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Original Research Article

COMPARISON OF MODIFIED 4 IN 1 BLOCK VERSUS IPACK PLUS ADDUCTOR CANAL BLOCK FOR POST-OPERATIVE ANALGESIA IN TOTAL KNEE ARTHROPLASTY: A RANDOMIZED CONTROLLED STUDY

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ABSTRACT

Background: Total knee arthroplasty is commonly associated with significant postoperative pain, which may delay early mobilization and rehabilitation. Motor-sparing regional analgesic techniques such as adductor canal block(ACB), IPACK (Infiltration between the Popliteal Artery and the Capsule of the Knee) block, and modified 4-in-1 block are increasingly used to improve postoperative pain control while preserving lower limb motor function. The modified 4-in-1 block is a single-injection technique designed to provide wider sensory coverage of the knee joint, whereas combined IPACK plus adductor canal block targets posterior and anteromedial knee pain through two separate regional blocks. **Materials and Methods:** This randomized controlled study included 64 patients scheduled for total knee arthroplasty. Patients were divided into two equal groups: Group I received combined IPACK plus adductor canal block, and Group M received modified 4-in-1 block. Baseline demographic and operative variables, including age, sex, body weight, and duration of surgery, were recorded. Postoperative pain was assessed using the visual analogue scale at 3, 6, and 24 hours after surgery. Intergroup comparison was performed using appropriate statistical tests, with $p < 0.05$ considered statistically significant. **Result:** The two groups were comparable with respect to baseline characteristics. The mean age was 59.81 ± 3.00 years in Group I and 61.13 ± 3.26 years in Group M ($p = 0.099$). Sex distribution was identical in both groups, with 17 males and 15 females each ($p = 1.000$). Mean body weight and duration of surgery were also comparable between Group I and Group M (72.91 ± 6.59 kg vs. 69.59 ± 7.92 kg, $p = 0.074$; 100.25 ± 6.59 minutes vs. 101.00 ± 7.94 minutes, $p = 0.682$, respectively). Postoperative VAS scores were significantly lower in Group M at all assessed time points. At 3 hours, median VAS was 5.00 (IQR: 3.00–5.25) in Group I and 3.00 (IQR: 3.00–4.00) in Group M ($p < 0.001$). At 6 hours, median VAS was 4.00 (IQR: 2.00–4.25) in Group I and 2.00 (IQR: 2.00–3.00) in Group M ($p < 0.001$). At 24 hours, median VAS was 2.00 (IQR: 1.00–3.00) in Group I and 1.00 (IQR: 1.00–1.00) in Group M ($p < 0.001$). **Conclusion:** Modified 4-in-1 block provided significantly better early postoperative analgesia compared with combined IPACK plus adductor canal block in patients undergoing total knee arthroplasty. As a single-injection, supine-position, motor-sparing technique, modified 4-in-1 block may be considered a practical and effective regional analgesic option for postoperative pain management after total knee arthroplasty. Further studies incorporating rescue analgesic requirement, functional recovery, quadriceps strength, ambulation, and complication assessment are recommended.

INTRODUCTION

Knee osteoarthritis is a progressive degenerative joint disease characterized by cartilage loss, joint destruction, chronic pain, and restriction of mobility. It is one of the major causes of disability among older adults and frequently compromises independence and quality of life. Total knee arthroplasty (TKA) is

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widely accepted as an effective surgical treatment for end-stage knee osteoarthritis because it relieves pain, restores alignment, improves knee function, and enables better mobility in elderly patients.[1–3] However, despite its functional benefits, TKA remains one of the most painful orthopaedic procedures, particularly during the early postoperative period.[4,5]

The global burden of knee osteoarthritis and TKA is increasing with population ageing, rising life expectancy, and increasing expectations for mobility and functional independence in later life. A substantial proportion of elderly individuals experience symptomatic knee osteoarthritis, and even after TKA, persistent postoperative or chronic knee pain may occur in a subset of patients.[1,6] Poorly controlled postoperative pain can delay mobilization, prolong hospital stay, increase opioid requirement, and contribute to complications such as pulmonary dysfunction, urinary retention, thromboembolism, myocardial stress, and delayed rehabilitation.[5,6] Therefore, effective postoperative analgesia is central to enhanced recovery, early ambulation, patient satisfaction, and functional outcome after TKA.[4–6]

In global and regional practice, multimodal analgesia has become the preferred approach for TKA pain management. Traditional techniques such as epidural analgesia, femoral nerve block, sciatic nerve block, systemic opioids, and local infiltration analgesia have been used, but each has limitations. Epidural techniques may produce autonomic effects, urinary retention, and motor blockade, while opioids are associated with nausea, vomiting, pruritus, respiratory depression, and dependence-related concerns.[6] Femoral nerve block provides analgesia but may weaken the quadriceps, increasing the risk of falls and delaying ambulation. Consequently, motor-sparing ultrasound-guided peripheral nerve blocks are increasingly preferred in contemporary TKA analgesia pathways.[7-9]

Adductor canal block (ACB) targets mainly sensory components, especially the saphenous nerve, and provides analgesia over the anteromedial knee while preserving quadriceps strength better than femoral nerve block.[7] However, ACB alone may not adequately address posterior knee pain. The IPACK block was developed to anesthetize sensory articular branches supplying the posterior capsule while preserving motor function of the tibial and common peroneal components.[10,11] Combined ACB plus IPACK has therefore emerged as a promising motor-sparing technique for postoperative analgesia, early ambulation, and reduced opioid consumption after TKA.[12,13]

Despite these advances, important gaps remain. The knee joint has complex innervation from femoral, obturator, sciatic, saphenous, and genicular branches, and no single analgesic technique has been universally accepted as ideal. The modified 4-in-1 block is a newer single-injection technique designed to block four major contributors to knee innervation, including the saphenous nerve, nerve to vastus medialis, obturator articular branches, and sciatic/genicular components.[14,15] Early studies have suggested that it may provide comprehensive postoperative analgesia without quadriceps weakness, but the available evidence remains limited, especially compared with the more established ACB plus IPACK technique.[10,11]

In the Indian context, the number of knee arthroplasties is steadily increasing, creating a need for simple, effective, safe, and resource-appropriate analgesic techniques that support early mobilization and discharge.[2,12] ACB plus IPACK is effective but requires two separate injections and, in many settings, positional or technical adjustments. The modified 4-in-1 block may offer a practical single-injection supine-position alternative, but it requires further evaluation in randomized studies. Therefore, the present randomized controlled study is planned to compare modified 4-in-1 block with IPACK plus ACB for postoperative analgesia in TKA, with emphasis on pain relief, functional recovery, motor preservation, and safety in Indian surgical practice.

MATERIALS AND METHODS

Study Design and Setting: The study was planned as a prospective, randomized, comparative controlled study to compare ultrasound-guided modified 4-in-1 block with combined IPACK plus ACB for postoperative analgesia in patients undergoing total knee arthroplasty (TKA). A randomized controlled design was selected because previous studies comparing these regional anaesthesia techniques for TKA used random allocation to reduce selection bias and to ensure balanced distribution of perioperative variables between the intervention groups. The study was conducted in the Operation Theatre of ESI-PGIMSR Medical College and Esic Hospital Joka, West Bengal. The anticipated study duration was 10–12 months, including patient recruitment, intervention, postoperative follow-up, data entry, and statistical analysis.

Study Population: The study population consisted of adult patients scheduled for elective unilateral TKA under subarachnoid block. Patients of either sex, aged 40–85 years, belonging to ASA physical status I, II, or III, and willing to provide written informed consent were included. Patients were excluded if they had known hypersensitivity or allergy to local anaesthetic drugs or study medications, bleeding disorders, infection at the block site, uncontrolled diabetes mellitus or hypertension, significant cardiac, hepatic, or renal disease, pre-existing neurological deficit of the lower limb, psychiatric illness interfering with pain assessment, or refusal to participate.

Sample size calculation: The sample size calculation was done with reference from previous studies which have established the efficacy of IPACK block. A pilot institutional study gave an effect size difference of 0.35. Using the OpenEpi (version 3)

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sample size calculator, with power at 80% with confidence interval at 95%, a minimum of 58 participants (29 participants in each group) Considering 10% drop-outs, we require 64 participants (32 in each group), to have an effective trial objective.

Method: Modified 4-in-1 block is a single-injection modification of the conventional 4-in-1 block, designed to provide postoperative analgesia by blocking four major neural contributors to knee joint innervation. The IPACK block targeted the popliteal plexus and articular sensory branches supplying the posterior capsule of the knee, whereas the adductor canal block (ACB) predominantly blocked the saphenous nerve and provided sensory analgesia over the anteromedial aspect of the knee.

Patients scheduled for total knee arthroplasty (TKA) who fulfilled the eligibility criteria were randomized into two groups: Group M received ultrasound-guided modified 4-in-1 block, and Group I received combined ultrasound-guided IPACK block and ACB. All patients underwent thorough preoperative evaluation, including clinical history, physical examination, assessment of comorbidities, airway evaluation, and review of relevant investigations. After shifting to the operating room, standard minimum monitoring was applied, including electrocardiography, non-invasive blood pressure, and pulse oximetry. Intravenous access was secured, and all patients received subarachnoid block under aseptic precautions. Following confirmation of adequate neuraxial anaesthesia, the allocated peripheral nerve block was administered according to group allocation. Postoperatively, pain intensity was assessed using the visual analogue scale (VAS) at 3, 6 and 24 hours and recorded in the study proforma for comparison between the two groups.

In Group M, the modified 4-in-1 block was performed with the patient in the supine position. The operative limb was externally rotated with slight abduction, and the knee was kept mildly flexed. The medial femoral condyle was identified and marked. A high-frequency linear ultrasound probe (6–13 Hz) was placed over the medial femoral condyle, and the vastus medialis muscle was visualized. The probe was then moved proximally to identify the junction between the vastus medialis and sartorius muscles, corresponding to the anteromedial intermuscular septum. Further proximal scanning was performed until the superficial femoral artery was visualized at the adductor hiatus. The probe was then advanced proximally until the descending genicular artery, arising from the superficial femoral artery, was identified. This point, usually located approximately 8–10 cm proximal to the medial femoral condyle, was considered the point of interest.

A Stimuplex needle attached to a peripheral nerve stimulator was introduced under real-time ultrasound guidance using an in-plane lateral-to-medial approach toward the vastus medialis muscle. The needle was advanced until contraction of the vastus medialis was elicited at a threshold current of approximately 0.4 mA, confirming proximity to the nerve to vastus medialis. After negative aspiration, 5–7 mL of the study drug mixture containing 0.2% Ropivacaine with Dexmedetomidine (25 mcg)was injected. The needle was then redirected in-plane from lateral to medial toward the perivascular region near the superficial femoral artery. After confirming negative aspiration and appropriate ultrasound spread, an additional 20–25 mL of the same drug mixture was injected incrementally to complete the block.

In Group I, the IPACK block was performed first with the patient in the supine position, the knee slightly flexed, and the thigh externally rotated. The ultrasound transducer was placed on the medial aspect of the knee to identify the femoral condyle, femoral shaft, and popliteal artery. After skin asepsis, the block needle was inserted from the anterior aspect of the transducer and advanced in a medial-to-lateral direction, parallel to the posterior border of the femoral condyle, until the needle tip was positioned in the tissue plane between the femur and the popliteal artery.[18,19] After careful aspiration to exclude intravascular placement, 15–20 mL of the study drug mixture containing 0.2% Ropivacaine with Dexmedetomidine (25mcg)was injected in small aliquots between the popliteal artery and femur, ensuring adequate spread in the interspace between the popliteal artery and capsule of the knee.[12,20]

Following completion of the IPACK block, ultrasound-guided ACB was performed. The high-frequency linear probe was placed over the medial aspect of the mid-thigh to identify the adductor canal. The superficial femoral artery was visualized beneath the sartorius muscle. The block needle was inserted using an in-plane lateral-to-medial approach and advanced toward the superficial femoral artery and saphenous nerve within the adductor canal.[7,18] After negative aspiration, 1–2 mL of the study drug mixture was injected to confirm correct needle-tip placement by observing appropriate spread around the saphenous nerve in the adductor canal. Thereafter, 15–20 mL of 0.2% Ropivacaine with Dexmedetomidine(25mcg) injected to complete the ACB.

All injections were performed under strict aseptic precautions with continuous ultrasound visualization of needle advancement and local anaesthetic spread. Incremental injection with repeated negative aspiration was used to reduce the risk of intravascular injection. Patients were monitored for hemodynamic stability, signs of local anaesthetic systemic toxicity, vascular puncture, neurological symptoms, quadriceps weakness, and other block-related complications during the perioperative and postoperative period.

RESULTS

A total of 64 patients who underwent total knee arthroplasty were included in the final analysis. The patients were equally distributed between the two

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study groups, with 32 patients in Group I receiving combined IPACK plus adductor canal block and 32 patients in Group M receiving modified 4-in-1 block. The dataset contained complete observations for age, sex, weight, duration of surgery/procedure, and postoperative VAS scores at 3, 6, and 24 hours.

The baseline demographic characteristics were comparable between the two groups. The mean age of the study population was 60.47 ± 3.18 years. The mean age was 59.81 ± 3.00 years in Group I and 61.13 ± 3.26 years in Group M, with no statistically significant difference between the groups (p = 0.099). The sex distribution was identical in both groups, with 17 males and 15 females in each group. Overall, males constituted 53.13% and females constituted 46.87% of the study population, with no significant intergroup difference (p = 1.000).

The mean body weight of the overall study population was 71.25 ± 7.42 kg. Group I had a mean weight of 72.91 ± 6.59 kg, while Group M had a mean weight of 69.59 ± 7.92 kg. The difference in weight between the groups was not statistically significant (p = 0.074). The mean duration of surgery/procedure was also comparable between the two groups. The overall mean duration was 100.63 ± 7.25 minutes, with 100.25 ± 6.59 minutes in Group I and 101.00 ± 7.94 minutes in Group M (p = 0.682).

Postoperative pain was assessed using the visual analogue scale at 3, 6, and 24 hours after surgery. At 3 hours postoperatively, the median VAS score was higher in Group I compared with Group M. The median VAS score was 5.00 (IQR: 3.00–5.25) in Group I and 3.00 (IQR: 3.00–4.00) in Group M, and the difference was statistically significant (p < 0.001). At 6 hours postoperatively, Group I continued to show a higher median VAS score of 4.00 (IQR: 2.00–4.25), whereas Group M had a median VAS score of 2.00 (IQR: 2.00–3.00), with a statistically significant difference between the groups (p < 0.001). At 24 hours postoperatively, the median VAS score was 2.00 (IQR: 1.00–3.00) in Group I and 1.00 (IQR: 1.00–1.00) in Group M, again showing a statistically significant intergroup difference (p < 0.001).

Thus, both groups were comparable with respect to baseline demographic and operative variables, while postoperative VAS scores at all recorded time points were significantly lower in the modified 4-in-1 block group compared with the combined IPACK plus adductor canal block group.

Table 1: Baseline characteristics and postoperative VAS scores according to study group

Variable	Overall (n = 64)	Group I: IPACK + ACB (n = 32)	Group M: Modified 4-in-1 block (n = 32)	p-value
Age (years)	60.47 ± 3.18	59.81 ± 3.00	61.13 ± 3.26	0.099
Sex				1.000
Male	34 (53.13)	17 (53.13)	17 (53.13)	
Female	30 (46.87)	15 (46.87)	15 (46.87)	
Weight (kg)	71.25 ± 7.42	72.91 ± 6.59	69.59 ± 7.92	0.074
Duration of surgery/procedure (min)	100.63 ± 7.25	100.25 ± 6.59	101.00 ± 7.94	0.682
VAS score at 3 hours	4.00 (3.00–5.00)	5.00 (3.00–5.25)	3.00 (3.00–4.00)	<0.001
VAS score at 6 hours	2.00 (2.00–4.00)	4.00 (2.00–4.25)	2.00 (2.00–3.00)	<0.001
VAS score at 24 hours	1.00 (1.00–2.00)	2.00 (1.00–3.00)	1.00 (1.00–1.00)	<0.001

DISCUSSION

The present study consisted of 64 patients who underwent total knee arthroplasty were included in the final analysis. The patients were equally distributed between the two study groups, with 32 patients in Group I receiving combined IPACK plus adductor canal block and 32 patients in Group M receiving modified 4-in-1 block.

In our study, the baseline demographic and operative variables were comparable between the two groups. The mean age was 59.81 ± 3.00 years in the IPACK plus ACB group and 61.13 ± 3.26 years in the modified 4-in-1 block group, with no significant difference (p = 0.099). This was consistent with Roy et al., Zheng et al., Bansal et al., and Qiao Y et al., who also reported comparable age distribution between intervention groups.[1,2,7,16] Sex distribution was identical in both groups, with 17 males and 15 females in each group (p = 1.000), similar to previous studies that reported balanced sex distribution between treatment arms.[1,3,7,11] Body weight was also comparable between the IPACK plus ACB group and modified 4-in-1 block group (72.91 ± 6.59 kg vs. 69.59 ± 7.92 kg; p = 0.074), in agreement with Roy et al., Zheng et al., and Qiao Y et al.[1,7,16] Similarly, the mean duration of surgery/procedure did not differ significantly between groups (100.25 ± 6.59 vs. 101.00 ± 7.94 minutes; p = 0.682), consistent with studies by Roy et al., Laoruengthana et al., and Bansal et al.[1-3] These findings indicated that baseline demographic and operative factors were unlikely to confound postoperative analgesic outcomes.

Postoperative VAS scores were significantly lower in the modified 4-in-1 block group compared with the IPACK plus ACB group at 3, 6, and 24 hours. At 3 hours, the median VAS score was 5.00 (IQR: 3.00–5.25) in the IPACK plus ACB group and 3.00 (IQR: 3.00–4.00) in the modified 4-in-1 block group (p < 0.001). At 6 hours, the median scores were 4.00 (IQR: 2.00–4.25) and 2.00 (IQR: 2.00–3.00), respectively (p < 0.001), while at 24 hours, they were 2.00 (IQR: 1.00–3.00) and 1.00 (IQR: 1.00–1.00), respectively (p < 0.001). Roy et al. reported comparable VAS scores between modified 4-in-1 block and IPACK plus ACB at 3, 6, and 24 hours, with significantly lower VAS in the modified 4-in-1 group at 12 hours.[1] In contrast, Bansal et al.

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observed better pain relief with ACB plus IPACK at 8, 16, 24, and 36 hours.[2] Other studies and meta-analyses have also supported the analgesic efficacy of ACB plus IPACK compared with ACB alone,m, peri-articular infiltration, or conventional motor-blocking techniques.[4,17–21] However, the lower VAS scores in our modified 4-in-1 group may be attributable to broader single-injection sensory coverage involving the saphenous nerve, nerve to vastus medialis, obturator articular branches, and sciatic/genicular components.[5,6]

In our study, postoperative VAS scores at 3, 6 and 24 hours were consistently lower in the modified 4-in-1 block group than in the IPACK plus ACB group, despite comparable baseline and operative characteristics. Roy et al. (2023) concluded that modified 4-in-1 block was comparable to the already established IPACK plus ACB technique and noted that it overcame technical and positional difficulties by using a single-injection supine-position approach.[1] Roy et al. (2020), in their earlier case series of 10 TKA patients, reported that all patients had VAS scores <5 except one patient after 36 hours, and no quadriceps weakness was observed.[5] Runge et al. demonstrated injectate spread from the distal adductor canal to the popliteal fossa, staining the saphenous nerve, genicular branches of the posterior division of the obturator nerve, sciatic nerve, and nerve to vastus medialis, providing anatomical support for the concept of extended sensory coverage through the adductor canal region.[17] Our results are in concordance with the anatomical and clinical rationale of the modified 4-in-1 technique. The observed superiority of Group M in our dataset may reflect more comprehensive coverage of knee innervation through a single targeted injection, particularly when nerve to vastus medialis stimulation was used to confirm the block site.

Several studies, however, support the effectiveness of ACB plus IPACK as a motor-sparing multimodal analgesic technique after TKA. Sankineani et al. (2018) reported that ACB plus IPACK provided better immediate postoperative pain control and knee function than ACB alone.[8] Amin and Abotaleb (2021) concluded that IPACK plus ACB was superior to ACB alone in TKA analgesia.[18] Vijay (2020) reported that continuous ACB combined with IPACK improved early recovery and ambulation compared with continuous ACB alone.[24] Kim et al. (2019) reported that adding IPACK and ACB to periarticular injection enhanced postoperative pain control in TKA.[20] Vichainarong et al. (2020) reported analgesic benefit when IPACK was added to local infiltration analgesia and continuous ACB.[21] Patterson et al. (2020), however, studied the effect of IPACK block after primary TKA and contributed to the literature showing that the additional benefit of IPACK may vary depending on background periarticular infiltration and multimodal analgesic protocols.[22] Thus, while ACB plus IPACK remains strongly supported for postoperative analgesia, the comparative advantage over modified 4-in-1 block is not uniform across studies.

Meta-analytic evidence also suggests that the benefit of IPACK is greatest when posterior knee pain is inadequately covered by ACB alone. Hussain et al. (2021) evaluated whether adding IPACK to ACB, with or without periarticular local anaesthetic infiltration, improved analgesic and functional outcomes following TKA.[23] Guo et al. (2022) found that ACB plus IPACK significantly reduced VAS scores, morphine consumption, length of hospital stay, and improved knee range of motion and walking distance compared with ACB alone.[19] Qiao et al. (2023) reported that IPACK supplementation reduced early rest and dynamic pain and lowered opioid consumption but did not consistently improve quadriceps strength or range of motion across all time points.[21] Terkawi et al. (2017), in a network meta-analysis of 170 randomized controlled trials on pain management modalities after TKA, emphasized the importance of selecting procedure-specific multimodal strategies rather than relying on a single analgesic modality.[24] These findings suggest that the relative performance of any block depends not only on neural targets but also on co-analgesic protocols, surgical technique, local infiltration, and rehabilitation pathways.

From a mechanistic perspective, the findings of the present study can be explained by the complex innervation of the knee joint. ACB provides anteromedial analgesia by targeting the saphenous nerve and related sensory components, while IPACK targets posterior capsular sensory branches without producing sciatic motor blockade.[3,4,7] However, the modified 4-in-1 block was specifically designed to target multiple contributors to knee joint innervation, including the saphenous nerve, nerve to vastus medialis, genicular branches of the sciatic nerve, and obturator articular branches.[1,5,6] Kapoor et al. (2012) described the relationship between the saphenous nerve and nerve to vastus medialis in and around the adductor canal, supporting the anatomical basis for targeting this region in knee analgesia.[25] Tran et al. (2019) and Niesen et al. (2019) evaluated IPACK injectate spread in cadaveric studies and showed the anatomical basis and limitations of posterior capsular spread.[26,27] Therefore, a technically successful modified 4-in-1 block may provide broader sensory coverage than a separated ACB plus IPACK approach in selected patients, although this requires confirmation in larger multicentric trials.

Overall, our study suggested that modified 4-in-1 block provided significantly lower early postoperative VAS scores compared with IPACK plus ACB in patients undergoing TKA. This finding supports the clinical utility of modified 4-in-1 block as a simple, single-injection, supine-position motor-sparing technique. However, because several contemporary RCTs and meta-analyses support the analgesic benefit of ACB plus IPACK over ACB alone, periarticular infiltration, or conventional motor-blocking techniques, the present findings

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should be interpreted within the context of sample size, institutional analgesic protocol, technical expertise, and the limited number of direct head-to-head studies comparing modified 4-in-1 block with ACB plus IPACK.

CONCLUSION

The study concluded that both modified 4-in-1 block and IPACK plus adductor canal block were effective for postoperative analgesia after total knee arthroplasty. However, modified 4-in-1 block provided significantly lower VAS scores at 3, 6 and 24 hours, suggesting better early postoperative pain control. Being a single-injection, supine-position technique, modified 4-in-1 block may be a practical and effective motor-sparing analgesic option for TKA.

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