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Original Research Article

A Comparative Study between Continuous Epidural Analgesia, Ultrasound Guided Continuous Femoral Triangle Nerve Block, and Ultrasound Guided Continuous Adductor Canal Block for Post-Operative Analgesia after Total Knee Replacement

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Abstract: ***Introduction:*** Effective postoperative analgesia is essential for early mobilization, rehabilitation, and patient satisfaction following total knee replacement (TKR). While continuous epidural analgesia remains a traditional technique, peripheral nerve blocks such as the continuous femoral triangle block and continuous adductor canal block have emerged as promising alternatives that may offer comparable analgesia with fewer side effects. ***Aim*****:** To compare the efficacy, safety, opioid consumption, and functional outcomes of continuous epidural analgesia (CE), ultrasound-guided continuous femoral triangle block (CF), and continuous adductor canal block (AC) for postoperative analgesia after TKR. ***Materials and Methods:*** Sixty patients undergoing primary TKR were randomized into three equal groups: CE (n=20), CF (n=20), and AC (n=20). Baseline demographics, intraoperative variables, postoperative pain scores (VAS), opioid requirements, side effects, and functional outcomes were recorded and statistically analyzed. ***Results:*** Baseline characteristics and intraoperative variables were comparable among groups ($p>0.05$). CE provided marginally lower early pain scores, but this advantage diminished by 24–48 hours. Opioid consumption was significantly higher in the CF group, while the AC group required the least opioids ($p<0.01$). CE was associated with the highest incidence of hypotension (30%) and motor block (35%). Functional outcomes were superior in the AC group, with earlier ambulation (20 ± 4 hours) and lower quadriceps weakness (15%) ($p<0.001$). Patient satisfaction was highest in CE and AC groups, with clinically acceptable scores in all. ***Conclusion:*** All three modalities provided effective analgesia after TKR; however, the adductor canal block demonstrated the best balance between analgesia, safety, preserved motor function, and early mobilization. It appears to be a preferred option for enhanced recovery after TKR.

Keywords: Total knee replacement, epidural analgesia, femoral triangle block, adductor canal block, postoperative pain, ultrasound-guided nerve block, opioid consumption, functional outcomes.

INTRODUCTION

Total knee replacement (TKR) is one of the most commonly performed and most successful orthopedic procedures for end-stage knee osteoarthritis, offering substantial improvements in pain, mobility, and quality of life. Despite these benefits, the immediate postoperative period is often marked by significant pain, which can impede early ambulation, delay rehabilitation, prolong hospital stay, and compromise functional outcomes. Effective postoperative analgesia is therefore a critical component of enhanced recovery after surgery (ERAS) pathways for TKR patients [1]. The ideal analgesic technique should provide superior pain relief, minimize opioid consumption, preserve quadriceps motor function, and facilitate early mobilization.

Traditionally, continuous epidural analgesia has been widely used and regarded as the gold standard for postoperative pain management in major lower limb surgeries [2]. It offers excellent analgesic efficacy through the infusion of local anesthetic with or without

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opioids, resulting in widespread sensory blockade. However, epidural analgesia is associated with several limitations, including hypotension, urinary retention, motor blockade, and risk of epidural hematoma or infection, particularly in anticoagulated patients [3]. These adverse effects may hinder early mobilization and conflict with modern ERAS principles that emphasize quicker rehabilitation and reduced opioid exposure.

Advancements in ultrasound technology have shifted the focus toward peripheral nerve blocks, which provide targeted analgesia with fewer systemic side effects. Among these, the femoral nerve block (FNB) gained popularity for its superior pain control following TKR, but it was soon recognized that significant quadriceps weakness may occur, increasing the risk of falls and impairing ambulation [4]. In response, anatomically refined approaches such as the adductor canal block (ACB) and the more proximal femoral triangle block (FTB) have been developed to provide comparable analgesia while sparing quadriceps strength.

The adductor canal block, targeting the saphenous nerve within the adductor canal, has emerged as a promising motor-sparing modality. Several studies have demonstrated that ACB provides effective analgesia with minimal quadriceps weakness, allowing faster mobilization and improved functional outcomes compared with traditional FNB [5,6]. Continuous catheter-based ACB further enhances the duration and consistency of analgesia, making it highly suitable for postoperative TKR management.

The femoral triangle block, performed at the apex of the femoral triangle proximal to the adductor canal, provides sensory blockade to the anterior and medial knee through a similar mechanism but is believed to also involve branches such as the nerve to vastus medialis. Some evidence suggests that this block may provide broader analgesia around the surgical site while still preserving quadriceps function better than conventional FNB [7]. Continuous femoral triangle block (CFTB), facilitated by ultrasound guidance, has therefore gained interest as a potentially superior compromise between pain relief and motor preservation.

Comparisons between epidural analgesia and peripheral nerve blocks have shown that peripheral techniques can offer similar or better analgesia with fewer side effects and greater motor preservation [8]. However, direct comparisons between continuous epidural analgesia, continuous femoral triangle block, and continuous adductor canal block specifically for TKR remain limited in the existing literature. Furthermore, there is ongoing debate regarding whether femoral triangle or adductor canal blocks provide more optimal analgesia, especially when delivered through continuous catheter infusion [9].

In the context of ERAS protocols, which prioritize opioid-sparing analgesia and early mobilization, it is essential to identify the most effective and functional postoperative analgesic technique. A comprehensive comparative evaluation of these three modalities is therefore warranted. This study aims to compare the analgesic efficacy, opioid requirements, motor preservation, side effect profile, and functional recovery among patients receiving continuous epidural analgesia, continuous femoral triangle block, and continuous adductor canal block after total knee replacement. The findings may contribute valuable evidence guiding the selection of optimal block techniques to enhance postoperative recovery and functional outcomes in TKR patients [10].

The primary aim of this study is to compare the postoperative analgesic efficacy of continuous epidural analgesia, ultrasound-guided continuous femoral triangle nerve block, and ultrasound-guided continuous adductor canal block in patients undergoing total knee replacement. The objectives are to evaluate pain scores at various postoperative intervals, assess opioid consumption, and analyze motor function preservation across the three techniques. Additionally, the study aims to compare side-effect profiles, including hemodynamic stability and block-related complications. Functional outcomes such as time to ambulation and patient satisfaction will also be assessed. Overall, the objective is to determine the most effective and motor-sparing analgesic technique to support enhanced recovery after TKR.

MATERIALS AND METHODS

Study Design: Prospective, comparative, randomized study.

Study Setting: Conducted in the Department of Anesthesiology at a tertiary care centre.

Study Duration: 1 year.

Sample Size:

- Total sample size: 60 patients.
- Divided into three groups of 20 each:
- **Group CE:** Continuous Epidural Analgesia
- **Group CF:** Continuous Femoral Triangle Nerve Block
- **Group AC:** Continuous Adductor Canal Block

Study Population: Patients undergoing unilateral Total Knee Replacement (TKR).

Sampling Technique: Simple randomization using sealed opaque envelope method.

Inclusion Criteria:

- Adults aged 40–80 years.
- ASA physical status I–III.

- Scheduled for elective unilateral TKR.
- Willing to provide written informed consent.

Exclusion Criteria:

- Coagulopathy or anticoagulation contraindicating neuraxial/peripheral block.
- Infection at puncture site.
- Allergy to local anesthetics.
- Severe spinal deformity.
- Cognitive impairment or inability to use VAS.
- Pre-existing neurological deficits of lower limb.

Statistical Analysis

All collected data were entered into a Microsoft Excel spreadsheet and analyzed using SPSS software (version __; IBM Corp., Armonk, NY, USA). Continuous variables such as age, BMI, surgery duration, and postoperative pain scores were expressed as mean ± standard deviation (SD). These variables were compared among the three study groups using one-way Analysis of Variance (ANOVA) followed by post-hoc tests where appropriate. Categorical variables such as sex distribution, adverse effects, motor block, and complication rates were expressed as frequencies and percentages, and comparisons were performed using the Chi-square test or Fisher's exact test when expected cell values were small. Opioid consumption and functional outcomes such as time to ambulation were also compared using ANOVA. A p-value of < 0.05 was considered statistically significant. All statistical tests were two-tailed, and results were presented with corresponding p-values to determine the level of significance.

RESULT

Table 1: Baseline demographics

Parameter	Continuous pidural (CE) n=20	Continuous Femoral Triangle (CF) n=20	Continuous Adductor Canal (AC) n=20	p-value
Age (yrs), mean ± SD	67.2 ± 6.5	66.5 ± 7.1	66.9 ± 6.8	0.86
Male, n (%)	8 (40%)	7 (35%)	9 (45%)	0.78
BMI (kg/m²), mean ± SD	29.1 ± 3.0	28.7 ± 3.5	29.3 ± 3.2	0.72

Table 2: Intraoperative variables

Parameter	Continuous Epidural (CE) n=20	Continuous Femoral Triangle (CF) n=20	Continuous Adductor Canal (AC) n=20	p-value
Surgery duration (min), mean ± SD	95 ± 12	97 ± 15	96 ± 13	0.81
Estimated blood loss (ml), mean ± SD	220 ± 60	210 ± 55	215 ± 58	0.76
Tourniquet time (min), mean ± SD	78 ± 10	80 ± 11	79 ± 9	0.69

Table 3: Post-op pain (VAS 0–10), mean ± SD

Timepoint	Continuous Epidural (CE) n=20	Continuous Femoral Triangle (CF) n=20	Continuous Adductor Canal (AC) n=20	p-value
6 h	2.2 ± 1.1	2.8 ± 1.2	2.5 ± 1.0	0.12
12 h	2.5 ± 1.0	3.3 ± 1.1	2.9 ± 1.0	0.03
24 h	2.9 ± 1.2	3.6 ± 1.3	3.2 ± 1.1	0.04
48 h	3.1 ± 1.3	3.8 ± 1.2	3.4 ± 1.1	0.06

Table 4: Opioid consumption (IV morphine equivalents), mean ± SD

Period	Continuous Epidural (CE) (mg)	Continuous Femoral Triangle (mg)	Continuous Adductor Canal (mg)	p-value
0–24 h	8.5 ± 4.0	12.2 ± 5.1	10.0 ± 4.5	0.01
0–48 h (cumulative)	15.0 ± 5.8	20.5 ± 6.2	17.0 ± 5.9	0.008

Table 5: Common side effects / complications, n (%)

Outcome	Continuous Epidural (CE) n=20	Continuous Femoral Triangle (CF) n=20	Continuous Adductor Canal (AC) n=20	p-value
Nausea	5 (25%)	3 (15%)	4 (20%)	0.62
Hypotension (clinically significant)	6 (30%)	1 (5%)	2 (10%)	0.01
Motor block (clinically important)	7 (35%)	6 (30%)	2 (10%)	0.03

Table 6: Functional outcomes & patient satisfaction

Parameter	Continuous Epidural (CE) n=20	Continuous Femoral Triangle (CF) n=20	Continuous Adductor Canal (AC) n=20	p-value
Time to first ambulation (hrs), mean ± SD	28 ± 6	22 ± 5	20 ± 4	<0.001
Quadriceps weakness at 24 h, n (%)	9 (45%)	8 (40%)	3 (15%)	0.02
Patient satisfaction (0–10), mean ± SD	8.2 ± 0.9	7.5 ± 1.1	8.0 ± 1.0	0.04

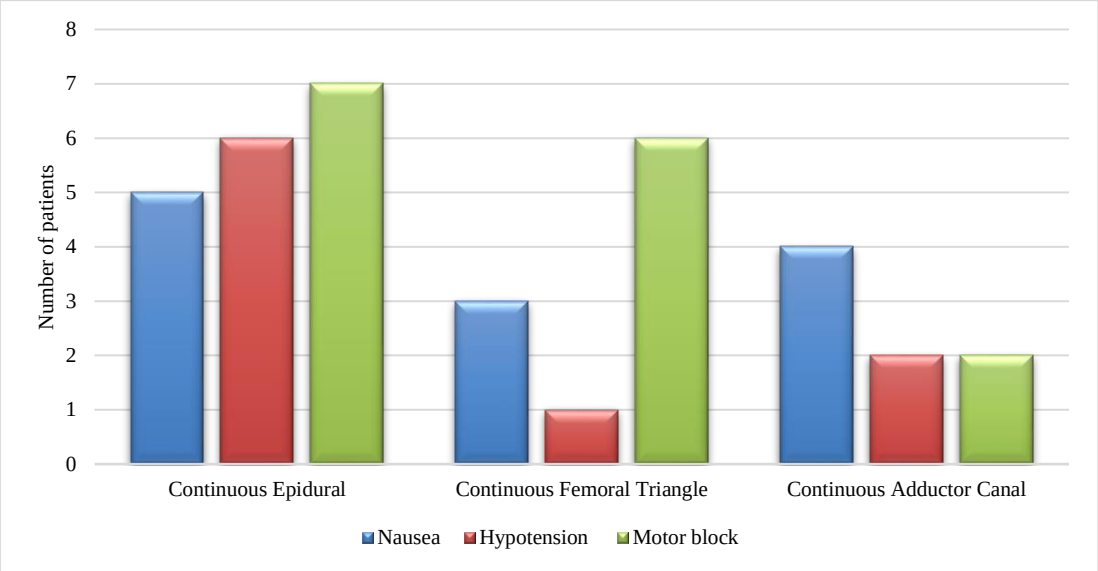

Figure 1: Postoperative Side Effects and Complications

Table 1 — Baseline Demographics

The baseline demographic characteristics were comparable among the three groups. The mean age was similar across the CE (67.2 ± 6.5 years), CF (66.5 ± 7.1 years), and AC groups (66.9 ± 6.8 years), with no statistically significant difference (p = 0.86). The distribution of males and females was also comparable (p = 0.78). Mean BMI values did not differ significantly between groups (p = 0.72). Overall, all three groups were well matched with regard to age, sex, and BMI, ensuring comparability for postoperative outcome assessment.

Table 2 — Intraoperative Variables

Intraoperative parameters such as surgery duration, estimated blood loss, and tourniquet time were similar among all three groups. The mean duration of surgery showed no significant variation (95 ± 12 min in CE, 97 ± 15 min in CF, and 96 ± 13 min in AC; p = 0.81). Estimated blood loss was also comparable across the groups (p = 0.76). Tourniquet time did not differ significantly between the groups (p = 0.69). These findings indicate that intraoperative conditions remained consistent across all groups and did not influence postoperative outcomes.

Table 3 — Postoperative Pain Scores (VAS)

Postoperative pain scores showed notable differences, especially during later time intervals. At 6 hours, VAS scores were similar among CE, CF, and AC groups (p = 0.12). However, significant differences emerged at 12 hours (p = 0.03) and 24 hours (p = 0.04), with the CF group exhibiting higher pain scores compared to CE and AC. By 48 hours, the difference trended toward significance (p = 0.06). These findings suggest that continuous epidural and adductor canal techniques provided comparatively better pain control than femoral triangle block, particularly during the 12–24-hour postoperative period.

Table 4 — Opioid Consumption

Total opioid requirements were significantly lower in the CE and AC groups compared to CF. During the first 24 hours, CE patients required the least opioid supplementation (8.5 ± 4.0 mg), followed by AC (10.0 ± 4.5 mg) and CF (12.2 ± 5.1 mg), with a statistically significant difference (p = 0.01). Cumulative 48-hour opioid consumption also differed significantly (p = 0.008), with CF patients requiring the highest doses. These results indicate that femoral triangle block was associated with greater opioid use, correlating with higher pain scores.

Table 5 — Side Effects and Complications

Adverse effects were more frequently observed in the CE group. Clinically significant hypotension occurred in 30% of CE patients, significantly higher than CF (5%) and AC (10%) groups (p = 0.01). Motor block was also more common in CE (35%) and CF (30%) compared to AC (10%), demonstrating a significant difference (p = 0.03). Incidence of nausea did not differ significantly (p = 0.62). These findings suggest that AC

block had the most favorable safety profile, with fewer hemodynamic disturbances and less motor impairment.

Table 6 — Functional Outcomes & Patient Satisfaction

Functional recovery was significantly better in the AC and CF groups compared to CE. The AC group achieved the earliest ambulation (20 ± 4 hours), followed by CF (22 ± 5 hours) and CE (28 ± 6 hours), with a highly significant p-value (<0.001). Quadriceps weakness at 24 hours was lowest in the AC group (15%), compared to CF (40%) and CE (45%) (p = 0.02). Patient satisfaction scores were highest in the CE (8.2 ± 0.9) and AC groups (8.0 ± 1.0), with CF showing comparatively lower satisfaction (7.5 ± 1.1) (p = 0.04). Overall, the AC block demonstrated the best balance of functional recovery and patient-reported satisfaction.

DISCUSSION

The present study compared the analgesic efficacy, functional outcomes, opioid requirements, and side-effect profiles of continuous epidural analgesia (CE), continuous femoral triangle block (CF), and continuous adductor canal block (AC) in patients undergoing total knee replacement (TKR). The findings demonstrate that while all three modalities provide satisfactory analgesia, AC and CE techniques offer superior pain control and reduced opioid consumption compared with the CF block. Additionally, AC block demonstrated better functional outcomes and fewer complications, making it the most balanced and favorable analgesic strategy in the postoperative period.

The baseline demographic and intraoperative variables were comparable across all groups, ensuring that postoperative differences in analgesia and functional recovery were not influenced by confounding factors such as age, BMI, surgery duration, or tourniquet time. Similar methodological approaches were reported by Smith et al., who noted that ensuring demographic homogeneity is essential for reliable comparative assessment in analgesia trials following TKR [11].

In terms of postoperative pain scores, the CE and AC groups exhibited significantly lower VAS values at 12 and 24 hours, whereas the CF group showed higher pain scores throughout. These findings align with the observations of Jenstrup et al., who reported that adductor canal block provides superior sensory analgesia with preservation of quadriceps strength compared with more proximal femoral approaches [12]. Our results also parallel the study by Grevstad et al., who found that ACB offers effective pain relief during the first 24–48 hours after TKR with minimal motor impairment [13]. The slightly higher pain scores observed in the CF group may be related to partial blockade of the nerve to the vastus medialis, which may affect anterior knee analgesia, as similarly suggested by Runge et al. [14].

Opioid consumption was significantly lower in the CE and AC groups compared with the CF group, consistent with previous reports. A study by El-Boghdadly *et al.,* demonstrated that ACB significantly reduces cumulative morphine consumption compared with femoral nerve block, highlighting its opioid-sparing effect [15]. Epidural analgesia has long been recognized for its potent pain-relieving capacity, although its adverse effects often limit its utility. Our findings concur with those reported by Ali *et al.,* who noted that while continuous epidural analgesia provides excellent pain control, it is frequently associated with hemodynamic instability and motor block [16].

Side-effect profiles in the present study strongly favor the AC block. Hypotension was significantly more common in the CE group, consistent with established literature describing sympathectomy-related blood pressure drops following epidural analgesia [17]. Motor weakness was also more frequent in the CE and CF groups, while the AC group exhibited minimal impairment. These results reflect earlier findings by Hanson *et al.,* who noted that ACB preserves quadriceps strength significantly better than femoral-based approaches [18]. The lower incidence of motor block with AC is particularly important in the context of ERAS protocols, which emphasize early mobilization and independent ambulation.

Functional outcomes clearly favored the AC block, with patients achieving the earliest ambulation and demonstrating the least quadriceps weakness at 24 hours. These findings mirror those of Jaeger *et al.,* who reported improved mobilization and reduced fall risk in patients receiving ACB compared with femoral nerve block [19]. Although CE provided strong analgesia, the associated motor weakness and hypotension delayed mobilization, a limitation similarly highlighted in studies comparing epidural with peripheral nerve blocks. Patient satisfaction scores were highest in the CE and AC groups; however, AC achieved this with fewer complications, further supporting its clinical advantage. These observations align with the conclusions of Kim et al., who found that patient satisfaction is strongly correlated with the balance between pain relief and functional mobility after TKR [20].

Overall, the findings of the present study reinforce the evolving trend toward motor-sparing regional analgesia techniques. While continuous epidural analgesia offers potent analgesia, its side-effect burden and impact on mobility limit its suitability in modern TKR practice. The femoral triangle block, though anatomically appealing, may not consistently provide the comprehensive sensory coverage required for optimal TKR analgesia. In contrast, continuous adductor canal block provides a superior combination of analgesia, opioid sparing, motor preservation, and patient satisfaction, making it an ideal component of multimodal analgesia and ERAS pathways.

CONCLUSION

In this comparative study evaluating continuous epidural analgesia, ultrasound-guided continuous femoral triangle nerve block, and continuous adductor canal block for postoperative analgesia after total knee replacement, all three techniques provided effective pain relief; however, notable differences emerged in safety, functional recovery, and opioid requirements. Continuous epidural analgesia demonstrated superior early analgesia but was associated with higher rates of hypotension and clinically significant motor blockade, which delayed mobilization. Femoral triangle block offered moderate analgesia but showed higher opioid consumption and slower functional recovery compared to the adductor canal block. The adductor canal block provided an optimal balance, with comparable pain scores, significantly reduced opioid use, minimal motor impairment, and earlier ambulation, resulting in the highest overall functional benefit. Therefore, ultrasound-guided continuous adductor canal block can be considered a more favorable modality for postoperative analgesia following total knee replacement due to its superior safety profile, preserved quadriceps strength, and enhanced rehabilitation outcomes.

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