Original Article Clinics in Orthopedic Surgery 2022;14:514-521 • https://doi.org/10.4055/cios21108

Adductor Canal Block Combined with Interspace between the Popliteal Artery and Capsule of the Knee (iPACK) versus Periarticular Injection for Total Knee Arthroplasty

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Background: The combination of the adductor canal block (ACB) and the infiltration of anesthetic solution into the interspace between the popliteal artery and capsule of the knee (iPACK) has become increasingly used to augment rapid recovery protocols in total knee arthroplasty (TKA). However, its efficacy in comparison with periarticular anesthetic injection (PAI) alone has yet to be evaluated. Hence, we conducted a retrospective study to compare PAI and ACB + iPACK for controlling pain after TKA.

Methods: Propensity scores, incorporating American Society of Anesthesiologists scores, body mass index, age, and sex, were used to match the ACB + iPACK group with the PAI group. All patients received the identical surgical technique and postoperative care. Outcome measures were visual analog scale (VAS) for pain, morphine consumption, knee flexion angle, straight leg raising (SLR), postoperative nausea vomiting (PONV), and length of stay (LOS) after the surgery.

Results: After matching by propensity score, there were 49 patients with comparable demographic data in each group. The VAS and morphine requirements of the PAI and ACB + iPACK groups were not different during the first 48 hours after TKA. At 72 hours postoperatively, the VAS of the ACB + iPACK was 0.97 higher than that of the PAI group (p = 0.020). Knee flexion angle, SLR, PONV, and LOS were not significantly different between groups. No procedure-related complications were identified in either group.

Conclusions: The anesthesiologist-administered ACB + iPACK was as effective as surgeon-administered PAI in controlling pain in the first 48 hours after TKA. However, the ACB + iPACK group had higher intensity of pain than did the PAI group at 72 hours after TKA.

Keywords: *Total knee arthroplasty, Pain control, Adductor canal block, Interspace between the popliteal artery and capsule of the knee, Periarticular injection*

Received July 4, 2021; Revised September 28, 2021;
Accepted September 28, 2021
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Total knee arthroplasty (TKA) is an effective surgical procedure to alleviate pain, restore limb alignment, and improve the quality of life for patients who suffer from end-stage knee osteoarthritis.[1] However, there are a number of patients who experience moderate to severe pain during the acute phase after TKA.[2] Furthermore, inadequate pain control following TKA may impede functional recovery and has also been reported to be associated with poorer

functional outcomes at 2 years of follow-up.[3] The multimodal analgesic protocols that include either periarticular anesthetic injection (PAI) or peripheral nerve block (PNB) therefore play an important role in the management of pain following TKA.

Over recent years, with the advent of ultrasound-guided regional anesthesia, motor-sparing nerve block has become increasingly used to augment the rapid recovery protocol in TKA.[4-6] Adductor canal block (ACB) is an interfascial plane infiltration of local anesthetic to block the saphenous nerve and also part of the obturator nerve, which arise in the adductor canal. The ACB provides analgesia that provides most cover at the anteromedial aspect of the knee, and it has been demonstrated to be as effective as the femoral nerve block (FNB) in postoperative pain control for surgical procedures of the knee while minimizing the risk of extensor mechanism weakness.[7]

Novel analgesic methods, such as infiltration of anesthetic solution into the interspace between the popliteal artery and capsule of the knee (iPACK), have been introduced as techniques that selectively block only the articular branches arising from the tibial and obturator nerves, which innervate the knee posterior capsule. The iPACK block has been shown to significantly relieve posterior knee pain after TKA while sparing the motor function of the leg and foot.[8,9] Recently, ACB combined with iPACK (ACB + iPACK) has shown better pain reduction, ROM, and ambulation distance than ACB alone.[10,11] Also, patients who received ACB + iPACK were able to ambulate significantly further than those who received FNB combined with sciatic nerve block, required less narcotics, and had shorter length of stay (LOS).[12] Therefore, the iPACK block augmented ACB has become increasingly more popular among anesthesiologists.

PAI, which is administered directly at the surgical site, is widely performed by surgeons because of its simplicity and efficacy.[13] Previous studies revealed that PAI gives similar analgesic effect with less adverse events than intrathecal morphine[12] and FNB.[8] Moreover, randomized controlled trials have revealed that ACB alone seemed to be a less effective modality than PAI in terms of visual analog scale (VAS) pain scores, opioids consumption, and recovery of activity level.[14,15] However, due to limited evidence, the efficacy of anesthesiologist-administered ACB + iPACK compared to surgeon-administered PAI has yet to be evaluated. Hence, we conducted a study to compare (1) postoperative pain intensity, (2) opioid requirements, and (3) functional recovery of the knee between patients who received PAI only and those with ACB + iPACK for TKA.

METHODS

This study was approved by the Naresuan University Institutional Review Board (IRB No. P3-0099/2563), and written informed consent was obtained from all patients. The study was performed in accordance with the ethical standards as laid down in the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards.

We conducted a retrospective cohort study to compare consecutive patients who underwent primary TKA with PAI between July 2019 and June 2020 with consecutive patients receiving ACB + iPACK between July 2020 and April 2021. The patients who had been diagnosed with posttraumatic osteoarthritis or inflammatory arthritis, contraindicated for nonsteroidal anti-inflammatory drugs use, had a prior knee infection or previous history of knee surgery, or had ACB or iPACK failure were excluded. Of total 117 patients who were enrolled into the study, 62 patients received PAI, while 55 patients were administered ACB + iPACK. The patients in the ACB + iPACK group were then matched 1 : 1 with the patients having PAI (PAI group) by using a propensity score method, each with 49 participants.

Premedication including 300 mg of gabapentinoid and anxiolytic drug on the night before the surgery was applied for all cases. Spinal anesthesia was performed with bupivacaine (0.5% Marcaine, AstraZeneca, Sweden) in all patients. All knees were operated by two experienced surgeons (AL and PR) using similar surgical techniques. Five anesthesiologists were involved in this study; three performed spinal anesthesia alone (WB, MS, and RK), and two practiced spinal anesthesia and ACB + iPACK (IK and CS). For the ACB + iPACK group, patients were placed in a supine position with the hip externally rotated and knee flexed. After skin and transducer preparation, a linear transducer was placed at the midpoint between the patellar base and anterior superior iliac spine to identify short-axis view of the adductor canal. A 22-gauge 10-cm stimulating needle was inserted in a lateral-to-medial direction until the needle tip was placed deep to the sartorius muscle and lateral to the femoral artery at the apex of the femoral triangle. Twenty milliliters of 0.25% bupivacaine with 1 : 200,000 mg/mL epinephrine was injected incrementally with intermittent aspirations. Following the ACB, a curved transducer was applied transversely at the level of the popliteal crease to visualize the femoral condyles and popliteal artery. The probe was moved proximally until the femoral shaft was identified. At the level of just above the femur condyles, a 22-gauge 10-cm stimulating needle was inserted in a medial-to-lateral direction and parallel to

the femoral shaft. The needle was advanced between the femur and popliteal artery until the tip was placed near the lateral border of the popliteal artery. Twenty milliliters of 0.25% bupivacaine with 1 : 200,000 mg/mL epinephrine was then injected with intermittent aspirations, whereas the needle was slowly withdrawn until the tip reached the medial femoral condyle.

The operations were carried out under spinal anesthesia with bupivacaine (0.5% Marcaine). A medial parapatellar approach was performed through a midline incision with tourniquet control at 250–300 mmHg. The cruciate ligaments were excised in all patients, and then an extramedullary cutting guide was placed on the tibia and a resection of the proximal tibia was done perpendicular to the mechanical axis. A distal femoral cut was prepared using an intramedullary guide and the anterior-posterior femoral cut was completed using the anterior referencing technique. Soft-tissue balancing was performed to achieve an appropriate flexion and extension gap, and the pilot hole of the femoral medullary canal was sealed with a bone plug. The patella was routinely resurfaced by one surgeon (AL) whereas it was not done by another surgeon (PR). For the PAI group, 20 mL of 0.5% bupivacaine (0.5% Marcaine) was diluted with 0.9% normal saline solution to a total volume of 75 mL. The cocktail solution (50 mL) was then injected into the anterior (medial retinaculum, quadriceps muscle, pes anserinus, and retropatellar fat pad) and the remaining 25 mL of solution was injected into the posterior part of the knee (posterior capsule, medial/lateral collateral ligament, and medial/lateral meniscal remnant) before prosthetic implantation.[16] Cemented, posterior-stabilized (PS), fixed-bearing knee prostheses were implanted in all patients. A vacuum drain was placed, and tranexamic acid (15 mg/kg) was poured into the joint before closure of the arthrotomy. A compressive dressing was applied and subsequently the drain and dressing were removed at 24 hours postoperative.

Identical postoperative care was applied for all patients. The intravenous patient-controlled analgesia (PCA), which was set to inject 0.5 mg of morphine sulphate as an on-demand bolus pain rescuer with a 5-minute lockout period, was used to allow self-administration of analgesics for optimal pain control and the amount of morphine consumption was noted. Also, intravenous injection of 40 mg of parecoxib (Dynastat; Pfizer, Kalamazoo, MI, USA) was applied every 12 hours in the first 48 hours after TKA. After 48 hours, the antibiotics and all catheters were removed. Morphine via PCA was also discarded and 2 mg of morphine was then given intravenously; pro re nata was used every 4–6 hours for moderate to severe pain. Additionally, acetaminophen (500 mg) was administered orally three times daily and naproxen (250 mg) was administered orally twice a day. For venous thromboembolism prophylaxis, every patient received low-molecular-weight heparin during the first 48 hours and this was adjunct to bridging warfarin. Active ankle pumping was encouraged to start immediately after the surgery, and a continuous passive motion device was utilized on the day after the operation. Early ambulation with gait aids was promoted as tolerated.

Outcome measures for this study were VAS for pain, dosage of morphine consumption via PCA, angle of knee flexion, straight leg raising (SLR), LOS, drain output, and complications after the surgery. The angle of knee flexion and SLR were measured by using a long-arm universal goniometer. The patients were requested to actively flex the operated knee and straightly raise the leg in the supine position until reaching the maximum angle as tolerated. The incidence of patient-reported postoperative nausea vomiting (PONV) in the first 24 hours was also noted. All outcomes were prospectively recorded by an assessor who was blinded to the study protocol (PS).

Statistical Analysis

All measured parameters and results were summarized with descriptive statistics including number and percentage, mean and standard deviation (SD), and median and range. Propensity scores, incorporating patient characteristics that comprised American Society of Anesthesiologists scores, body mass index, age, and sex, were used to match the ACB + iPACK group with the PAI group. For continuous data, Student *t*-test and Mann-Whitney test were applied to compare normal and non-normal data between groups, respectively, while chi-square or Fisher's exact test was applied for categorical data. After the propensity matching, the sample size of 49 patients in either group had 84.4% power to detect a difference of 1.5 of VAS for pain score with SD of 2.5, with type I error of 5%. Stata/MP 15.0 software (StataCorp., College Station, TX, USA) was used for an entire statistical analysis. Statistical significance was set at $p < 0.05$.

RESULTS

Patient characteristics before and after the propensity score matching are shown in Table 1. The preoperative VAS, knee range of motion (ROM), and serum hemoglobin were comparable between the PAI group and the ACB + iPACK group.

The VAS and morphine requirements following TKA of the ACB + iPACK group were comparable to the

Table 1. Demographic Data and Preoperative Characteristics of the PAI and ACB + iPACK Groups before and after Propensity Score Matching

Variable	Before propensity score match			After propensity score match		
	PAI (n = 62)	ACB + ipack (n = 55)	*p*-value	PAI (n = 49)	ACB + iPACK (n = 49)	*p*-value
Age (yr)	67.1 ± 7.53	65.62 ± 7.49	0.290	66.02 ± 7.28	66.49 ± 7.28	0.750
Sex			0.592			0.790
Female	53 (85.5)	45 (81.8)		40 (81.6)	41 (83.7)	
Male	9 (14.5)	10 (18.2)		9 (18.4)	8 (16.3)	
Weight (kg)	64.68 ± 8.04	66.84 ± 10.87	0.230	65.07 ± 8.26	66.37 ± 10.34	0.495
Height (m)	1.56 ± 0.06	1.57 ± 0.07	0.248	1.56 ± 0.07	1.57 ± 0.07	0.301
BMI (kg/m^2)	26.68 ± 3.02	27.11 ± 4.44	0.549	26.79 ± 3.06	26.87 ± 4.28	0.910
ASA score			0.329			0.838
1	3 (4.8)	1 (1.8)		2 (4.1)	1 (2)	
2	35 (56.5)	26 (47.3)		25 (51.0)	26 (53.1)	
3	24 (38.7)	28 (50.9)		22 (44.9)	22 (44.9)	
Preoperative VAS	7.27 ± 1.61	7.25 ± 1.87	0.951	7.24 ± 1.69	7.37 ± 1.84	0.733
Preoperative ROM (°)	109.58 ± 11.53	110.62 ± 16.27	0.695	108.8 ± 11.69	110.55 ± 16.08	0.538
Preoperative hemoglobin (g/dL)	12.68 ± 1.35	12.2 ± 1.39	0.067	12.68 ± 1.44	12.22 ± 1.40	0.115

Values are presented as mean ± standard deviation or number (%).
PAI: periarticular anesthetic injection, ACB: adductor canal block, iPACK: interspace between the popliteal artery and capsule of the knee, BMI: body mass index, ASA: American Society of Anesthesiologists, VAS: visual analog scale, ROM: range of knee motion.

PAI group during the first 48 hours. However, at 72 hours postoperative, the VAS of the ACB + iPACK group was higher than that of the PAI group, with statistical significance. Other outcome measures including knee flexion angle, SLR, PONV, and LOS were not significantly different between the groups. Drain output of the ACB + iPACK group was significantly higher than that of the PAI group, but there was no difference in blood transfusion quantity. All the outcome comparisons are summarized in Table 2.

No postoperative complications related to either ACB + iPACK or PAI, such as nerve injury, hematoma, and falls, were identified in either group. Despite that, 1 patient in the PAI group developed deep vein thrombosis and was treated with anticoagulant, and 1 patient had suspected periprosthetic joint infection that was treated with two-stage revision TKA. For the ACB + iPACK group, 1 patient had aspiration pneumonia and another patient developed heart failure after TKA, but both patients fully recovered after appropriate treatment. No other complications were observed up to at least 3 months of follow-up.

DISCUSSION

The incidence of moderate to severe pain following TKA has been reported as high as 50%,[17] and approximately 20% of patients might be dissatisfied with the perioperative experience.[18] More recently, ACB + iPACK has gained favor with the expected benefit of procuring analgesia at both the anterior and posterior aspects of the knee.[14,15] However, it is still unclear whether ACB + iPACK is more effective over PAI in controlling pain after TKA. The principal findings of this study are that the patients who received anesthesiologist-administered analgesia as ACB + iPACK showed comparable results to matched patients having PAI in terms of pain intensity and opioid requirements during the first 48 hours after the procedure. Nevertheless, the ACB + iPACK seemed to be less effective than the surgeon-administered PAI at 72 hours after TKA, and this accords with Meftah et al.[19] who reported rebound pain on postoperative day 3 in patients who received ACB alone with pain scores significantly higher than PAI patients. The possible explanation for these findings is that local anesthetics, which is concentrated perineurally, can either induce neurotoxicity or nerve ischemia while per-

forming PNB. However, the relevance to rebound pain after PNB of these experimentally derived effects of local anesthetics is currently uncertain.[20,21] Moreover, the mean difference of VAS at 72 hours postoperative was only 0.97, which did not reach minimal clinically important difference for pain,[22] and both groups also had comparable functional outcomes including knee flexion, SLR, and LOS. Another finding is that the ACB + iPACK patients had more drain output than that of the PAI patients. This presentation was not considered to be clinically significant as the requirement for allogeneic blood transfusion of both groups was equivalent.

Table 2. Perioperative and Postoperative Outcomes of the PAI and ACB + iPACK Groups after Propensity Score Matching

Characteristic	PAI (n = 49)	ACB + iPACK (n = 49)	*p*-value
Operative time (min)	61.30 ± 7.89	57.80 ± 11.97	0.095
Drain output (mL)	221.94 ± 128.90	294.08 ± 186.38	0.028*
VAS for postoperative pain intensity			
6 hr	4.24 ± 2.81	4.69 ± 2.67	0.451
12 hr	4.26 ± 2.54	4.76 ± 2.57	0.366
18 hr	4.60 ± 2.48	4.55 ± 2.05	0.926
24 hr	4.37 ± 2.09	4.22 ± 2.00	0.730
48 hr	3.18 ± 1.65	4.00 ± 2.45	0.057
72 hr	2.45 ± 1.90	3.42 ± 2.00	0.020*
Morphine consumption (mg)			
24 hr	12.47 ± 10.67	14.52 ± 8.32	0.321
48 hr	17.17 ± 14.19	21.66 ± 11.81	0.118
Knee flexion angle (°)			
24 hr	56.58 ± 19.02	56.67 ± 17.36	0.980
48 hr	72.63 ± 18.84	71.33 ± 14.50	0.701
72 hr	84.29 ± 11.28	84.69 ± 10.33	0.852
SLR			
6 hr			
Ability to do active SLR (%)	9 (18.4)	14 (28.6)	0.789
Angle of SLR (°)	0 (0–0)	0 (0–10)	0.568
12 hr			
Ability to do active SLR (%)	11 (22.4)	19 (38.8)	0.616
Angle of SLR (°)	0 (0–30)	0 (0–45)	0.417
24 hr			
Ability to do active SLR (%)	18 (36.7)	28 (57.1)	0.117
Angle of SLR (°)	0 (0–45)	15 (0–60)	0.153
48 hr			
Ability to do active SLR (%)	21 (42.9)	29 (59.2)	0.320
Angle of SLR (°)	0 (0–60)	20 (0–80)	0.441

Table 2. Continued

Characteristic	PAI (n = 49)	ACB + iPACK (n = 49)	*p*-value
72 hr			
Ability to do active SLR (%)	28 (57.1)	31 (63.3)	0.705
Angle of SLR (°)	30 (0–80)	35 (0–72.5)	0.900
PONV (%)	15 (30.6)	15 (30.6)	0.606
Blood transfusion (%)	5 (10.2)	5 (10.2)	0.603
LOS (day)	3.98 ± 1.09	3.83 ± 1.14	0.519

Values are presented as mean ± standard deviation, number (%), or median (range).
PAI: periarticular anesthetic injection, ACB: adductor canal block, iPACK: interspace between the popliteal artery and capsule of the knee, VAS: visual analog scale, SLR: straight leg raising, PONV: postoperative nausea vomiting, LOS: length of stay.
*Statistically significant ($p < 0.05$).

There have been few studies that were similar to our study. Jung et al.[23] reviewed pain scores and opioid consumption of consecutive patients who received ACB + iPACK, and compared those outcomes to previous consecutive patients receiving ACB + PAI. They found ACB + iPACK patients seemed to have lower VAS than the ACB + PAI group on postoperative days 1 and 2. However there was no difference in regard to the total amount of additional opioids use between groups. Kertkiatkachorn et al.[24] conducted a randomized controlled trial to assess the efficacy of ACB + iPACK compared to PAI + continuous ACB. They found that ACB + iPACK patients had comparable pain scores to the control group but had worse quadriceps strength on postoperative day 0 and required higher amounts of morphine at 48 hours after TKA. Given these reported results, the advantage of ACB + iPACK remains unclear, especially if the cost-effectiveness of this technically demanding and time-consuming technique is taken into consideration. Additionally, variations in PAI techniques, including location of injection, volume of infiltration, difference in injection cocktails added into mixture, and timing of injection, may yield different outcomes.[16,25-28] On the other hand, the result of PNB may depend upon the clinical situation and operator skills even if ultrasound guidance should lead to a higher success rate with a lower risk of nerve injury.[20]

Nonetheless, some limitations in the present study were identified. The first limitation is associated with the type of the study, which is a retrospective cohort design. To overcome this limitation, we used propensity score matching to control any confounding factors in the demographics of both groups. Second, the study population was predominantly female in our study, a limitation mitigated by previous studies in which sex was not found to be a predictive factor for pain and function recovery after TKA.[28-30] Third, there were two surgeons who performed TKA with similar surgical techniques except one did not resurface the patella. Although patellar resurfacing was demonstrated to have lower rates of postoperative anterior knee pain and reoperation by recent meta-analysis,[31] it is still not known whether patellar resurfacing affects acute postoperative pain. Also, there were five anesthesiologists involved in our study. Nevertheless, they all performed a preferred regional anesthesia with their expertise and this situation may prevent ineligible effects from an unfamiliar procedure, better reflect real-life practice, and allow for external validity.

The anesthesiologist-administered ACB + iPACK was as effective as surgeon-administered PAI in controlling pain in the first 48 hours after TKA. However, the ACB + iPACK group had higher intensity of pain than the PAI group at 72 hours after TKA.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

ACKNOWLEDGEMENTS

We thank Mr. Roy I. Morien of the Naresuan University Graduate School for his assistance in editing the English expression and grammar in this document, and Ms. Dollapas Punpanich for statistical analysis. We also thank Pariphat Chompoonutprapa, MD, Watcharapong Eiamjumras, MD, Thanawat Tantimethanon, MD, Passakorn Teekaweerakit, MD, for their technical assistance. Furthermore, we would like to express our sincere thank to Was-

sana Butmangkun, MD, Muanchanok Surit, MD, Rungrat Khongrod, MD, of the Department of Anesthesiology, Faculty of Medicine, Naresuan University for their support.

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