needed to validate the results in diverse settings and populations to better assess their broader relevance.

Based on the finding of our study, the additional I-iPACK can reduce postoperative cumulative morphine consumption, reduce blood loss and encourage postoperative range of motion of patients without increasing adverse event such as nerve palsy. The technique is effective and safe and we recommend surgeon can perform during the surgery independently. Moreover, the technique intraoperative blockage could also be adopted in diverse surgical settings.

Abbreviations

iPACK	Infiltration between posterior capsule and popliteal artery
I-iPACK	Intraoperative infiltration between posterior capsule and popliteal artery
TKA	Total knee arthroplasty
VAS	Visual analog scale
ROM	Range of motion
PAI	Periarticular injection
FNB	Femoral nerve blocks
ACB	Adductor canal blocks
NSAIDs	Nonsteroidal anti-inflammatory drugs

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Author contributions
Concept, literature search and data collection: H-HM, Y-PS. Statistics, data analysis and interpretation: H-HM, S-AK. Drafting article: H-HM, F-YC. Critical revision of article: Y-PS. All authors have read and approved the manuscript.

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Availability of data and materials
No datasets were generated or analysed during the current study.

Declarations

Ethics approval
All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. The study was approved by the institutional review board of Taipei Veterans General Hospital. We confirmed that all methods were carried out in accordance with relevant guidelines and regulations. Informed consent was obtained from all individual participants included in the study.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

Statement of location
This work was performed at Taipei Veterans General Hospital, Taipei, Taiwan.

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