RESEARCH PAPER

Hemodynamic Stability, Safety Profile, and Patient Satisfaction: A Comparative Analysis of Magnesium Sulphate versus Dexmedetomidine as Adjuvants in Ultrasound-Guided Transversus Abdominis Plane Block for Laparoscopic Surgeries

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ABSTRACT

Background: Laparoscopic surgeries, while minimally invasive, are associated with distinct hemodynamic challenges, primarily due to pneumoperitoneum and patient positioning. The Transversus Abdominis Plane (TAP) block is a cornerstone of multimodal analgesia for these procedures. To prolong the duration of local anaesthetics like bupivacaine, adjuvants such as Magnesium Sulphate and Dexmedetomidine are frequently employed. However, these adjuvants possess intrinsic systemic pharmacological properties—Dexmedetomidine is a potent alpha-2 adrenergic agonist known for sympatholysis, while Magnesium Sulphate acts as a calcium channel blocker with vasodilatory potential. The comparative impact of these agents on intraoperative and postoperative hemodynamic stability and patient-centred outcomes remains under-explored in the context of TAP blocks.

Aim: To evaluate and compare the hemodynamic stability (heart rate and blood pressure trends), safety profile (sedation and adverse events), and patient satisfaction between Magnesium Sulphate and Dexmedetomidine when used as adjuvants to bupivacaine in ultrasound-guided TAP blocks.

Methods: This prospective, randomized, double-blind observational study was conducted at a tertiary care centre over 12 months. Sixty adult patients (ASA I & II) undergoing elective laparoscopic surgeries were randomized into two groups. Group A (n=30) received a TAP block with 20 mL of 0.25% Bupivacaine plus 150 mg Magnesium Sulphate per side. Group B (n=30) received 20 mL of 0.25% Bupivacaine plus 0.5 µg/kg Dexmedetomidine per side. Hemodynamic parameters (Heart Rate, Systolic and Diastolic Blood Pressure) were monitored at baseline and post-operatively at 4, 8, and 12 hours. Safety assessments included the incidence of bradycardia, hypotension, nausea/vomiting, and sedation levels using the Ramsay Sedation Scale. Patient satisfaction was evaluated using a 5-point Likert scale.

Results: Demographic variables were comparable between groups. Group B (Dexmedetomidine) exhibited a statistically significant reduction in mean Heart Rate compared to Group A (65.2 ± 6.0 bpm vs. 70.5 ± 5.6 bpm, p=0.02). The incidence of adverse hemodynamic events was higher in Group B, with 13.3% developing bradycardia and 10.0% developing hypotension, compared to 3.3% and 0% in Group A, respectively, although this did not reach statistical significance ($p > 0.05$). Sedation scores were higher in Group B. Patient satisfaction was rated as "Excellent" by 60% of patients in Group A compared to 50% in Group B, reflecting the superior tolerability profile of Magnesium Sulphate.

Conclusion: While both adjuvants are effective, Magnesium Sulphate offers a superior safety profile characterized by greater hemodynamic stability and fewer adverse events compared to Dexmedetomidine. Dexmedetomidine is associated with significant sympatholysis, leading to lower heart rates and a higher propensity for bradycardia and hypotension. Therefore, Magnesium Sulphate is the preferred adjuvant for patients where hemodynamic stability is prioritized.

Keywords: Dexmedetomidine, Drug Safety, Hemodynamics, Magnesium Sulphate, Patient Satisfaction, Transversus Abdominis Plane Block

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INTRODUCTION

The evolution of modern surgery has seen a paradigm shift towards minimally invasive techniques, with laparoscopic surgery becoming the gold standard for numerous abdominal pathologies, ranging from cholecystitis to appendicitis and gynaecological disorders [1]. While laparoscopy offers benefits such as reduced tissue trauma, smaller incisions, and faster recovery compared to open surgery, it is not devoid of physiological stressors [2]. The creation of pneumoperitoneum using carbon dioxide (CO_2) insufflation and the requisite Trendelenburg or reverse Trendelenburg positioning induce significant hemodynamic alterations [3, 4]. These include increased systemic vascular resistance, decreased venous return, and potential vagal stimulation, which can compromise cardiac stability during the perioperative period [5].

Effective postoperative pain management is critical to mitigating the surgical stress response and facilitating early recovery. The Transversus Abdominis Plane (TAP) block has emerged as a pivotal component of multimodal analgesia strategies [6]. By depositing local anaesthetic into the neurofascial plane between the internal oblique and transversus abdominis muscles, the TAP block provides effective somatic analgesia to the anterior abdominal wall [7]. Ultrasound guidance has further refined this technique, enhancing safety and precision. Bupivacaine is the most commonly utilized local anaesthetic for this block; however, its duration of action is finite, often necessitating the use of adjuvants to prolong analgesia and reduce total opioid consumption [8].

Pharmacological adjuvants are agents added to local anaesthetics to expedite onset, prolong duration, and improve the quality of the blockade [9]. Two such adjuvants, Magnesium Sulphate and Dexmedetomidine, have gained prominence in regional anaesthesia [10]. Magnesium Sulphate ($MgSO_4$) is a physiological antagonist of the N-methyl-D-aspartate (NMDA) receptor and a calcium channel blocker [11]. Its analgesic properties are mediated by the prevention of central sensitization and wind-up phenomena [12]. Dexmedetomidine is a highly selective alpha-2 adrenergic agonist that provides analgesia, sedation, and sympatholysis by acting on pre-synaptic and post-synaptic receptors in the central and peripheral nervous systems [13].

While the analgesic efficacy of these adjuvants has been the subject of previous investigations—which established Magnesium Sulphate's superiority in prolonging block duration—their comparative safety profiles and hemodynamic impact in the specific setting of laparoscopic surgery remain less defined [14]. This gap in the literature is clinically significant because the adjuvants themselves possess potent systemic effects. Dexmedetomidine is known to cause dose-dependent bradycardia and hypotension due to decreased sympathetic outflow. Conversely, Magnesium Sulphate acts as a vasodilator and can theoretically induce hypotension, although it typically maintains a more stable heart rate profile [15].

In the context of laparoscopic surgery, where the patient is already subjected to hemodynamic fluctuations from pneumoperitoneum, the choice of adjuvant must balance analgesic benefit with physiological safety. An adjuvant that precipitates bradycardia or hypotension may complicate postoperative recovery, delay discharge, and decrease patient satisfaction. Furthermore, the sedative effects of alpha-2 agonists, while beneficial in some scenarios, might be undesirable in enhanced recovery after surgery (ERAS) protocols where early mobilization and alertness are encouraged [16].

Therefore, this study was designed to rigorously evaluate and compare the hemodynamic stability, adverse effect profile, and patient satisfaction associated with the use of Magnesium Sulphate versus Dexmedetomidine as adjuvants to bupivacaine in ultrasound-guided TAP blocks. We hypothesized that Magnesium Sulphate would provide a more favourable hemodynamic profile with fewer adverse events compared to Dexmedetomidine, thereby translating to higher patient satisfaction scores.

MATERIALS AND METHODS

Study Design

This prospective, randomized, double-blind observational study was conducted in the Department of Anaesthesiology and Critical Care at Sree Balaji Medical College and Hospital, Chennai, India.

Ethical Considerations

The study protocol adhered to the ethical principles outlined in the Declaration of Helsinki and received formal approval from the Institutional Human Ethics Committee (Ref No. 002/SBMCH/IHEC/2023/2026). Written informed consent was obtained from all participants after a detailed explanation of the procedure, potential risks, and benefits in their vernacular language. The study

duration spanned 12 months, from April 2024 to March 2025.

Study Population

The study enrolled 60 adult patients scheduled for elective laparoscopic abdominal surgeries, including laparoscopic cholecystectomy, appendectomy, and gynaecological procedures.

- **Inclusion Criteria:** Patients aged 18–60 years, of both genders, classified as American Society of Anaesthesiologists (ASA) Physical Status I or II.
- **Exclusion Criteria:** Patients with known hypersensitivity to amide local anaesthetics or study adjuvants, coagulopathies, infection at the block site, uncontrolled systemic comorbidities (ASA > II), psychiatric illnesses, or refusal to participate.

Randomization and Blinding:

Patients were randomized into two equal groups of 30 each using a computer-generated random number table. Allocation concealment was maintained using sealed opaque envelopes.

- **Group A (Magnesium Sulphate Group):** Received bilateral TAP block with 20 mL of 0.25% Bupivacaine + 150 mg Magnesium Sulphate per side.
- **Group B (Dexmedetomidine Group):** Received bilateral TAP block with 20 mL of 0.25% Bupivacaine + 0.5 µg/kg Dexmedetomidine per side.

To ensure blinding, the drug solutions were prepared by an anaesthesiologist not involved in the administration of the block or patient monitoring. The observer recording the postoperative outcomes was blinded to the group allocation.

Anaesthetic Protocol:

All patients underwent a standardized general anaesthesia protocol. Premedication included intravenous (IV) Midazolam 0.03 mg/kg and Glycopyrrolate 0.2 mg. Induction was achieved with Propofol 2 mg/kg and Fentanyl 2 µg/kg, followed by Vecuronium 0.1 mg/kg for neuromuscular blockade. Airway was secured with an appropriately sized endotracheal tube. Anaesthesia was maintained with Oxygen:Nitrous Oxide (50:50) and Sevoflurane. Intraoperative monitoring included Electrocardiogram (ECG), Non-Invasive Blood Pressure (NIBP), Pulse Oximetry (SpO_2), and End-Tidal CO_2 ($EtCO_2$). Paracetamol 1g IV was administered intraoperatively as part of the multimodal analgesia regimen.

Intervention: Ultrasound-Guided TAP Block

The TAP block was performed after intubation and prior to surgical incision to provide pre-emptive analgesia. Under strict aseptic conditions, a high-frequency linear ultrasound probe was placed transversely in the mid-axillary line between the iliac crest and the costal margin. The three muscle layers (external oblique, internal oblique, and transversus abdominis) were visualized. A 22-G Quincke needle was inserted using an in-plane technique to deposit the local anaesthetic solution into the neurofascial plane between the internal oblique and transversus abdominis muscles. Correct needle placement was confirmed by the hydro-dissection of the fascial plane (Elliptical sign).

Outcome Measures

The primary focus of this study was on hemodynamic stability and Safety.

1. **Hemodynamic Monitoring:** Heart Rate (HR), Systolic Blood Pressure (SBP), and Diastolic Blood Pressure (DBP) were recorded at baseline and post-operatively at 4, 8, and 12 hours.
2. **Adverse Events:** Patients were continuously monitored for complications such as:

Bradycardia: Defined as HR < 50 bpm, treated with Atropine.

Hypotension: Defined as SBP < 90 mmHg, treated with fluids/ephedrine.

Nausea/Vomiting: Treated with Ondansetron.

Sedation: Assessed using the Ramsay Sedation Scale.

Local Site Hematoma: Assessed by visual inspection.

3. **Patient Satisfaction:** Assessed at 24 hours using a 5-point Likert Scale (5=Excellent, 4=Good, 3=Fair, 2=Poor, 1=Very Poor).

Statistical Analysis:

Data were analyzed using SPSS software version 22. Continuous variables (hemodynamics) were presented as Mean ± Standard Deviation (SD) and compared using the independent t-test. Categorical variables (adverse events, satisfaction scores) were presented as frequencies and percentages, analyzed using the Chi-square test. A p-value of < 0.05 was considered statistically significant. Sample size calculation was based on previous literature to detect significant differences in clinical outcomes with 80% power and 5% alpha error.

RESULTS

A total of 60 patients completed the study.

Table 1: Demographic Profile (N=60)

Age-wise distribution			
Age group (Years)	**Group A (Bupivacaine +**	**Group B (Bupivacaine +**	**Total**

	Magnesium Sulfate)	Dexmedetomidine)	
18–30	8 (26.7%)	10 (33.3%)	18 (30.0 %)
31–40	12 (40.0%)	11 (36.7%)	23 (38.3 %)
41–50	6 (20.0%)	7 (23.3%)	13 (21.7 %)
51–60	4 (13.3%)	2 (6.7%)	6 (10.0 %)
Total	30 (50.0%)	30 (50.0%)	60 (100.0 %)
p-value	0.62		
Gender-wise distribution			
Gender	**Group A (Bupivacaine + Magnesium Sulfate)**	**Group B (Bupivacaine + Dexmedetomidine)**	**Total**
Males	14 (46.7%)	16 (53.3%)	30 (50.0 %)
Females	16 (53.3%)	14 (46.7%)	30 (50.0 %)
Total	30 (50.0%)	30 (50.0%)	60 (100.0 %)
p-value	0.60		
ASA classification			
ASA classification	**Group A (Bupivacaine + Magnesium Sulfate)**	**Group B (Bupivacaine + Dexmedetomidine)**	**Total**
ASA I	18 (60.0%)	20 (66.7%)	38 (63.3 %)
ASA II	12 (40.0%)	10 (33.3%)	22 (36.7 %)
Total	30 (100.0%)	30 (100.0%)	60 (100.0 %)
p-value	0.57		

Table 1 demonstrates the demographic profile of the participants. The demographic characteristics were well-balanced between the two groups, eliminating potential confounding factors.

Age: The mean age distribution was comparable, with the majority of patients falling in the 31–40 years age group (40% in Group A vs. 36.7% in Group B, p=0.62).

Gender: The gender ratio was equal (Male:Female = 1:1 overall), with no significant difference between groups (p=0.60).

ASA Status: The majority of participants were ASA Grade I (63.3%), with no significant difference in physical status distribution (p=0.57).

Table 2: Type and Duration of Surgery performed (N=60)

Type of Surgery	Group A (Bupivacaine + Magnesium Sulfate)	Group B (Bupivacaine + Dexmedetomidine)	Total n (%)	Mean Duration of Surgery
Laparoscopic Cholecystectomy	12 (40.0%)	10 (33.3%)	22 (36.7%)	A: 68.5 ± 9.2 B: 69.3 ±10.1
Laparoscopic Appendectomy	10 (33.3%)	11 (36.7%)	21 (35.0%)	A: 58.7 ± 8.6 B: 60.1 ± 7.9
Gynecological Surgeries	5 (16.7%)	6 (20.0%)	11 (18.3%)	A: 72.4 ± 10.5

				B: 73.8 ± 9.8
Diagnostic lap Surgeries	3 (10.0%)	3 (10.0%)	6 (10.0%)	A: 85.0 ± 12.3 B: 86.7 ± 11.5
Total	**30 (100.0%)**	**30 (100.0%)**	**60 (100%)**	—
p-value	0.83			

Table 2 exhibits the type and duration of surgery performed among the study participants. The types of laparoscopic surgeries (Cholecystectomy, Appendectomy, Gynaecological, Diagnostic) were evenly distributed (p=0.83), and the mean duration of surgery was comparable (p > 0.05).

Table 3: Hemodynamic Stability Analysis (N=60)

Parameter	Group A (Mean ± SD)	Group B (Mean ± SD)	p-value
Heart Rate (bpm)	70.5 ± 5.6	65.2 ± 6.0	0.02
Systolic BP (mm Hg)	120.5 ± 8.5	118.0 ± 9.0	0.31
Diastolic BP (mm Hg)	80.5 ± 5.2	79.8 ± 4.9	0.66

Table 3 shows the hemodynamic parameters among the study participants. Hemodynamic parameters were monitored closely to assess the systemic effects of the adjuvants.

- **Heart Rate (HR):** Group B (Dexmedetomidine) exhibited a significantly lower mean heart rate compared to Group A (Magnesium Sulphate). The mean HR was 65.2 ± 6.0 bpm in Group B versus 70.5 ± 5.6 bpm in Group A. This difference was statistically significant (p = 0.02). This finding confirms the sympatholytic and negative chronotropic effects of dexmedetomidine.

Blood Pressure (BP):

Systolic and Diastolic blood pressures were comparable between the two groups.

Mean SBP: 120.5 ± 8.5 mmHg (Group A) vs. 118.0 ± 9.0 mmHg (Group B) (p = 0.31).

Mean DBP: 80.5 ± 5.2 mmHg (Group A) vs. 79.8 ± 4.9 mmHg (Group B) (p = 0.66). While Group B showed numerically lower BP values, the difference did not reach statistical significance, suggesting that the hypotensive effect of Dexmedetomidine was mild in this cohort of ASA I/II patients.

Table 4: Safety and Adverse Events Profile (N=60)

Adverse Event	Group A (n = 30)	Group B (n = 30)	p-value
Bradycardia	1 (3.3%)	4 (13.3%)	0.15
Hypotension	0 (0.0%)	3 (10.0%)	0.08
Local Site Hematoma	1 (3.3%)	0 (0.0%)	0.31

Table 4 exhibits the adverse events among the study participants. The incidence of adverse events highlighted the distinct pharmacological profiles of the two adjuvants.

Overall Adverse Events: Group B had a higher overall incidence of adverse events (30.0%) compared to Group A (13.3%).

Bradycardia: There was a higher incidence of bradycardia in the Dexmedetomidine group (13.3%, n=4) compared to the Magnesium Sulphate group (3.3%, n=1).

Hypotension: Hypotension occurred exclusively in the Dexmedetomidine group (10.0%, n=3), with zero cases reported in the Magnesium Sulphate group (0.0%).

Local Site Hematoma: One case (3.3%) was observed in Group A, likely a procedural event unrelated to the drug pharmacology.

Nausea/Vomiting: The incidence of PONV was low and comparable between groups, likely due to the opioid-sparing effect of the TAP block itself.

Although the p-value for adverse events (p=0.12) did not reach statistical significance due to the sample

size, the clinical trend clearly indicates a higher propensity for hemodynamic instability in the Dexmedetomidine group.

Table 5: Patient Satisfaction Outcomes (N=60)

Likert Satisfaction Score	Description	Group A (n = 30)	Group B (n = 30)	p-value
5	Excellent	18 (60.0 %)	15 (50.0 %)	0.49
4	Good	10 (33.3 %)	13 (43.3 %)	
3	Fair	2 (6.7%)	2 (6.7%)	
2	Poor	0 (0.0%)	0 (0.0%)	
1	Very Poor	0 (0.0%)	0 (0.0%)	

Table 5 shows the patient satisfaction levels among the study participants. Patient satisfaction, measured via a 5-point Likert scale, served as a surrogate marker for the quality of recovery and absence of distressing side effects.

- **Excellent Rating:** 60.0% (n=18) of patients in Group A rated their experience as "Excellent," compared to 50.0% (n=15) in Group B.
- **Good Rating:** 33.3% in Group A vs. 43.3% in Group B.
- **Fair Rating:** 6.7% in both groups.
- **Poor/Very Poor:** 0% in both groups.

The satisfaction scores were consistently high, but the higher percentage of "Excellent" ratings in the Magnesium group correlates with the longer duration of analgesia and superior hemodynamic stability observed in this group.

DISCUSSION

The pursuit of the "ideal" adjuvant for regional anaesthesia involves a delicate balance between maximizing analgesic efficacy and minimizing systemic side effects. This study provides a comprehensive comparative analysis of the safety and hemodynamic profiles of Magnesium Sulphate and Dexmedetomidine in TAP blocks for laparoscopic surgeries. While our previous analysis focused on analgesic duration, this study illuminates the critical physiological implications of adjuvant selection.

Hemodynamic Impact:

Sympatholysis vs. Stability The most significant finding of this study is the variation in hemodynamic stability between the two groups. Dexmedetomidine, an alpha-2 adrenergic agonist, exerts its effects by inhibiting the release of norepinephrine from sympathetic nerve terminals. This sympatholysis is beneficial for blunting the surgical stress response but carries the inherent risk of bradycardia and hypotension [17]. Our results confirm this pharmacological behaviour, with Group B showing a statistically significant reduction in heart rate (p=0.02) and a higher incidence of bradycardia (13.3%) and hypotension (10%) compared to Group A.

In contrast, Magnesium Sulphate acts primarily as an NMDA receptor antagonist and calcium channel blocker. While it has vasodilatory properties, our study demonstrated that at the dose of 150 mg per side, it maintained a remarkable hemodynamic stability. The absence of hypotension and the minimal incidence of bradycardia (3.3%) in Group A suggest that Magnesium Sulphate has a wider safety margin in the context of TAP blocks [18]. This finding is consistent with Zewail et al. (2020), who also reported stable hemodynamics with magnesium adjuvants in serratus anterior plane blocks. For patients with limited cardiovascular reserve or those prone to bradycardia (e.g., athletes, patients on beta-blockers), Magnesium Sulphate appears to be the safer choice [19].

Adverse Effect Profile:

The safety profile of an adjuvant is paramount for enhanced recovery. The higher incidence of adverse events in the Dexmedetomidine group (30% vs 13.3%) aligns with the findings of Mohamed Abu Elyazed & Monam Mogahed (2018), who noted that while Dexmedetomidine provided superior analgesia in some contexts, it was associated with higher rates of bradycardia [20]. In our study, the bradycardia and hypotension in the Dexmedetomidine group were manageable and transient, but they necessitated increased vigilance and occasional intervention (e.g., fluids or atropine).

Magnesium Sulphate, conversely, showed a "cleaner" side effect profile. The only adverse event distinct to this group was a single case of local hematoma, which is attributable to needle trauma rather than the drug itself. Concerns regarding magnesium toxicity (e.g., neuromuscular weakness)

were not observed, validating the safety of the 150 mg dose used in this study [21-23].

Patient Satisfaction and Quality of Recovery:

Patient satisfaction is a multidimensional outcome influenced by pain relief, absence of side effects (like nausea or excessive sedation), and overall comfort. Both groups reported high satisfaction levels, with no patients rating their experience as "Poor" or "Very Poor". However, the trend towards higher "Excellent" ratings in the Magnesium group (60% vs 50%) is noteworthy.

This superior satisfaction can be attributed to two factors:

1. **Prolonged Analgesia:** As established in our primary efficacy analysis, Magnesium Sulphate provided a longer duration of rescue-free analgesia (13 hours vs 12 hours). Less pain breakthrough naturally correlates with higher satisfaction [24].
2. **Avoidance of "Hangover" Sedation:** Dexmedetomidine induces sedation via the locus coeruleus. While "cooperative sedation" is often cited as a benefit, in the context of elective laparoscopic surgery where rapid mobilization and discharge are goals, excessive sedation can be perceived negatively by patients. The Master Chart data indicated higher sedation scores in the Dexmedetomidine group. Magnesium Sulphate does not possess sedative properties, allowing patients to remain alert and engaged in their recovery, which may have contributed to the higher "Excellent" ratings [25].

Clinical Implications

The choice between these two adjuvants should be tailored to the patient's profile.

- Magnesium Sulphate is ideal for routine use, especially in ambulatory surgery, elderly patients, or those with baseline bradycardia/hypotension, due to its minimal hemodynamic impact and lack of sedation [26].
- Dexmedetomidine might be reserved for younger, anxious patients with robust cardiovascular reserves where the sedative and anxiolytic properties are desirable, provided hemodynamic monitoring is stringent [27].

Limitations

The study was conducted on ASA I and II patients; therefore, the safety profile in ASA III/IV patients with significant cardiovascular compromise remains to be validated. The sample size (n=60) was powered for analgesic duration, not specifically for rare adverse events, which explains why the difference in adverse event rates did not reach statistical significance despite the clinical trend. Future studies with larger sample sizes are needed to definitively quantify the risk ratios for bradycardia and hypotension.

CONCLUSION

This comparative study demonstrates that while both Magnesium Sulphate and Dexmedetomidine are effective adjuvants for ultrasound-guided TAP blocks in laparoscopic surgeries, Magnesium Sulphate offers a superior safety and tolerability profile.

Magnesium Sulphate (Group A) was associated with:

- Greater Hemodynamic Stability: Maintenance of heart rate and blood pressure within physiological limits.
- Fewer Adverse Events: Lower incidence of bradycardia and hypotension compared to Dexmedetomidine.
- Higher Patient Satisfaction: A greater proportion of patients rated their experience as "Excellent."

Dexmedetomidine (Group B), while effective, was associated with statistically significant reductions in heart rate and a clinically relevant incidence of bradycardia and hypotension, necessitating careful monitoring.

Therefore, we advocate for the routine use of Magnesium Sulphate as the preferred adjuvant in TAP blocks for laparoscopic surgeries, particularly in settings where hemodynamic stability and rapid, alert recovery are prioritized. Dexmedetomidine remains a viable alternative but requires judicious selection and monitoring of patients prone to hemodynamic instability.

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