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Ropivacaine-Dexamethasone vs. Ropivacaine-Magnesium Sulfate in TAP Block: A Randomized Study of Postoperative Analgesia in Lower Abdominal Surgeries

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ABSTRACT

Background: Postoperative pain following lower abdominal surgery is a major contributor to patient morbidity. The transversus abdominis plane (TAP) block provides effective regional analgesia, but its duration is limited by local anesthetic pharmacokinetics. Adjuvants such as dexamethasone and magnesium sulfate have been explored to prolong analgesia, though comparative evidence remains inconsistent. This study evaluated the efficacy of ropivacaine combined with dexamethasone versus ropivacaine with magnesium sulfate in ultrasound-guided TAP block.

Methods: A randomized controlled trial was conducted in a tertiary care hospital in eastern India. One hundred twenty ASA I–II patients aged 18–60 years undergoing elective lower abdominal surgery under spinal anesthesia were randomized into two groups. Group RM received 20 mL of 0.2% ropivacaine with 1 mg magnesium sulfate per site, while Group RD received 20 mL of 0.2% ropivacaine with 8 mg dexamethasone per site. Bilateral TAP blocks were performed under ultrasound guidance at the end of surgery. Primary outcome was time to first rescue analgesia within 24 hours. Secondary outcomes included pain scores, total tramadol consumption, and hemodynamic parameters.

Results: Baseline demographics were comparable. Group RM demonstrated a significantly longer time to first rescue analgesia (13.83 ± 2.96 h vs. 11.58 ± 2.87 h, $p < 0.0001$). However, Group RD showed consistently lower pain scores at 6, 12, and 24 hours ($p < 0.001$) and more stable hemodynamic trends.

Conclusion: Both adjuvants enhanced TAP block efficacy but with distinct advantages. Magnesium sulfate prolonged the pain-free interval, whereas dexamethasone provided superior sustained analgesia and hemodynamic stability. Adjuvant selection should be tailored to clinical priorities-maximizing analgesia duration versus ensuring consistent pain control.

Keywords: TAP block; Ropivacaine; Dexamethasone; Magnesium Sulfate; Postoperative Analgesia

INTRODUCTION

Effective postoperative pain management remains a cornerstone of perioperative care, particularly in lower abdominal surgeries where parietal pain contributes significantly to patient discomfort. [1] Traditionally, systemic opioids and non-steroidal anti-inflammatory drugs (NSAIDs) have been employed, but their use is often limited by adverse effects such as respiratory depression, nausea, vomiting, and delayed recovery. [2]

Regional anesthesia techniques, especially the transversus abdominis plane (TAP) block, have emerged as valuable alternatives to systemic analgesia. The TAP block provides targeted analgesia by depositing local anesthetic in the fascial plane between the internal oblique and transversus abdominis muscles, thereby blocking the thoracolumbar nerves (T6–L1) that innervate the anterior abdominal wall. With the advent of ultrasound guidance, TAP block has become safer and more precise, allowing for consistent visualization of muscle layers and needle trajectory. [3] Despite its effectiveness, the duration of analgesia with TAP block remains limited by the pharmacokinetics of the local anesthetic used, necessitating exploration of adjuvants that can prolong analgesic effects and reduce postoperative opioid consumption. [4]

Ropivacaine, a long-acting amide local anesthetic, is widely used in regional anesthesia due to its favorable safety profile compared to bupivacaine. It acts by reversibly inhibiting sodium ion influx in nerve fibers, thereby blocking impulse conduction. Its lower lipophilicity reduces penetration into large myelinated motor fibers, conferring a degree of sensory selectivity. This makes ropivacaine particularly suitable for postoperative analgesia, as it preferentially blocks pain-transmitting Aδ and C fibers while sparing motor function. [5]

Magnesium sulfate ($MgSO_4$), a physiological cation, has gained attention as an adjuvant in regional anesthesia. Its analgesic properties are primarily mediated through non-competitive antagonism of N-methyl-D-aspartate (NMDA) receptors, which play a central role in pain transmission and central sensitization. By blocking NMDA receptor-mediated calcium influx, magnesium reduces excitatory neurotransmission and attenuates hyperalgesia. Importantly, magnesium does not cross the blood–brain barrier easily, minimizing central nervous system side effects while providing peripheral analgesic benefits. [6]

Dexamethasone, a synthetic glucocorticoid, exerts potent anti-inflammatory and immunosuppressive effects. It acts by binding to intracellular glucocorticoid receptors, modulating gene transcription, and reducing the release of pro-inflammatory mediators such as interleukins, prostaglandins, and leukotrienes. [7] In regional anesthesia, dexamethasone has been shown to prolong the duration of local anesthetic action, possibly through local effects on nociceptive C fibers and enhancement of inhibitory potassium channel activity. Its ability to reduce postoperative inflammation and edema further contributes to improved analgesia and reduced opioid requirements. [8]

Several studies have evaluated the role of adjuvants in prolonging the efficacy of TAP block. [4] Dexamethasone has consistently demonstrated benefits in extending analgesia and reducing rescue analgesic consumption across various peripheral nerve blocks. Magnesium sulfate, though mechanistically promising, has shown mixed results, with some studies reporting improved analgesia and others finding no significant benefit. The variability in outcomes may be attributed to differences in surgical procedures, block techniques, dosages, and patient populations. [6, 8]

This study is guided by the central research question of whether the addition of dexamethasone to ropivacaine provides superior postoperative analgesia compared to the addition of magnesium sulfate to ropivacaine in patients undergoing lower abdominal surgeries with ultrasound-guided classical TAP block. The hypothesis proposes that ropivacaine combined with dexamethasone will yield better analgesic outcomes than ropivacaine with magnesium sulfate. The primary objective is to compare the time to first rescue analgesia between the two groups, while secondary objectives include evaluating total rescue analgesic consumption within 24 hours, assessing postoperative pain scores at defined intervals, and monitoring hemodynamic parameters to ensure safety and stability. By systematically addressing these outcomes, the study aims to identify the optimal adjuvant for enhancing the efficacy of TAP block in lower abdominal surgeries, thereby improving patient recovery and reducing dependence on systemic opioids.

MATERIALS & METHODS

Study Overview

This study was designed as randomized controlled trial conducted in the Department of Anaesthesiology at tertiary care hospital of eastern India in one year duration. Ethical approval was obtained from the institutional ethics committee, and the study adhered to the Good Clinical Practice guidelines and the Declaration of Helsinki. Written informed consent was obtained from all participants prior to enrollment.

Study Population

Patients aged between 18 and 60 years of either sex, classified as American Society of Anaesthesiologists (ASA) physical status I or II, [9] and scheduled for elective lower abdominal surgeries under spinal anesthesia were included. Surgeries with a duration of less than 120 minutes were eligible. Exclusion criteria comprised history of allergy to study drugs (ropivacaine, magnesium sulfate, or dexamethasone), contraindications to spinal anesthesia such as coagulopathy or local infection, and surgeries lasting less than 30 minutes or more than 120 minutes.

Intervention

Patients were randomized into two groups using a computer-generated randomization table and allocation concealment through opaque sealed envelopes.

- **Group RM (Ropivacaine + Magnesium Sulfate):** Patients received ultrasound-guided bilateral classical TAP block at the end of surgery using 20 mL of 0.2% ropivacaine with 1 mg magnesium sulfate at each site.
- **Group RD (Ropivacaine + Dexamethasone):** Patients received ultrasound-guided bilateral classical TAP block at the end of surgery using 20 mL of 0.2% ropivacaine with 8 mg dexamethasone at each site.

The TAP block was performed under direct ultrasound visualization using a linear probe (9–12 MHz). A 10 cm Braun Stimuplex needle was advanced in-plane until the fascial plane between the internal oblique and transversus abdominis muscles was reached. Correct placement was confirmed by expansion of the plane (Doyle's internal bulge sign) before drug injection.

Outcome Parameters

- **Primary Outcome:** Time to first rescue analgesia within the first 24 hours postoperatively.
- **Secondary Outcomes:**
  - Total rescue analgesic consumption in the first 24 hours.
  - Postoperative pain scores assessed using the Numerical Visual Analogue Scale (VAS).
  - Hemodynamic parameters.

Methodology

All patients were monitored intraoperatively with electrocardiography, pulse oximetry, and non-invasive blood pressure. At the end of surgery, the TAP block was administered according to group allocation. Postoperatively, patients were transferred to the post-anesthesia care unit and subsequently to the ward. Pain scores were recorded at predefined intervals using the VRS scale. Rescue analgesia was provided with tramadol when VRS exceeded 4. The time to first rescue analgesia and total tramadol consumption were documented. Hemodynamic parameters were monitored throughout the 24-hour postoperative period.

Statistical Analysis

Data were compiled in Microsoft Excel and analyzed using Graph Pad version 8.4.3. Continuous variables such as age, weight, blood pressure, heart rate, and pain scores were expressed as mean ± standard deviation (SD). Between-group comparisons of continuous data were performed using unpaired t-tests. Within-group comparisons over time were analyzed using repeated measures ANOVA. Categorical variables such as ASA status and type of surgery were expressed as frequencies and percentages, and compared using chi-square or Fisher’s exact test. A p-value of <0.05 was considered statistically significant.

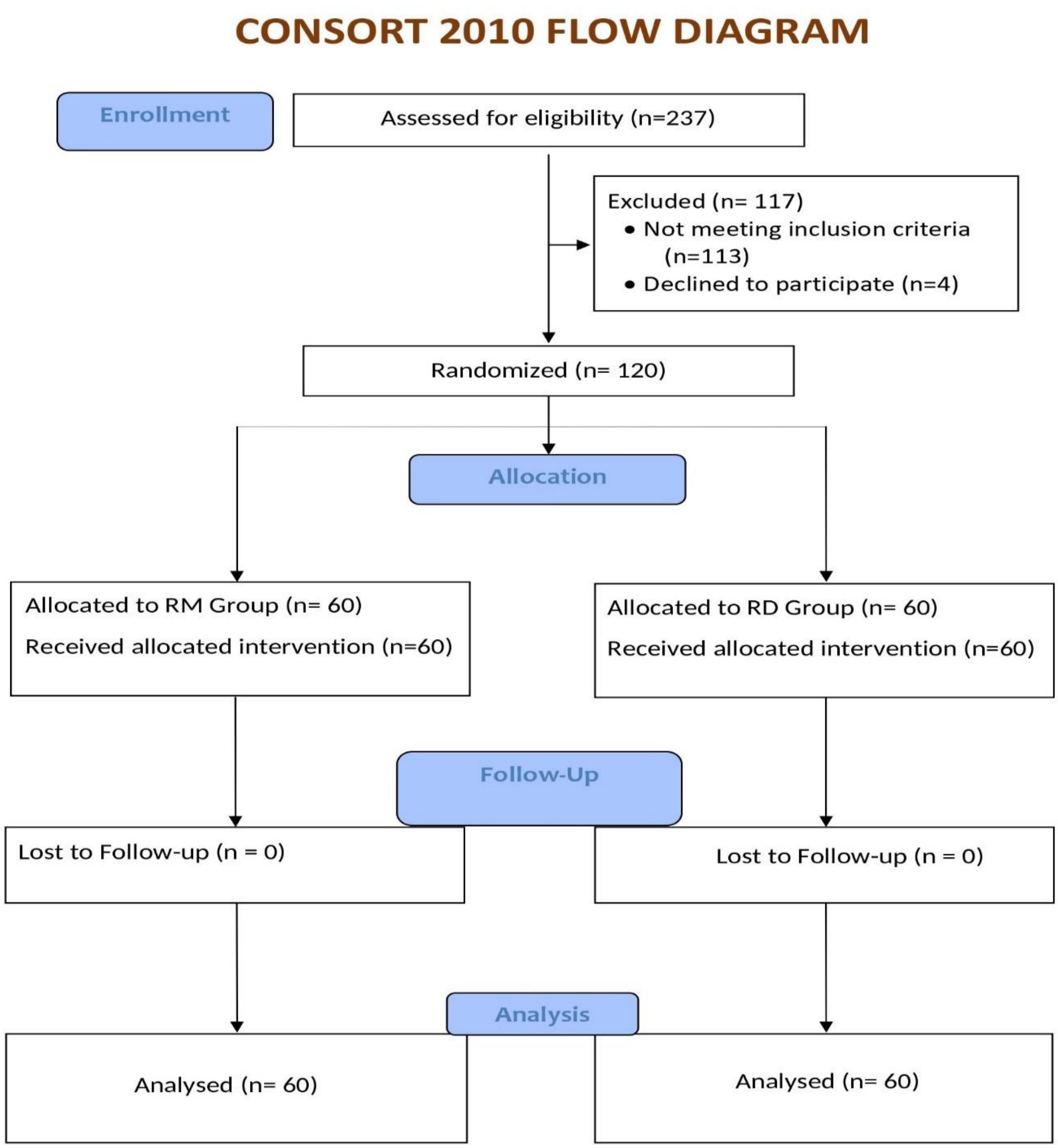

Figure 1: CONSORT Flow Diagram

RESULT

60 patients Group RM (Ropivacaine + Magnesium Sulfate) received ultrasound-guided bilateral classical TAP block at the end of surgery using 20 mL of 0.2% ropivacaine with 1 mg magnesium sulfate at each site whereas 60 patients in Group RD (Ropivacaine + Dexamethasone) received ultrasound-guided bilateral classical TAP block at the end of surgery using 20 mL of 0.2% ropivacaine with 8 mg dexamethasone at each site [Figure 1]

Table 1: Comparison of Baseline Demographic & Clinical Characteristics between Group RM and Group RD

Parameters	Group RM (n = 60)	Group RD (n = 60)	P-Value
Age in Years, Mean ± SD	35.77 ± 11.66	35.13 ± 10.59	0.7535
BMI in kg/m^2, Mean ± SD	25.38 ± 4.53	25.71 ± 4.92	0.7030
ASA Status, n (%)			
I	3 (5.00)	2 (3.33)	>0.9999
II	57 (95.00)	58 (96.67)	
Procedure			
TAH	17	15	0.8446** (LSCS vs others)
LSCS	40	42	
Uterine Torsion	2	1	
Open Myomectomy	1	2	

The two groups were well-matched in terms of age, BMI, ASA status, and types of surgical procedures performed, as all reported p-values were greater than 0.05, indicating no statistically significant differences. This similarity at baseline enhances the validity of subsequent comparisons, suggesting that any differences in outcomes can more reliably be attributed to the intervention rather than to pre-existing demographic or clinical disparities [Table 1].

The mean time to rescue analgesia was significantly longer in Group RM (13.83 hours) compared to Group RD (11.58 hours), with a mean difference of -2.25 hours and a p-value of <0.0001 [Table 2].

Table 2: Comparison of Time to Rescue Analgesia between Group RM and Group RD

	Group RM	**Group RD**
Number of Patients (N)	60	60
Mean	13.83	11.58
Standard Deviation (SD)	2.96	2.87
Difference in Mean (B-A) ± SEM	-2.250 ± 0.5323	
95% Confidence Interval (Difference of Mean)	-3.304 to -1.196	
P Value (Unpaired t Test)	<0.0001	

Table 3: Comparison of VAS Score between Group RM and Group RD

Time in Hours	**Value in Mean ± SD**		**P-Value (Unpaired t test)**
	Group RM (n = 60)	Group RD (n = 60)	
1	2.05 ± 0.49	1.97 ± 0.73	0.4823
2	2.23 ± 0.37	2.28 ± 0.41	0.4845
6	2.76 ± 0.32	2.51 ± 0.46	0.0008
12	3.62 ± 0.49	3.14 ± 0.38	<0.0001
24	4.86 ± 0.59	4.03 ± 0.50	<0.0001
P-Value (Repeated Measure ANOVA)	<0.0001	<0.0001	

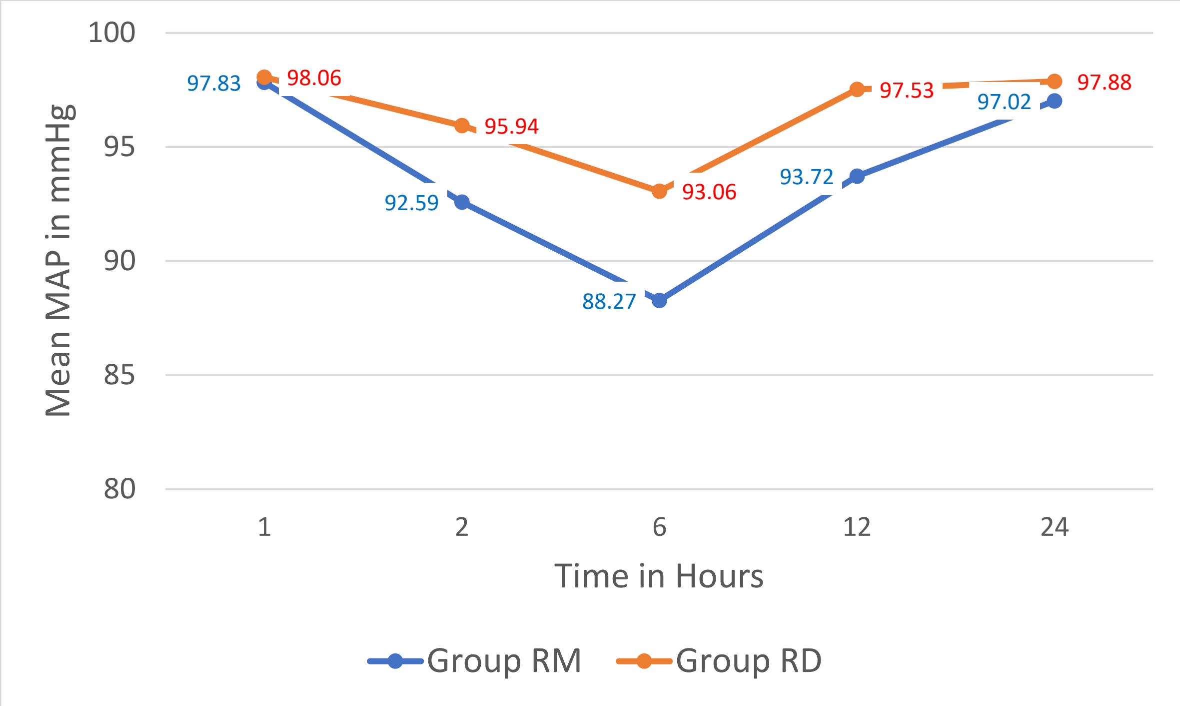

Figure 2: Comparison of Mean Arterial Pressure between Group RM and Group RD

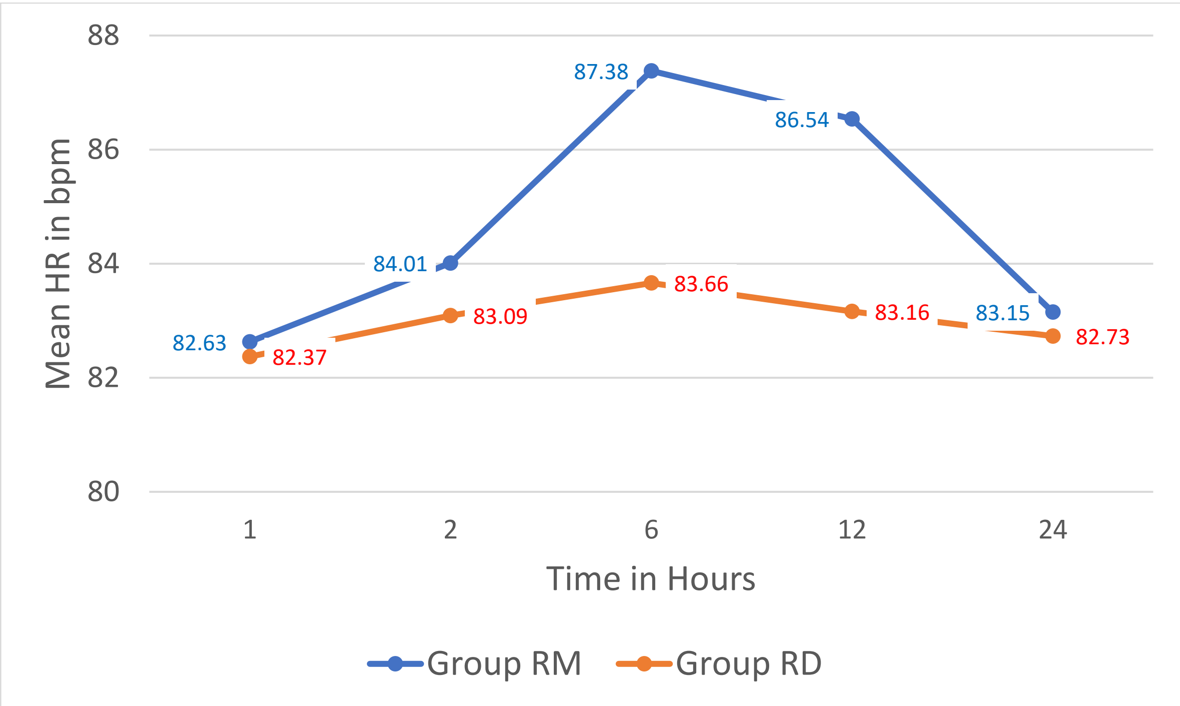

Figure 3: Comparison of Heart Rate between Group RM and Group RD

Over the 24-hour period, a clear and parallel declining trend in MAP is observed in both groups. However, Group RD consistently maintained a slightly higher MAP than Group RM at every subsequent time point. This suggests that the use of dexamethasone as an adjuvant may be associated with better hemodynamic stability, or less of a drop in blood pressure, in the postoperative period compared to magnesium sulfate [Figure 2], Heart rate was comparatively more stable in dexamethasone group as compared to minor surge in RM group [Figure 3].

DISCUSSION

The efficacy of a peripheral nerve block rests on the ability of local anesthetics to inhibit voltage-gated sodium channels, thereby interrupting the transmission of pain signals. To enhance and prolong this analgesic effect, adjuvants are often employed. These agents act through different mechanisms, targeting complementary pain pathways to improve both the duration and quality of analgesia.

Dexamethasone, a potent corticosteroid, exerts its effects through multiple mechanisms. It is thought to prolong local anesthetic action by suppressing the inflammatory response, reducing the release of mediators such as prostaglandins and bradykinin that sensitize nociceptors. Additionally, dexamethasone induces vasoconstriction, slowing systemic absorption of the anesthetic and thereby extending its local effect. [10] Evidence also suggests a direct inhibitory action on nociceptive C-fibers, further contributing to its analgesic properties. [11] Magnesium sulfate, in contrast, acts primarily as an N-methyl-D-aspartate (NMDA) receptor antagonist. Severe postoperative pain often involves central sensitization and wind-up phenomena, both mediated by NMDA receptors in the spinal cord. By blocking these receptors, magnesium reduces hyperexcitability and prevents the amplification of pain signals. This mechanism provides a deeper and potentially longer-lasting analgesic effect, particularly against tonic pain. [12]

Our study directly compared these two adjuvants-ropivacaine-magnesium (RM) versus ropivacaine-dexamethasone (RD)-in bilateral TAP blocks for lower abdominal surgeries. The most striking observation was the dissociation between analgesia duration and pain intensity. Group RM demonstrated a significantly longer time to first rescue analgesia (13.83 hours vs. 11.58 hours, $p<0.0001$), suggesting magnesium is highly effective at delaying breakthrough pain through its central NMDA antagonism. Conversely, Group RD showed superior pain control at intermediate and late time points (6, 12, and 24 hours), with consistently lower VAS scores. This indicates that while the initial block effect may wear off sooner, dexamethasone's anti-inflammatory action ensures smoother recovery and sustained pain relief.

Hemodynamic trends further support these findings. Group RD maintained slightly higher mean arterial pressures, suggesting better stability, possibly due to reduced stress responses from superior pain control or a direct pharmacologic effect of dexamethasone. Heart rates remained similar across groups, indicating neither adjuvant produced significant cardiovascular side effects.

Clinically, the choice of adjuvant represents a trade-off. Magnesium may be preferable when the priority is to maximize the pain-free interval, such as in high-turnover surgical settings. Dexamethasone, however, appears superior when the goal is to minimize pain intensity consistently over the first 24 hours postoperatively.

Our findings align with and diverge from previous literature, underscoring the complexity of adjuvant selection. Studies by Prasad et al. (2017) and Kiran et al. (2019) support dexamethasone's superior pain control and reduced opioid consumption, [13, 14] while Shambhavi et al. (2023) confirmed its advantage over magnesium in terms of analgesia duration and tramadol use. [15] On the other hand, Peng et al. (2022) and Balakrishna KP (2023) corroborate magnesium's role in prolonging analgesia, consistent with our "time to rescue" results. [16, 17]

Contradictions arise with Gad et al. (2019), who found magnesium superior to dexamethasone in all metrics when combined with bupivacaine. Differences in local anesthetic choice, surgical models, and dosing likely explain these discrepancies, highlighting that outcomes are context-dependent. [18] Similarly, Imani et al. (2018) reported no significant benefit of magnesium in TAP blocks, suggesting its effect size may vary with perioperative conditions. [19] Abdelrahman and Abu-Sinna (2021) further complicate the picture by showing intravenous magnesium outperformed intravenous dexamethasone, emphasizing the importance of administration route. [20]

Despite its valuable findings, this study has several limitations that should be considered. Firstly, the study design lacks a control group receiving only plain ropivacaine, making it impossible to definitively quantify the absolute benefit of each adjuvant over the local anesthetic alone. Secondly, the study was not double-blinded, as the investigators administering the block were likely aware of the adjuvants used, which could introduce performance bias. Finally, the findings from this specific patient population and surgical procedures may not be directly generalizable to other types of abdominal surgeries or different regional anesthesia techniques.

Based on these limitations, several directions for future research are proposed. Further research is needed to determine the optimal dosing for both magnesium sulfate and dexamethasone in TAP blocks and to investigate whether combining these adjuvants at lower, safe doses could synergistically provide both the prolonged duration of magnesium and the superior pain control of dexamethasone.

CONCLUSION

In conclusion, our study contributes valuable evidence to a field marked by conflicting results. Both dexamethasone and magnesium sulfate enhance the efficacy of local anesthetics, but their benefits differ. Dexamethasone provides consistent pain relief across 24 hours, while magnesium excels at delaying the onset of breakthrough pain. The optimal choice depends on clinical priorities, the local anesthetic used, the surgical context, and the desired balance between analgesia duration and intensity. Our findings reinforce dexamethasone's role in comprehensive pain control while validating magnesium as a potent option for extending the pain-free window.

Declaration by Authors

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