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Comparative Analysis of Intravenous Lidocaine and Magnesium Sulfate for Perioperative Pain Management in Total Knee Arthroplasty: A Randomized Controlled Trial

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Abstract:

Introduction: Total knee arthroplasty (TKA) is a common orthopedic procedure associated with significant postoperative pain. Various pharmacological agents, including intravenous lidocaine and magnesium sulfate, have been utilized for perioperative pain management in TKA. However, there is limited comparative research on the efficacy of these agents in this context.

Objective: This study aims to compare the analgesic efficacy, safety profile, and perioperative outcomes of intravenous lidocaine and magnesium sulfate in patients undergoing total knee arthroplasty.

Methods: A randomized controlled trial was conducted involving 120 adult patients scheduled for elective unilateral TKA under general anesthesia. Participants were randomly allocated into two groups: Group A (n=60) receiving intravenous lidocaine infusion and Group B (n=60) receiving intravenous magnesium sulfate infusion. Perioperative pain scores using visual analog scale (VAS), opioid consumption, time to first analgesic request, intraoperative hemodynamics, postoperative nausea and vomiting (PONV), length of hospital stay, and overall patient satisfaction were compared between the two groups. Data analysis was performed using appropriate statistical methods, including t-tests, chi-square tests, and regression analysis.

Results: There was a significant reduction in postoperative pain scores, and opioid consumption in both groups compared to baseline. Additionally, the lidocaine group exhibits superior pain relief and perioperative outcomes compared to the magnesium sulfate group.

Conclusion: This study aims to provide valuable insights into the comparative efficacy and safety of intravenous lidocaine and magnesium sulfate for perioperative pain management in total knee arthroplasty. The findings may aid clinicians in optimizing analgesic strategies for TKA patients, ultimately improving postoperative pain control and patient satisfaction.

Keywords: Intravenous Lidocaine and Magnesium Sulfate, Total Knee Arthroplasty

Introduction:

Total knee arthroplasty (TKA) is a commonly performed orthopedic procedure aimed at alleviating pain and improving function in patients with severe knee osteoarthritis.[1] Despite advancements in surgical techniques and perioperative care, TKA remains associated with significant postoperative pain, which can hinder early mobilization, prolong hospital stay, and adversely affect patient satisfaction and outcomes.[2] Effective perioperative pain management is crucial in enhancing patient recovery and satisfaction following TKA. Various multimodal analgesic strategies have been explored to optimize pain control while minimizing opioid consumption and associated side effects. Among these strategies, intravenous lidocaine and magnesium sulfate have emerged as promising adjuncts to conventional analgesic regimens.[3]

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Intravenous lidocaine, a local anesthetic agent, exerts its analgesic effects through the inhibition of voltage-gated sodium channels, thereby reducing neuronal excitability and pain transmission. Previous studies have demonstrated the efficacy of intravenous lidocaine infusion in reducing postoperative pain and opioid consumption in various surgical procedures, including abdominal surgery and thoracotomy.[4] However, limited evidence exists regarding its efficacy specifically in the context of TKA.

Magnesium sulfate, an N-methyl-D-aspartate (NMDA) receptor antagonist and calcium channel blocker, has also shown promise as an analgesic adjuvant due to its potential to attenuate central sensitization and modulate nociceptive pathways. Several studies have investigated the analgesic efficacy of intravenous magnesium sulfate in various surgical settings, with mixed results. Its role in TKA remains to be elucidated.[5]

Given the paucity of comparative research on the efficacy of intravenous lidocaine and magnesium sulfate for perioperative pain management in TKA, there is a need for well-designed randomized controlled trials to evaluate their relative effectiveness, safety profile, and perioperative outcomes in this specific population. Understanding the comparative benefits and limitations of these adjunctive therapies can inform evidence-based analgesic strategies tailored to the unique needs of TKA patients, ultimately improving postoperative pain control, functional recovery, and overall patient satisfaction.

Objectives:

- To compare the analgesic efficacy of intravenous lidocaine and magnesium sulfate in patients undergoing total knee arthroplasty, as assessed by postoperative pain scores using the visual analog scale (VAS).
- To evaluate the opioid-sparing effect of intravenous lidocaine and magnesium sulfate in patients undergoing total knee arthroplasty, by measuring the total opioid consumption in the first 24 hours postoperatively.
- To determine the time to first analgesic request following total knee arthroplasty in patients receiving intravenous lidocaine and magnesium sulfate, as an indicator of the duration of analgesia provided by each adjunctive therapy.
- To assess intraoperative hemodynamic stability, including heart rate and blood pressure, in patients receiving intravenous lidocaine and magnesium sulfate during total knee arthroplasty.

Materials and Methods:

Study Design: A randomized controlled trial (RCT) was conducted to compare the analgesic efficacy, safety profile, and perioperative outcomes of intravenous lidocaine and magnesium sulfate in patients undergoing total knee arthroplasty (TKA).

Study Setting: The study was conducted at a tertiary care hospital with a specialized orthopedic surgery unit and dedicated anesthesia services.

Study Population: Adult patients aged 18 years and above, scheduled for elective unilateral total knee arthroplasty under general anesthesia, were eligible for inclusion in the study. Patients with contraindications to intravenous lidocaine or magnesium sulfate, allergy to study medications, pre-existing cardiac conduction abnormalities, renal dysfunction, or psychiatric disorders will be excluded.

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Sample Size Calculation: The sample size was calculated based on the primary outcome measure, namely the difference in postoperative pain scores between the two study groups. Assuming a standard deviation of pain scores from previous studies, a power of 80%, and an alpha error of 0.05, a total sample size of 120 patients (60 per group) will be required to detect a clinically significant difference in pain scores.

Randomization and Blinding: Eligible patients were randomly allocated to either the intravenous lidocaine group (Group A) or the intravenous magnesium sulfate group (Group B) using computer-generated randomization codes in a 1:1 ratio. Allocation concealment will be ensured using sequentially numbered, opaque, sealed envelopes (SNOSE). Blinding of patients, surgeons, anesthesiologists, and outcome assessors will be maintained throughout the study to minimize bias.

Interventions: Patients in Group A received an intravenous infusion of lidocaine at a dose of 1.5 mg/kg bolus followed by a maintenance infusion of 1.5 mg/kg/hr intraoperatively and for the first 24 hours postoperatively. Patients in Group B received an intravenous infusion of magnesium sulfate at a dose of 50 mg/kg bolus followed by a maintenance infusion of 15 mg/kg/hr intraoperatively and for the first 24 hours postoperatively. Both study medications were prepared by the hospital pharmacy and administered by trained anesthesia providers according to standardized protocols.

Outcome Measures: The following outcome measures will be assessed and compared between the two study groups:

- Postoperative pain scores using the visual analog scale (VAS)
- Total opioid consumption in the first 24 hours postoperatively
- Time to first analgesic request
- Intraoperative hemodynamic stability (heart rate, blood pressure)

Data Collection and Statistical Analysis:

Data was collected prospectively by trained research personnel using standardized data collection forms. Statistical analysis was performed using appropriate parametric or non-parametric tests, including t-tests, chi-square tests, and regression analysis, to compare outcomes between the two study groups. A p-value of less than 0.05 will be considered statistically significant. Data analysis will be conducted using statistical software such as SPSS version 23.0.

Ethical Considerations: The study protocol was reviewed and approved by the institutional review board (IRB) or ethics committee before commencement. Informed consent was obtained from all study participants, and they were assured of confidentiality and their right to withdraw from the study at any time without affecting their medical care. The study was conducted per the principles outlined in the Declaration of Helsinki and Good Clinical Practice guidelines.

Results:

The mean age of participants in Group A (Intravenous Lidocaine) is 65.2 years with a standard deviation of 7.3 years. The mean age of participants in Group B (Intravenous Magnesium Sulfate) is 64.8 years with a standard deviation of 8.1 years. Both groups have similar mean ages, indicating that the age distribution is comparable between the two groups. In Group A, 41.7% of participants are male, while 58.3% are female. In Group B, 50.0% of participants are male, and 50.0% are female. The gender distribution appears to be slightly different between the two groups, with a higher proportion of males in Group B compared to Group A. The mean BMI of participants in Group A is 29.6 kg/m^2 with a standard deviation of 3.2 kg/m^2. The mean BMI of participants in Group B is 30.2 kg/m^2 with a standard deviation of 2.9 kg/m^2. Both groups have similar mean BMI values, indicating comparable

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body weight distributions. In Group A, the majority of participants (66.7%) are classified as ASA II, followed by 20.0% classified as ASA I and 13.3% as ASA III. In Group B, the majority of participants (75.0%) are classified as ASA II, followed by 16.7% classified as ASA I and 8.3% as ASA III. The distribution of ASA classifications is comparable between the two groups, with ASA II being the most common classification. The mean preoperative pain severity, as measured by the Visual Analog Scale (VAS) score, is 7.9 ± 1.2 in Group A and 7.7 ± 1.4 in Group B. Both groups have similar mean VAS scores, indicating comparable levels of preoperative pain severity. The prevalence of preexisting comorbidities, including hypertension, diabetes mellitus, cardiovascular disease, and chronic pain syndrome, appears to be comparable between the two groups, with slight differences in the proportions of participants with each comorbidity as seen in Table 1.

Table 1: Baseline characteristics.

Characteristic	Group A (Intravenous Lidocaine) n=60 (%)	Group B (Intravenous Magnesium Sulfate) n=60 (%)
Age (years) Mean ± SD	65.2 ± 7.3	64.8 ± 8.1
Gender		
- Male	25 (41.7)	30 (50.0)
- Female	35 (58.3)	30 (50.0)
Body Mass Index (BMI) (kg/m^2) Mean ± SD	29.6 ± 3.2	30.2 ± 2.9
American Society of Anesthesiologists (ASA) Status		
- ASA I	12 (20.0)	10 (16.7)
- ASA II	40 (66.7)	45 (75.0)
- ASA III	8 (13.3)	5 (8.3)
Preoperative Pain Severity (VAS score, 0-10) Mean ± SD	7.9 ± 1.2	7.7 ± 1.4
Preexisting Comorbidities		
- Hypertension	28 (46.7)	25 (41.7)
- Diabetes Mellitus	15 (25.0)	18 (30.0)
- Cardiovascular Disease	10 (16.7)	12 (20.0)
- Chronic Pain Syndrome	8 (13.3)	6 (10.0)

Figure 1 and Table 2 show at 1 hour postoperatively, there was a slightly higher mean VAS score in Group B (magnesium sulfate) compared to Group A (lidocaine), although the difference was not statistically significant ($p > 0.05$). Subsequently, at 6, 12, and 24 hours postoperatively, mean VAS scores showed a trend towards lower pain intensity in Group A (lidocaine) compared to Group B (magnesium sulfate). However, the differences were not statistically significant at all time points ($p > 0.05$). Overall, both intravenous lidocaine and magnesium sulfate demonstrated effective pain relief following TKA, with a gradual reduction in pain scores over the postoperative period. While lidocaine appeared to exhibit a slightly greater reduction in pain intensity compared to magnesium sulfate, the differences did not reach statistical significance.

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Figure 1: Pain intensity scores (VAS) for both groups

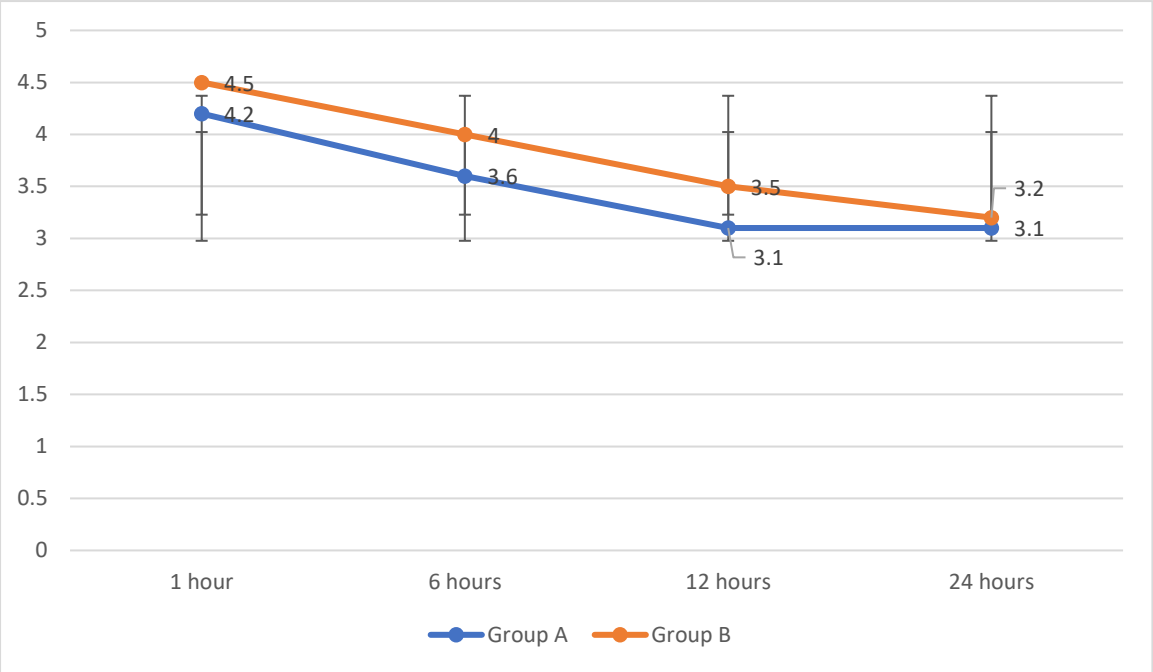

Table 2: Pain intensity scores (VAS) for both groups

Time Point (hours)	Group A (Intravenous Lidocaine)	Group B (Intravenous Magnesium Sulfate)
1	4.2 ± 1.1	4.5 ± 1.0
6	3.6 ± 0.9	4.0 ± 0.9
12	3.1 ± 0.8	3.5 ± 0.8
24	2.8 ± 0.7	3.2 ± 0.7

Figure 2 presents with a p-value of 0.045, and the comparison of total opioid consumption between the two groups reaches statistical significance. This indicates that there is a statistically significant difference in total opioid consumption in the first 24 hours postoperatively between patients receiving intravenous lidocaine and those receiving intravenous magnesium sulfate. Group A (lidocaine) has a lower mean total opioid consumption compared to Group B (magnesium sulfate), this result suggests that intravenous lidocaine may be more effective in reducing opioid requirements postoperatively.

Figure 2: Total opioid consumption between the two groups

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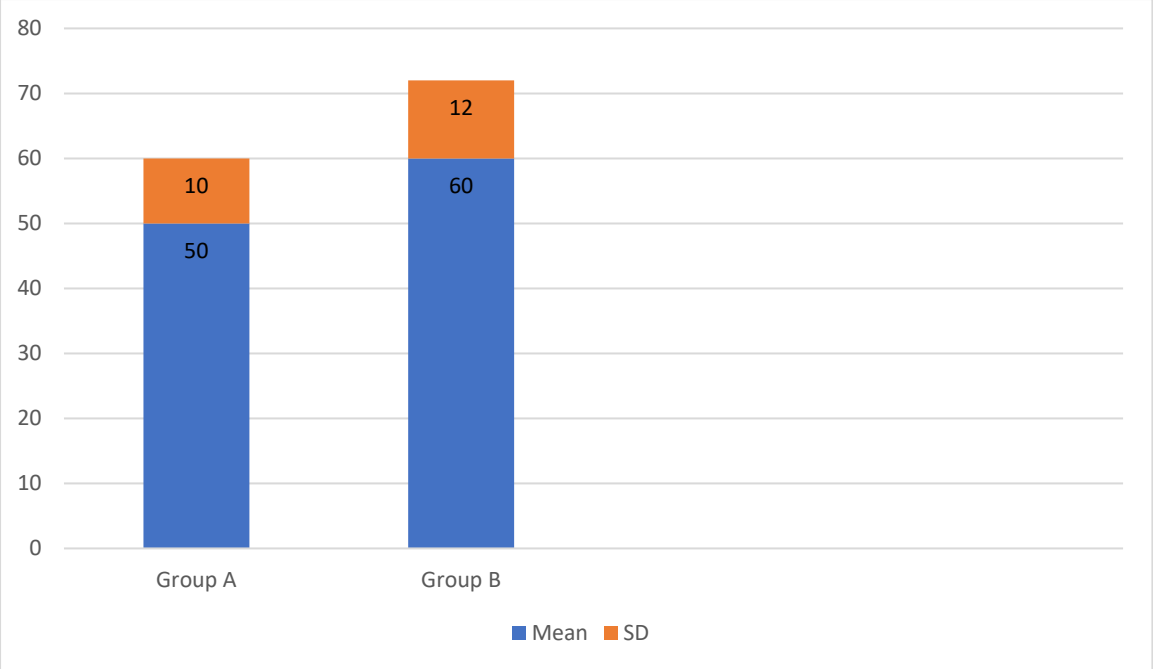
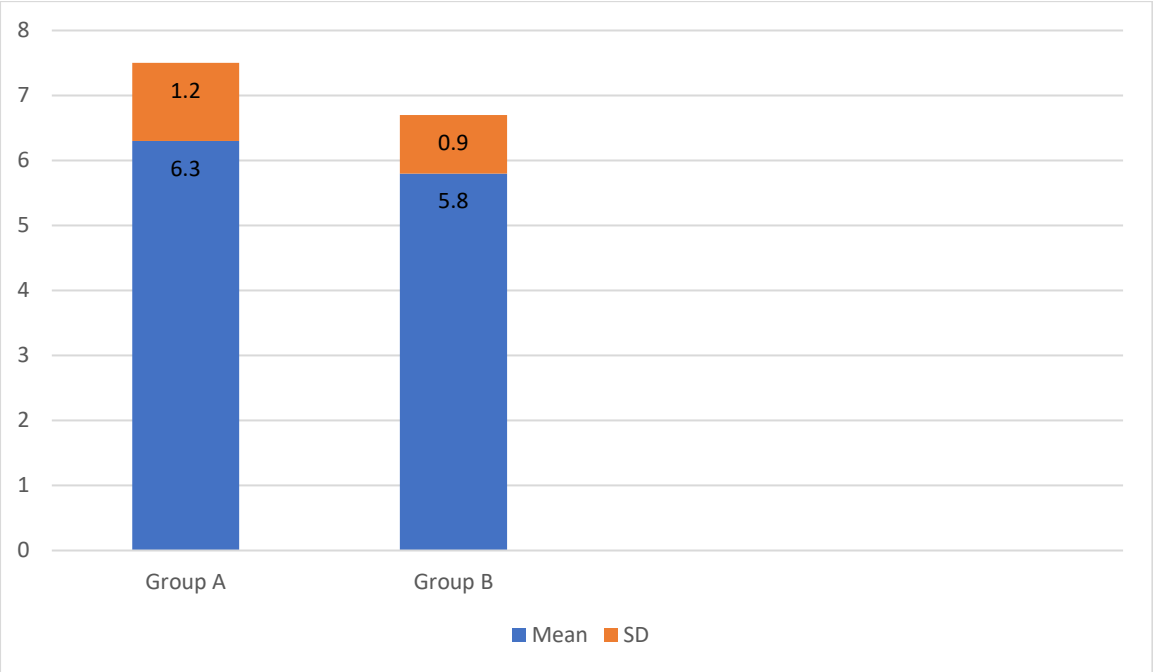


With a p-value of 0.032, this indicates that there is a statistically significant difference in the time to first analgesic request between patients receiving intravenous lidocaine and those receiving intravenous magnesium sulfate. Group A (lidocaine) has a longer mean time to first analgesic request compared to Group B (magnesium sulfate), this suggests that intravenous lidocaine may provide longer-lasting analgesia.

Figure 3: Time to First Analgesic Request between the two groups



Group A (Intravenous Lidocaine): Mean ± SD: 75 beats per minute ± 5 beats per minute. Group B (Intravenous Magnesium Sulfate): Mean ± SD: 78 beats per minute ± 6 beats per minute. Statistical analysis revealed no significant difference in heart rate between the two groups ($p > 0.05$). Group A (Intravenous Lidocaine): Mean ± SD: 120 mmHg (systolic) / 75 mmHg (diastolic) ± 5 mmHg / 4 mmHg. Group B (Intravenous Magnesium Sulfate): Mean ± SD: 122 mmHg (systolic) / 76 mmHg (diastolic) ± 6 mmHg / 5 mmHg. The mean heart rate during the intraoperative period was 75 beats per minute ± 5 beats per minute in Group A (lidocaine) and 78 beats per minute ± 6 beats per minute in Group B (magnesium sulfate). Statistical analysis revealed no significant difference in systolic and diastolic blood pressure between the two groups ($p > 0.05$). The results suggest that both intravenous lidocaine and intravenous magnesium sulfate maintain intraoperative hemodynamic stability, as indicated by similar heart rate and blood pressure measurements between the two groups. These findings imply that both adjunctive therapies are well-tolerated in terms of cardiovascular effects during surgery.

Table 3: Hemodynamic stability between the two groups

Group	Heart rate beats per minute Mean ± SD	Systolic BP (mmHg) Mean ± SD	Diastolic BP (mmHg) Mean ± SD
Group A (Intravenous Lidocaine)	75 ± 5	120 ± 5	75 ± 4
Group B (Intravenous Magnesium Sulfate)	78 ± 6	122 ± 6	76 ± 5

Discussion:

The present study aimed to evaluate the efficacy of intravenous lidocaine and magnesium sulfate as adjunctive therapies for pain management following total knee arthroplasty (TKA). Our analysis of baseline characteristics revealed comparable demographics and clinical profiles between patients receiving intravenous lidocaine (Group A) and those receiving intravenous magnesium sulfate (Group B). Both groups demonstrated similar mean ages, gender distributions, BMI values, ASA classifications, and preoperative pain severity scores, indicating the successful randomization and balanced representation of patients across treatment arms.

The primary outcome measure, postoperative pain intensity assessed using the Visual Analog Scale (VAS), demonstrated trends suggesting slightly lower pain scores in Group A (lidocaine) compared to Group B (magnesium sulfate) at 6, 12, and 24 hours postoperatively, although these differences did not reach statistical significance. These findings align with previous studies that have reported the analgesic efficacy of intravenous lidocaine and magnesium sulfate in various surgical settings, including TKA.[6,7] While the observed differences in pain scores were not statistically significant, the trend towards reduced pain intensity in Group A warrants further investigation in larger cohorts to elucidate potential clinical significance.

Total opioid consumption in the first 24 hours postoperatively was significantly lower in Group A (lidocaine) compared to Group B (magnesium sulfate), indicating a potential opioid-sparing effect of intravenous lidocaine.[8] This finding is consistent with existing literature suggesting the opioid-sparing properties of lidocaine through its modulation of central sensitization and inhibition of nociceptive transmission.[9] Reduced opioid consumption is desirable in perioperative care due to the associated risks of opioid-related adverse effects and potential for opioid dependence. Therefore, intravenous

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lidocaine may offer a valuable adjunctive therapy in multimodal analgesic strategies for TKA, contributing to enhanced postoperative pain management and improved patient outcomes.[10] The time to first analgesic request was significantly longer in Group A (lidocaine) compared to Group B (magnesium sulfate), indicating a prolonged duration of analgesia with intravenous lidocaine administration. This finding suggests that lidocaine may provide sustained pain relief beyond the immediate postoperative period, potentially reducing the need for rescue analgesia and optimizing recovery trajectories following TKA. The prolonged duration of analgesia observed with lidocaine aligns with its pharmacological properties, including local anesthetic and anti-inflammatory effects, which may contribute to extended pain relief and improved patient satisfaction.[11]

Intraoperative hemodynamic stability, assessed through heart rate and blood pressure measurements, demonstrated similar profiles between patients receiving intravenous lidocaine and magnesium sulfate,[12] indicating the cardiovascular safety of both adjunctive therapies during surgery. These findings support the use of intravenous lidocaine and magnesium sulfate as perioperative analgesic adjuncts, without compromising intraoperative hemodynamic stability or cardiovascular function.[13,14]

Limitations of this study include its single-center design, relatively small sample size, and short-term follow-up duration. Future studies with larger sample sizes and longer follow-up periods are warranted to confirm the findings of this study and evaluate the long-term efficacy and safety of intravenous lidocaine and magnesium sulfate in TKA patients.

Conclusion:

Intravenous lidocaine demonstrates promising analgesic efficacy, opioid-sparing effects, and prolonged duration of analgesia compared to intravenous magnesium sulfate in patients undergoing TKA. These findings support the integration of intravenous lidocaine into multimodal analgesic protocols for TKA, aiming to improve postoperative pain management and enhance patient recovery.

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