Section: Orthopaedics

Original Research Article

EFFICACY OF MULTIMODAL ANALGESIA IN REDUCING OPIOID CONSUMPTION AND IMPROVING RECOVERY AFTER FRACTURE FIXATION

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ABSTRACT

Background: Effective pain management following fracture fixation is essential for early mobilization and recovery. Opioid-only regimens, while commonly used, are limited by adverse effects and the risk of dependence. Multimodal analgesia, targeting multiple pain pathways, may improve analgesic efficacy, reduce opioid requirements, and enhance recovery.

Materials and Methods: A retrospective comparative study was conducted at a tertiary care centre including 98 patients aged 18–65 years who underwent surgical fixation of long bone fractures between February 2024 and July 2025. Patients were categorized into Group A (multimodal analgesia with paracetamol, NSAID, and / or local infiltration/nerve block; n=49) and Group B (opioid-only regimen; n=49). Pain intensity was assessed using the visual analogue scale up to 48 hours postoperatively. Secondary outcomes included total opioid consumption, opioid-related adverse effects, time to mobilization, hospital stay, and patient satisfaction.

Results: Baseline demographics were comparable between groups. Group A demonstrated significantly lower mean VAS scores at 24 hours (3.2 ± 1.1 vs. 5.1 ± 1.3) and 48 hours (2.8 ± 1.0 vs. 4.6 ± 1.2; both $p<0.001$). Total opioid use was reduced by 44% in the multimodal group (34.6 ± 12.3 mg vs. 61.8 ± 15.9 mg OME, $p<0.001$). Multimodal patients achieved earlier mobilization (1.9 ± 0.6 vs. 2.7 ± 0.8 days, $p<0.001$), had shorter hospital stays (5.8 ± 1.2 vs. 7.1 ± 1.5 days, $p<0.001$), and reported higher satisfaction (83.7% vs. 55.1%, $p=0.002$). Opioid-related side effects such as nausea, constipation, and sedation were significantly lower in Group A.

Conclusion: Multimodal analgesia provides superior pain control, reduces opioid consumption, and improves recovery outcomes compared with opioid-only regimens in patients undergoing fracture fixation. Adoption of multimodal strategies may enhance postoperative care and mitigate opioid-related complications in orthopaedic practice.

Keywords: Multimodal analgesia, opioid-only regimen, fracture fixation, postoperative pain, orthopaedics, opioid sparing, patient recovery.

INTRODUCTION

Effective postoperative pain management remains one of the most important determinants of recovery after orthopaedic surgery. Fracture fixation, particularly of long bones, is associated with substantial nociceptive and inflammatory pain, which can impede early mobilization, delay rehabilitation, and prolong hospitalization if inadequately controlled.[1,2] Beyond short-term discomfort, poorly managed acute pain is an established risk factor for the development of chronic postsurgical pain syndromes, which significantly impair quality of life and functional outcomes.[3]

Traditionally, opioids have been the cornerstone of perioperative analgesia due to their potent efficacy. However, reliance on opioids alone has been increasingly challenged because of their well-recognized side effects, including nausea, vomiting, constipation, respiratory depression, sedation, and

the risk of dependence.[4] Orthopaedic patients are particularly vulnerable to these complications because many require high opioid doses to control severe postoperative pain. Moreover, opioid-related morbidity can counteract the benefits of early mobilization, a key principle in fracture rehabilitation.[5]

To address these limitations, the concept of multimodal analgesia has gained widespread acceptance. Multimodal analgesia involves the combination of pharmacological agents and techniques acting at different points in the pain pathway, thereby producing additive or synergistic analgesic effects.[6] By incorporating non-opioid medications such as acetaminophen, non-steroidal anti-inflammatory drugs (NSAIDs), gabapentinoids, ketamine, and regional anesthesia techniques, multimodal regimens reduce opioid consumption while improving pain relief.[7] Clinical trials and systematic reviews in orthopaedic populations, including joint arthroplasty and spine surgery, have consistently demonstrated that multimodal approaches are associated with lower pain scores, fewer opioid-related adverse effects, faster mobilization, and shorter hospital stays compared to opioid-only strategies.[8,9]

Despite this growing body of evidence, the application of multimodal analgesia in the context of fracture fixation has been less extensively studied than in arthroplasty. Given that fracture fixation surgeries are common and associated with significant postoperative pain, there is a pressing need to evaluate the comparative efficacy of multimodal regimens in this setting. Establishing superiority over opioid-only protocols would have substantial implications for enhancing recovery, reducing healthcare costs, and improving patient satisfaction in orthopaedic trauma care.[10]

Therefore, the present study was designed to compare the efficacy of multimodal analgesia versus opioid-only regimens for postoperative pain management in patients undergoing fracture fixation at a rural tertiary care centre. By analyzing pain scores, opioid consumption, adverse effects, and functional recovery parameters, this study aims to provide real-world evidence to guide analgesic strategies in orthopaedic surgery.

MATERIALS AND METHODS

Study Design and Setting: This study was designed as a retrospective comparative cohort analysis and was conducted in the Department of Orthopaedics, Sri Devaraj Urs Medical College and RL Jalappa Hospital, a tertiary care teaching hospital in South India. The study period extended from February 2024 to July 2025, during which all adult patients undergoing surgical fixation of long bone fractures were screened for eligibility. Institutional Ethics Committee clearance was obtained prior to data collection.

Study Population: Patients between the ages of 18 and 65 years who underwent open reduction and internal fixation of femoral, tibial, or humeral fractures were eligible. Diagnosis and operative procedures were confirmed through operative records, discharge summaries, and radiological documentation. Only those with complete perioperative data, including anesthetic records, analgesic prescriptions, and postoperative monitoring charts, were included in the analysis.

Inclusion and Exclusion Criteria

Patients were included if they had undergone definitive fracture fixation during the study period and had at least 14 days of postoperative follow-up data available. Exclusion criteria were polytrauma requiring multiple surgeries, chronic opioid use (>3 months preoperatively), chronic liver or kidney dysfunction, known hypersensitivity to any study drugs, pregnancy, and incomplete medical records. Patients who received both regimens simultaneously or switched between regimens intraoperatively were excluded from the final comparative analysis.

Study Groups

Two distinct postoperative analgesic regimens were evaluated.

- Group A (Multimodal group): Patients who received scheduled paracetamol (intravenous or oral) combined with a non-steroidal anti-inflammatory drug, supplemented in most cases with local anesthetic wound infiltration or peripheral nerve block. Rescue opioids were permitted on demand.
- Group B (Opioid-only group): Patients managed with standard opioid regimens (morphine or tramadol administered intravenously or intramuscularly) as per institutional protocol. No scheduled non-opioid medications were administered in this group.

Outcome Measures: The primary outcome was postoperative pain intensity, assessed using the Visual analogue Scale (VAS Score; 0 = no pain, 10 = worst possible pain). Pain scores at rest were recorded at fixed intervals (6, 12, 24, and 48 hours postoperatively) by ward nursing staff as part of routine clinical monitoring.

Secondary outcomes included total opioid consumption in oral morphine equivalents during the first 48 postoperative hours, time to first mobilization with physiotherapy, total length of hospital stay, incidence of opioid-related adverse effects (nausea, vomiting, constipation, sedation, respiratory depression), and patient satisfaction with analgesia at discharge (measured using a five-point Likert scale).

Sample Size

Sample Size Calculation

The primary endpoint was the between-group difference in mean postoperative pain (VAS Score) at 24 hours. A two-sided two-sample t-test with $\alpha = 0.05$ and power = 80% was planned. Based on prior orthopaedic pain studies reporting a common standard deviation (σ) of approximately 1.5–1.8 VAS

Score units and considering a clinically meaningful difference (Δ) of 1.0 VAS Score unit as the minimal clinically important difference (MCID),[11] the required sample size was calculated.

Formula (per group):

$n = 2 \times (Z_{1-\alpha/2} + Z_{1-\beta})^2 \times \sigma^2 / \Delta^2$

where $Z_{1-\alpha/2} = 1.96$ and $Z_{1-\beta} = 0.84$.

Substitution ($\sigma = 1.7$, $\Delta = 1.0$):

$n = 2 \times (1.96 + 0.84)^2 \times (1.7)^2 / (1.0)^2$

$n = 45.3 \approx 46$ per group

Allowing for approximately 10% attrition/missing data, the target was 50 patients per group (total = 100).

The final achieved sample size was 98 patients (49 in each group), which met the a priori requirement and ensured ≥80% statistical power.

Data Collection: Data were extracted from hospital medical records and case files by two independent investigators using a pre-validated data abstraction form. Extracted parameters included demographic details (age, sex), comorbidities, fracture site, type of anesthesia, operative duration, prescribed analgesic regimen, VAS Score pain scores, total opioid consumption, adverse events, mobilization time, and hospital stay. Discharge summaries were reviewed to record patient satisfaction scores. Any discrepancies were resolved through consensus after joint review of the source records.

Statistical Analysis: All data were entered into Microsoft Excel and analyzed using SPSS version 25.0 (IBM Corp., Armonk, NY, USA). Continuous variables were expressed as means with standard deviations and compared using Student's t test or Mann–Whitney U test, depending on data distribution. Categorical variables were expressed as counts and percentages and compared using the Chi-square test or Fisher's exact test where appropriate. Repeated measures analysis of variance (ANOVA) was performed to compare changes in pain scores over time between groups. A p-value <0.05 was considered statistically significant.

Ethical Considerations: The study protocol was approved by the Institutional Ethics Committee of Sri Devaraj Urs Academy of Higher Education and Research. As this was a retrospective chart-review study, the requirement for individual patient consent was waived. All data were anonymized before analysis, and strict confidentiality was maintained throughout.

RESULTS

Cohort Assembly: A total of 102 patients underwent surgical fixation of long bone fractures during the study period. After applying exclusion criteria, 98 patients were included in the final analysis. Of these, 49 received multimodal analgesia (Group A) and 49 received opioid-only regimens (Group B).

Baseline Characteristics: Baseline demographics and clinical variables were well balanced between groups (Table 1). The mean age was 41.8 ± 12.7 years in the multimodal group and 42.5 ± 13.1 years in the opioid-only group. Male predominance was observed in both groups (59.2% vs 55.1%). The distribution of fracture sites (femur, tibia, humerus) was comparable, and there were no significant differences in comorbidities, anesthesia type, or operative time.

Table 1: Baseline characteristics

Characteristic	Multimodal (n=49)	Opioid-only (n=49)	p-value
Age, years (mean ± SD)	41.8 ± 12.7	42.5 ± 13.1	0.78
Male sex, n (%)	29 (59.2)	27 (55.1)	0.69
Diabetes, n (%)	6 (12.2)	7 (14.3)	0.76
Hypertension, n (%)	5 (10.2)	6 (12.2)	0.75
Fracture site: Femur/Tibia/Humerus	22/18/9	20/20/9	0.91
Anesthesia: GA/Spinal	28/21	29/20	0.84
Operative time, min (mean ± SD)	94 ± 16	97 ± 18	0.42

Analgesic Exposure: All patients in the multimodal group received scheduled acetaminophen, and 44 (89.8%) received NSAIDs within 24 hours. Local infiltration was documented in 28 patients (57.1%), and peripheral nerve block in 14 patients (28.6%). The opioid-only group relied exclusively on morphine or tramadol as per protocol.

Table 2: Perioperative analgesia

Variable	Multimodal (n=49)	Opioid-only (n=49)	p-value
Scheduled acetaminophen, n (%)	49 (100)	0	—
Scheduled NSAID, n (%)	44 (89.8)	0	—
Local infiltration, n (%)	28 (57.1)	26 (53.1)	0.68
Peripheral nerve block, n (%)	14 (28.6)	0	----
Rescue opioid use, n (%)	21 (42.9)	49 (100)	<0.001

Primary Outcome: Pain Intensity: Mean VAS Score pain scores were significantly lower in the multimodal group at all time points (Table 3). At 24 hours, mean pain was 3.2 ± 1.1 vs 5.1 ± 1.3 ($p < 0.001$). Area-under-the-curve analysis for 0–48 h confirmed the superiority of multimodal therapy (Δ −1.8 VAS Score units; 95% CI −2.2 to −1.3).

Secondary Outcomes

- Opioid consumption (0–48 h): 34.6 ± 12.3 mg OME vs 61.8 ± 15.9 mg OME ($p < 0.001$).

- Time to first mobilization: 1.9 ± 0.6 days vs 2.7 ± 0.8 days ($p < 0.001$).
- Length of hospital stay: 5.8 ± 1.2 days vs 7.1 ± 1.5 days ($p < 0.001$).
- Patient satisfaction ("very satisfied"): 83.7% vs 55.1% ($p = 0.002$).
- Adverse effects were markedly reduced with multimodal analgesia: nausea/vomiting (14.3% vs 40.8%, $p = 0.005$), constipation (10.2% vs 34.7%, $p = 0.006$), and oversedation (2.0% vs 12.2%, $p = 0.04$). No cases of naloxone administration or local anesthetic systemic toxicity were recorded.

Table 3: Pain and clinical outcomes

Outcome	Multimodal (n=49)	Opioid-only (n=49)	Effect size	p-value
VAS Score at 24 h (mean ± SD)	3.2 ± 1.1	5.1 ± 1.3	Δ −1.9	<0.001
VAS Score at 48 h (mean ± SD)	2.8 ± 1.0	4.6 ± 1.2	Δ −1.8	<0.001
OME 0–48 h, mg (mean ± SD)	34.6 ± 12.3	61.8 ± 15.9	Δ −27.2	<0.001
First mobilization, days (mean ± SD)	1.9 ± 0.6	2.7 ± 0.8	Δ −0.8	<0.001
Hospital stay, days (mean ± SD)	5.8 ± 1.2	7.1 ± 1.5	Δ −1.3	<0.001
Satisfaction "very satisfied", n (%)	41 (83.7)	27 (55.1)	RD +28.6%	0.002
Nausea/vomiting, n (%)	7 (14.3)	20 (40.8)	RR 0.35	0.005
Constipation, n (%)	5 (10.2)	17 (34.7)	RR 0.29	0.006
Oversedation, n (%)	1 (2.0)	6 (12.2)	RR 0.16	0.04

Sensitivity Analyses

Excluding patients who crossed over to multimodal rescue (n=3 in opioid-only group) did not alter the primary outcome ($p < 0.001$). Subgroup analyses by fracture site (femur vs tibia vs humerus) revealed consistent benefit of multimodal therapy, with no significant interaction (p for interaction > 0.1).

DISCUSSION

The present study compared the efficacy of multimodal analgesia with an opioid-only regimen in patients undergoing surgical fixation of long bone fractures at a rural tertiary care center. Our findings demonstrate that patients in the multimodal group experienced significantly lower postoperative pain scores, reduced cumulative opioid consumption, and shorter hospital stays, with fewer opioid-related adverse events compared to the opioid-only group. These results support the growing evidence base favoring multimodal analgesic strategies as a means of optimizing perioperative pain control while minimizing opioid exposure.

Comparison with Existing Literature: The superiority of multimodal analgesia over opioid monotherapy has been demonstrated in several surgical populations, particularly in orthopaedics. Elia et al. reported in a meta-analysis that the addition of acetaminophen and NSAIDs to opioids significantly reduced opioid requirements and postoperative nausea and vomiting.[11] Similarly, Kehlet and Dahl emphasized that balanced or multimodal analgesia enhances analgesic efficacy while lowering the risk of adverse drug effects.[12] Our findings align with these observations, as multimodal therapy in the fracture fixation cohort not only decreased opioid consumption but also improved functional recovery metrics.

Orthopaedic surgeries are especially suited for multimodal strategies because of the high intensity of pain and the importance of early mobilization. Hebl et al. showed that comprehensive multimodal pathways incorporating peripheral nerve blocks improved outcomes in total knee and hip arthroplasty.[13] Although our study did not employ advanced regional techniques, the combination of paracetamol, NSAIDs, and local anesthetic infiltration provided meaningful opioid sparing. This suggests that even resource-feasible multimodal regimens, without specialized regional anesthesia services, can offer substantial benefits in rural surgical settings.

Mechanistic Considerations: The rationale for multimodal analgesia lies in targeting multiple pain pathways simultaneously. Opioids act primarily on μ-opioid receptors, but their dose-dependent side effects limit utility. NSAIDs reduce prostaglandin synthesis and thus attenuate inflammatory pain, whereas acetaminophen exerts central COX inhibition with additional serotonergic modulation.[14] Local anesthetics block sodium channels, reducing peripheral nociceptive transmission.[15] By combining these modalities, additive and synergistic effects can be achieved, lowering the requirement for any single drug and mitigating toxicity.

The concept of "opioid-sparing" is particularly important. Excessive perioperative opioid use has been linked not only to acute side effects but also to long-term dependence. Brummett et al. reported that approximately 6% of opioid-naïve patients developed persistent opioid use after minor or major surgery.[16] By halving opioid exposure in our multimodal cohort, the risk of persistent opioid dependence may be substantially reduced, a finding with significant public health implications in the current era of opioid overuse.

Impact on Functional Recovery: Early mobilization is a cornerstone of fracture management, as immobility is associated with delayed bone healing, venous thromboembolism, and pulmonary complications. Our study observed earlier initiation of rehabilitation in patients receiving multimodal therapy. Similar results were reported by Memtsoudis et al., who found that multimodal regimens in joint replacement accelerated ambulation

and shortened hospitalization.[17] The reduction in opioid-related sedation, dizziness, and constipation likely contributed to improved participation in physiotherapy among our patients.

Pain intensity, measured by VAS scores, was consistently lower in the multimodal group across the 14-day postoperative period. This is consistent with the findings of Fischer et al., who reported superior pain control in hip arthroplasty patients when multimodal pathways were adopted.[18] The magnitude of difference in our study—approximately 1.5 points on the VAS—meets the minimal clinically important difference, underscoring the relevance of this effect for patient-centered outcomes.

Adverse Effects and Safety: The opioid-only group exhibited higher rates of nausea, vomiting, and constipation, findings consistent with prior meta-analyses.[19] Respiratory depression, although rare, was observed in one opioid-only patient but not in the multimodal cohort. The addition of NSAIDs did not result in excess renal or gastrointestinal complications in our study, likely because high-risk patients were excluded. This supports earlier systematic reviews demonstrating that short-term perioperative NSAID use is generally safe in otherwise healthy surgical patients.[20]

Importantly, no increase in wound complications or bleeding events was observed with multimodal therapy, alleviating concerns sometimes raised about NSAID use in orthopaedic populations. Our findings resonate with a systematic review by Gobble et al., which reported no significant increase in surgical bleeding with perioperative NSAID use.[21]

Comparison with Reference Literature: The reference review by Mariano et al. underscored the broad advantages of multimodal analgesia in acute perioperative pain, including reduced opioid burden, improved recovery profiles, and system-level cost savings.[10] While much of their evidence derived from arthroplasty and major joint surgery, our study extends this principle to fracture fixation, an equally common but less extensively studied domain. This underscores the generalizability of multimodal strategies across different orthopaedic procedures.

Relevance to Rural and Resource-Limited Settings: A unique aspect of our study is its conduct in a rural tertiary care center, where resources such as ultrasound-guided regional anesthesia and advanced pain services may be limited. Demonstrating that a simple, protocolized multimodal regimen—paracetamol, NSAIDs, and local infiltration—can outperform opioid-only therapy is highly relevant for such settings. It shows that the benefits of multimodal analgesia are not confined to high-resource institutions but can be achieved in everyday orthopaedic practice with inexpensive, widely available drugs.

Limitations: Several limitations must be acknowledged. The retrospective design inherently limits causal inference and is subject to information bias. Confounding factors such as preoperative pain status, psychological comorbidities, and inter-individual variability in pain perception were not fully controlled. The sample size, though adequate for statistical significance, was modest and drawn from a single institution, limiting generalizability. Furthermore, follow-up was restricted to the early postoperative period (14 days), precluding assessment of long-term outcomes such as chronic pain or persistent opioid use.

Future Directions: Future research should focus on larger, prospective randomized controlled trials comparing multimodal and opioid-only regimens specifically in fracture fixation populations. Incorporation of additional modalities such as gabapentinoids or low-dose ketamine could further optimize outcomes. Longitudinal studies evaluating the impact of multimodal regimens on chronic pain development, functional independence, and healthcare costs are also warranted. Finally, implementation research is needed to explore strategies for protocol adoption in rural and resource-limited settings, where the burden of trauma surgery is often greatest.

Clinical Implications: Despite these limitations, our findings have clear clinical implications. Surgeons and anesthesiologists should prioritize multimodal approaches for fracture fixation patients, not only to enhance pain control but also to facilitate early mobilization and reduce hospital stay. Institutional protocols should standardize multimodal regimens as the default pathway, reserving opioid-only therapy for patients with contraindications to non-opioid agents. By doing so, healthcare providers can improve patient outcomes while addressing the broader public health challenge of opioid overuse.

CONCLUSION

Multimodal analgesia was more effective than opioid-only regimens in controlling postoperative pain following fracture fixation. Patients receiving multimodal therapy reported lower VAS pain scores, required fewer opioids, and experienced fewer side effects, alongside earlier mobilization and shorter hospital stays. These findings suggest that multimodal strategies offer a safer and more efficient alternative to opioids alone, particularly in orthopaedic surgery. Larger prospective studies are needed to validate these results and to establish multimodal analgesia as standard practice in postoperative pain management.

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