Prospective Study

The Interspace Between Popliteal Artery and Posterior Capsule of the Knee (IPACK) Block in Knee Arthroplasty: A Prospective Randomized Trial

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Background: Optimal analgesia following knee surgery is essential for early mobilization and rehabilitation and minimizing morbidity.

Objectives: We compared the addition of the interspace between the popliteal artery and the posterior capsule of the knee (IPACK) block to the adductor canal block (ACB) versus ACB alone on postoperative analgesia and ambulation ability in patients undergoing total knee arthroplasty (TKA).

Study Design: A prospective randomized study.

Setting: An academic medical center.

Methods: Eighty patients undergoing TKA were randomly allocated to receive either ACB or combined ACB-IPACK block at the end of surgery. ACB was performed using 20 mL bupivacaine 0.25% in both groups, while IPACK block using 30 mL bupivacaine 0.25% was added in the ACB-IPACK group only. Visual analog scale (VAS) was evaluated at rest and with 45° knee flexion at 4, 6, 12, and 24 hours postoperatively. The quadriceps muscle power and mobilization ability were assessed at 12 hours and 24 hours postoperative. Total 24 hour postoperative morphine consumption, time to first rescue analgesic request, and patient satisfaction were documented.

Results: The mean postoperative morphine consumption was higher in the ACB group (20.93 ± 7.17 mg) than the ACB-IPACK group (9.68 ± 3.56 mg) ($P < 0.001$, 95% CI; 8.71; 13.79). The time to 1st rescue analgesic consumption was longer in the ACB-IPACK group (645 ± 254 min) than ACB group (513 ± 247 min) ($P = 0.021$, 95% CI; 20.4; 243.6).

At 4 hours, 6 hours, and 12 hours postoperative, the median postoperative VAS scores were higher in the ACB group than those of the ACB-IPACK group at rest ($P = 0.003$, 0.001 and 0.007) and on 45° knee flexion ($P = 0.001$, 0.001, 0.002) respectively. At 24 hours, the median VAS score was comparable between both groups both at rest and on 45° knee flexion ($P = 0.358$ & 0.054), respectively. The TUG test and the straight leg raise (MRC) scales at 12 hours, and 24 hours postoperative were comparable between both groups ($P > 0.05$).

Limitations: This study was limited by its small sample size.

Conclusion: The addition of IPACK to the ACB significantly reduced the postoperative morphine consumption and postoperative pain scores compared to the ACB alone without significant difference in mobilization ability in patients undergoing TKA.

Key words: Pain, postoperative, arthroplasty, knee replacement

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Optimal pain control after total knee arthroplasty (TKA) is important to decrease complications, enable early rehabilitation, and facilitate rapid recovery (1,2). Multimodal analgesia, including regional anesthetic techniques, has been documented to improve analgesia and reduce opioid-related side effects following TKA (3).

Effective pain control after TKA is challenging, as the operative procedure often affects 2 main innervations to the knee: the femoral nerve, which innervates the anterior and, to a lesser degree, the medial aspects of the knee and the sciatic nerve, which innervates the posterior aspect of the knee (4,5).

Despite continuous femoral nerve block (FNB) providing excellent postoperative analgesia and decreasing opioid consumption (3,6), patients often encounter a significant degree of quadriceps weakness that hinders early physical rehabilitation (7-9). The adductor canal block (ACB) has been reported to provide similar analgesia to a single-shot FNB block with improved postoperative physical therapy (10).

Patients undergoing TKA under FNB block or ACB frequently encounter postoperative posterior knee pain requiring supplemental opioid medications (11,12). The sciatic nerve block has been shown to improve analgesia and reduce opioid consumption when combined with FNB (13) but can lead to sensory and motor deficits below the knee with a subsequent increase in the risk of falls (3). Therefore, an ideal regional anesthetic technique would include a regional block that provides analgesia to the posterior knee without causing distal neurologic deficits.

An ultrasound-guided local anesthetic infiltration of the interspace between the popliteal artery and the posterior capsule of the knee (IPACK) (14) provides effective posterior knee analgesia by targeting only the genicular branches of the sciatic nerve without affecting the motor function (14).

The aim of this trial was to compare the effects of combined ACB-IPACK block versus ACB alone on postoperative analgesia and ambulation ability in patients undergoing TKA.

Methods

After obtaining approval from the Hospital Ethics Committee (32653/10/18), registration in the Pan African Clinical Trials Registry (PACTR201812776434860), and informed written consent, 80 patients aged 50-80 years, of either gender, ASA I-III, undergoing unilateral primary TKA under spinal anesthesia were enrolled in this prospective randomized controlled study. The study was carried out between January 2019 and May 2020.

Exclusion Criteria

Exclusion criteria included body mass index (BMI) more than 40 kg/m^2, renal or hepatic insufficiency, localized infection at the site of regional anesthetic intervention, allergy to local anesthetic, chronic opioid use, preexisting lower extremity neurological deficit, and patient refusal of either spinal anesthesia or regional block.

Patients were randomly allocated into 2 groups of 40 patients each. Randomization was performed using a computer-generated randomization sequence concealed in sealed opaque envelopes. Group I: Patients received ACB. Group II: Patients received IPACK block in addition to the ACB.

Upon arrival to the operating room, placement of the standard ASA monitoring was done. All patients had a standardized spinal anesthesia using hyperbaric bupivacaine (12.5-15 mg) plus fentanyl (25 µg) in the sitting position performed by the primary anesthesiology team. Intraoperative sedation was achieved by midazolam 30 µg/kg and fentanyl 1 µg/kg IV if required.

The study intervention was performed at the end of the surgical procedure. Ultrasound-guided ACB (15) was performed in both groups using a high-frequency linear ultrasound probe placed transversely in midthigh halfway between the anterior superior iliac spine and the patella, visualizing a short-axis view of the femoral artery and saphenous nerve in the adductor canal. The femoral artery was identified underneath the sartorius muscle, with the vein inferior and the saphenous nerve lateral to the artery. A 100 mm 22-gauge (G) block needle was inserted from the lateral side of the transducer using the in-plane technique through the sartorius muscle until the tip of the needle was just lateral to the artery, and 20 mL bupivacaine 0.25% was injected.

In group II, in addition to ACB, IPACK block (14) was performed. Using a curvilinear ultrasound probe, the popliteal fossa was scanned at or proximal to the popliteal crease until the femoral condyles were visualized. The probe was then proximally aligned until the condyles disappeared and the shaft of the femur was visible. At this level, a 100 mm 22 G block needle was inserted in the medial thigh using the in-plane technique from anteromedial to posterolateral direction between the popliteal artery and the femur until the needle tip was 1 cm beyond the lateral edge of the popliteal artery and 20 mL bupivacaine 0.25% was injected. As the

needle was slowly withdrawn, another 10 mL bupivacaine 0.25% was injected (Fig. 1).

Patients were transferred to the post anesthesia care unit (PACU). Assessment of postoperative pain was performed both at rest and with motion (knee flexion to 45°) using the visual analog scale (0-100 mm) at 4, 6, 12, and 24 hours postoperatively. All patients received standardized postoperative analgesia in the form of paracetamol 1 g IV/6 hours and ibuprofen 400 mg/8 hours. Morphine sulfate 3 mg IV injection was administered as rescue analgesia if the VAS score was ≥ 40 and the time to the 1st rescue analgesic request was recorded.

The quadriceps muscle power was assessed with the patients in the supine position. Patients were asked to perform a straight leg raise. The quadriceps muscle power was assessed at 12 hours and 24 hours after performing the block using the Medical Research Council (MRC) scale (16) and was graded from 0 to 5 as: grade 0 = no voluntary contraction possible; grade 1 = muscle flicker, or trace of contraction but no movement of limb; grade 2 = active movement only with the elimination of gravity; grade 3 = active movement against gravity but without resistance; grade 4 = active movement against gravity with some resistance; and grade 5 = normal motor power against resistance.

Mobilization ability was assessed at 12 hours and 24 hours after performing the block using the Timed-Up-and-Go (TUG) test (17). We measured the time the patient took to get up from a chair, walk 3 meters, turn, walk back to the chair, and sit down. As assisted aids during performing the test, all patients used a high walker with arm support. This test was only done if the patient felt that he was capable of rising and walking without the risk of falling.

Any side effects were recorded. Patient satisfaction using a 4-point scale (4 = very satisfied, 3 = satisfied, 2 = dissatisfied, 1 = very dissatisfied) was also recorded.

Primary outcome was the total 24-hour postoperative rescue morphine consumption.

Secondary outcomes included VAS score at rest and motion and the time to 1st rescue analgesic administration.

All study parameters were assessed by a dedicated anesthesiologist blinded to group allocation.

Statistical Analysis

Calculation of the sample size was done based on the postoperative analgesic consumption. The postoperative morphine consumption in our pilot study was 24 ± 16.8 mg in ACB and 12.6 ± 7.8 mg in the ACB-IPCAK group. Assuming this difference in postoperative morphine consumption, at least 36 patients were needed in each group at α error of 0.05 and power of study of 80%. Forty patients were recruited in each group to avoid the dropout patients. The sample size calculation was based on a 2-sample independent t-test (2-sided) of the postoperative morphine consumption. Sample size was calculated using G* Power3 analysis program (Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Germany).

We used SPSS version 16.0 software (SPSS Inc., Chicago, IL, USA) for statistical analysis. The Shapiro-Wilk test and the visualization of the histogram were utilized to verify the assumption of normality. The

Fig. 1. *Ultrasound-guided demonstration of the interspace between the popliteal artery and the posterior capsule of the knee (IPACK) block.*
A; Scanning the popliteal fossa at or proximal to the popliteal crease visualizing the femoral condyles. PA: popliteal artery.
B: Proximal alignment of the probe until visualization of the femoral shaft. PA: popliteal artery.
C; Block needle visualized (yellow arrows) with local anesthetics (LA) deposited between the popliteal artery (PA) and the femur.

quantitative parameters that normality distributed were expressed as mean ± SD and analyzed by independent sample t-test. The parameters that did not follow the normal distribution were expressed as median with interquartile range and analyzed among the studied groups using the Mann-Whitney U test. Categorical data were depicted as number, and chi-square was utilized for comparison between both groups. *P* value < 0.05 was considered significant, and the nature of the hypothesis testing was 2-sided.

Results

Eighty-eight patients were evaluated for eligibility; 6 patients did not match the inclusion criteria, and 2 patients refused to participate in the trial. Eighty patients were enrolled in the study and allocated in 2 groups of 40 patients each (Fig. 2).

Demographic data regarding the age, BMI, and gender were comparable between the 3 groups (*P* = 0.323, 0.546, and 0.499, respectively) (Table 1).

The mean postoperative morphine consumption was higher in the ACB group (20.93 ± 7.17 mg) than the ACB-IPACK group (9.68 ± 3.56 mg) (*P* < 0.001, 95% CI; 8.71; 13.79). The time to 1st postoperative rescue analgesic consumption was longer in the ACB-IPACK group (645 ± 254 min) than ACB group (513 ± 247 min) (*P* = 0.021, 95% CI; 20.4; 243.6) (Table 2).

At 4 hours, 6 hours, and 12 hours postoperative, the median postoperative VAS scores at rest were higher in the ACB group than those of the ACB-IPACK group (*P* = 0.003, 0.001, and 0.007 respectively). At 24 hours postoperative, the median VAS score at rest was comparable between both groups (*P* = 0.358) (Fig. 3).

The median VAS scores during the 45° knee flex-

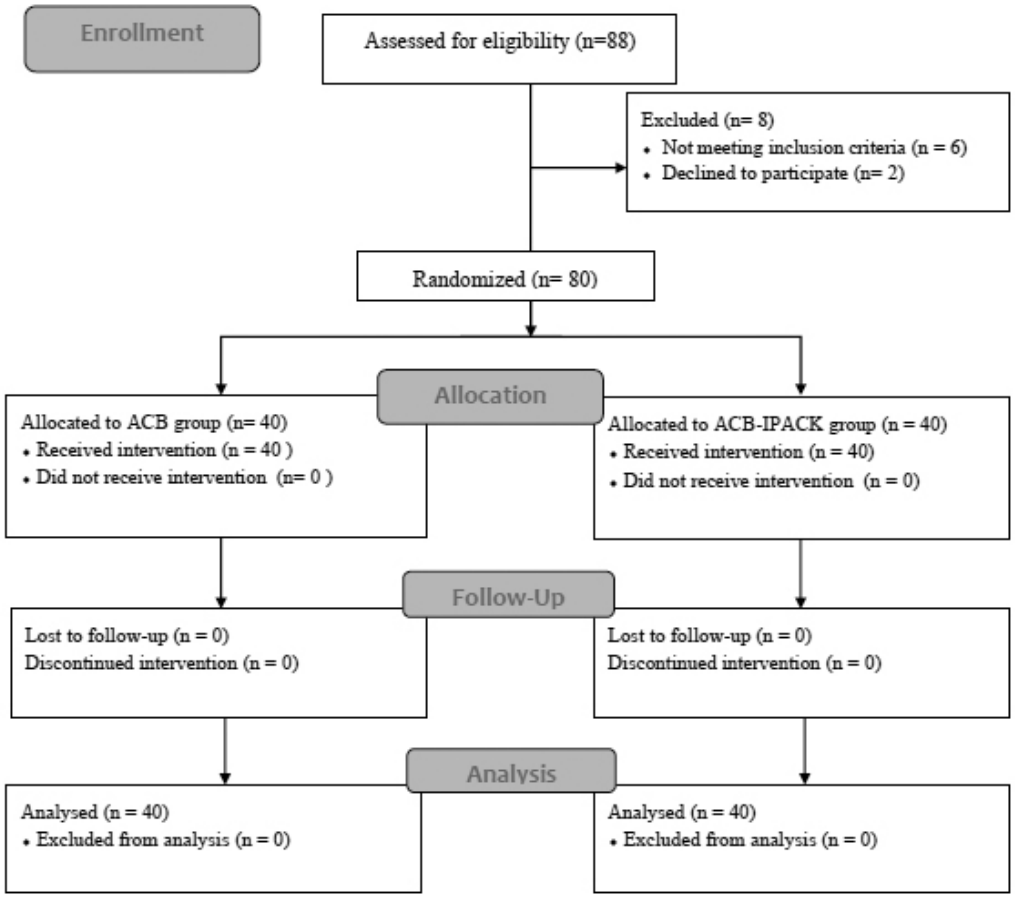

Fig. 2. *CONSORT flow diagram of patients through each stage of the randomized trial.*

ion were higher in the ACB group than those of the ACB-IPACK group at 4 hours, 6 hours, and 12 hours postoperative (P = 0.001, 0.001, 0.002). At 24 hours postoperative, the VAS score became insignificantly different between both groups (P = 0.054) (Fig. 4).

The TUG test at 12 and 24 hours postoperative and the straight leg raise (MRC) scales at 12 hours and 24 hours postoperative were comparable between both groups (P = 0.121, 0.180, 0.450, and 0.399, respectively).

There was no significant difference between both groups regarding the incidence of complications or patient satisfaction (Table 2).

Discussion

Our study revealed that the combination of IPACK block and ACB provided lower postoperative pain scores and less opioid consumption during the 1st 24 postoperative hours without difference between both groups regarding the quadriceps strength and the TUG test.

The "ideal" regional analgesic technique for TKA patients continues to evolve since adequate analgesia must be weighed against challenging goals like early mobilization (18). ACB has been documented to provide significant analgesia and early mobilization due to its quadriceps strength sparing effect (9,15). However, this technique provides analgesia only to the anteromedial aspects of the knee due to lack of effect on deep genicular nerves (19).

From the anatomical point of view, the posterior aspect of the knee receives sensory innervations through the articular branch of the tibial nerve, with variable contributions from the posterior branch of the obturator nerve (5). These branches represent a plexus closely associated with the popliteal vessels at the level of the popliteal fossa. Therefore, blocking the articular branch of the tibial nerve can provide analgesia to the posterior aspect of the knee without motor weakness (20).

IPACK block involves local anesthetic infiltration of the space between the popliteal artery and the posterior knee capsule to achieve blockade of the deep genicular nerves supplying the posterior aspect of the knee joint. The technique selectively blocks the terminal sensory branches of the posterior knee without affecting the motor branches of the tibial and peroneal nerves leading to analgesia with muscle power sparing (14,21-23).

Niesen et al (24) performed a cadaveric study to evaluate the spread of injectate in the IPACK block. They reported injectate spread throughout the popliteal fossa without proximal sciatic involvement. However, they reported potential spread to the tibial or common peroneal nerves. Injectate spread to the middle genicular artery proposes a probable mechanism of analgesia for the IPACK block through blockade of the sensory

Table 1. *Demographic data of both groups.*

	ACB	ACB-IPACK	*P* value
Age (years)	60.75 ± 5.27	62.05 ± 6.37	0.323
Gender (male/ female)	16/24	19/21	0.499
BMI (kg/m²)	27.55 ± 4.66	26.90 ± 4.93	0.546
ASA I/II/III	7/28/5	5/31/4	0.742
Duration of surgery (min)	98.25 ± 11.86	95.30 ± 9.90	0.231

Data presented as mean ± SD or patient number.

Table 2. *Postoperative characteristics.*

		ACB	ACB-IPACK	*P* value	Mean/ Median difference	95% CI
Time to 1st rescue (min)		513 ± 247	645 ±254	0.021	132.0	20.4; 243.6
Morphine consumption (mg)		20.93 ± 7.17	9.68 ± 3.56	< 0.001	11.25	8.71; 13.79
Straight leg raise (MRC scale)	12h	5 (4.25-5.0)	5 (4.0 -5.0)	0.450	0.0	0.0; 0.0
	24h	5 (5.0 -5.0)	5 (5.0 - 5.0)	0.399	0.0	0.0; 0.0
TUG test at 12 h (sec)		88.5 ± 15.1	93.6 ± 12.2	0.121	5.1	- 1.38; 11.58
TUG test at 24 h (sec)		44.88 ± 8.93	47.65 ± 9.39	0.180	2.77	-1.30; 6.85
Postoperative nausea and vomiting		7 (17.5)	3 (7.5)	0.176		
Patient satisfaction	Very satisfied	28 (70)%	33 (82.5)%	0.189		
	Satisfied	12 (30)%	7 (17.5)%			
	Dissatisfied	0	0			
	Very dissatisfied	0	0			

Data presented as mean ± SD, median (IQR) or patient number (%). CI; confidence interval. MRC scale; Medical Research Council scale.

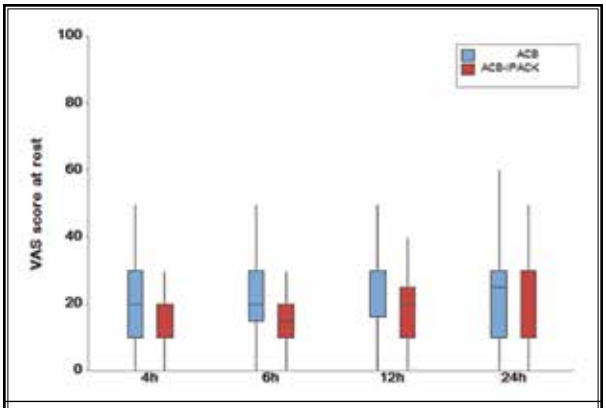

Fig. 3. *Visual analog scale (VAS) at rest in the studied groups.*

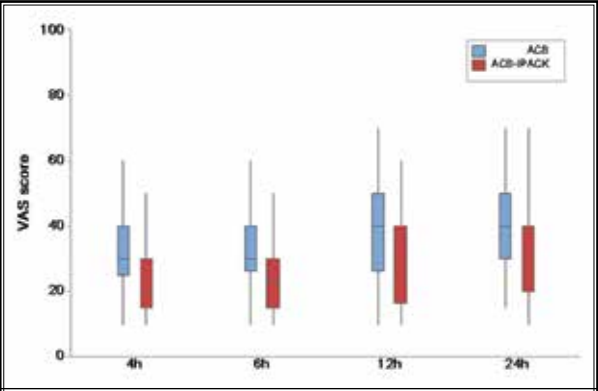

Fig. 4. *Visual analog scale (VAS) during 45° knee flexion in the studied groups.*

nerves supplying the posterior aspect of the knee joint due to the predictable relationship between articular sensory nerves and this artery.

The analgesic efficacy of the IPACK following TKA had been reported in previous literature (19,21,25). In our study, the needle tip was located between the popliteal artery and posterior capsule at the level of the femoral shaft adjoining the femoral condyle (16,21). Kampitak et al (20) suggested that the ideal level to perform IPACK block is below the upper edge of the lateral femoral condyle where the tibial nerve is immediately superficial to the popliteal vessel (distal approach IPACK). They reported no incidences of injectate spread to the common peroneal nerve and minimal spread to the tibial nerve. Excellent analgesia without complete tibial and common peroneal motor blockade was observed in all patients in their clinical study. Additionally, they reported the ease of performing their technique as the site of injection was more superficial, allowing clear visualization of the needle tip.

We recommend further clinical studies to determine the optimal location of IPACK injection.

Our study had some limitations. In addition to the relatively small sample size, we did not evaluate the level of sensory block.

Conclusion

The addition of IPACK to the ACB was associated with lower postoperative pain scores and reduced postoperative opioid consumption compared to the ACB in patients undergoing TKA.

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