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Original Article

Comparison of Effect of Dexmedetomidine and Magnesium Sulphate on Attenuation of Hemodynamic Response yo Co2 Pneumoperitonium in Patients Undergoing Laparoscopic Surgeries

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ABSTRACT

Background: Laparoscopic surgeries are associated with significant hemodynamic alterations due to CO_2 pneumoperitoneum, leading to increased sympathetic activity and cardiovascular stress. Attenuation of these responses is crucial to reduce perioperative morbidity. Dexmedetomidine and magnesium sulphate have emerged as potential pharmacological agents for controlling such hemodynamic fluctuations.
Aim: To compare the efficacy of dexmedetomidine and magnesium sulphate in attenuating the hemodynamic response to CO_2 pneumoperitoneum in patients undergoing laparoscopic surgeries.
Materials and Methods: This prospective, randomized, double-blinded study included 150 patients of ASA physical status I and II, aged 18–55 years, undergoing elective laparoscopic surgeries. Patients were randomly allocated into three groups (n=50 each): Group C (control, normal saline), Group D (dexmedetomidine 1 µg/kg loading followed by 0.4 µg/kg/hr infusion), and Group M (magnesium sulphate 50 mg/kg loading followed by 15 µg/kg/min infusion). Standardized general anesthesia protocol was followed. Hemodynamic parameters including heart rate (HR), systolic blood pressure (SBP), diastolic blood pressure (DBP), and mean arterial pressure (MAP) were recorded at predefined intervals. Postoperative pain (VAS), sedation scores, and adverse events were also assessed. Statistical analysis was performed using ANOVA, repeated measures ANOVA, Chi-square test, and Tukey's post-hoc test.
Results: Baseline demographic and clinical parameters were comparable across all groups ($p > 0.05$). Following pneumoperitoneum, Group C demonstrated a significant increase in HR, SBP, DBP, and MAP, whereas Groups D and M showed effective attenuation of these responses. Dexmedetomidine provided superior hemodynamic stability compared to magnesium sulphate, with significantly lower HR and blood pressure values at all intraoperative time points ($p < 0.001$). Postoperative VAS scores were significantly lower in Group D compared to Groups C and M at all time intervals ($p < 0.001$). Sedation scores were higher in the dexmedetomidine group immediately post-extubation ($p < 0.001$) but comparable thereafter. Bradycardia was more frequent in Group D ($p = 0.03$), while other adverse events were comparable across groups.
Conclusion: Dexmedetomidine is more effective than magnesium sulphate in attenuating hemodynamic responses to CO_2 pneumoperitoneum, providing superior intraoperative stability and improved postoperative analgesia with an acceptable safety profile. It can be considered a preferable adjunct in laparoscopic surgeries for optimal perioperative hemodynamic control.

***Keywords**: Dexmedetomidine, Magnesium Sulphate, Pneumoperitoneum, Hemodynamic Response, Laparoscopic Surgery, CO_2 Insufflation.*

INTRODUCTION

Laparoscopic surgery, though minimally invasive, is associated with significant hemodynamic alterations primarily due to carbon dioxide pneumoperitoneum. CO_2 insufflation leads to increased circulating catecholamines and vasopressin, resulting in sympathetic stimulation that may precipitate adverse cardiovascular events, particularly in patients with compromised cardiac reserve. The principal factors responsible for these changes include elevated arterial carbon dioxide levels ($PaCO_2$) and increased intra-abdominal pressure.[1]

The hemodynamic effects of pneumoperitoneum are mediated through both mechanical and neuroendocrine mechanisms. Increased intra-abdominal pressure (>10 mmHg) reduces thoracopulmonary compliance, increases systemic and pulmonary vascular resistance, and elevates arterial pressure, while compression of the inferior vena cava decreases venous return and cardiac output by 10–30%.[2-3] These changes are further exacerbated by hypercarbia-induced sympathetic activation.

Anesthetic management during laparoscopic procedures is therefore aimed at attenuating these stress responses while maintaining cardiovascular stability. However, pneumoperitoneum, along with laryngoscopy, intubation, and extubation, produces significant sympathoadrenal stimulation due to increased catecholamine and vasopressin release, leading to tachycardia and hypertension. Although generally tolerated in ASA I–II patients, these responses may be exaggerated in high-risk individuals.[7-8] Conventional anesthetic agents such as volatile anesthetics and opioids provide partial attenuation but may not completely suppress these responses during sustained intra-abdominal insufflation.[7-9]

Various pharmacological strategies have been employed to control perioperative hemodynamic fluctuations, including propofol, beta-blockers, vasodilators, and regional anesthesia techniques. However, the search for an ideal agent continues. Dexmedetomidine and magnesium sulphate have emerged as promising adjuncts due to their distinct pharmacological properties.[8-9]

Dexmedetomidine, a highly selective α2-adrenergic agonist, exerts its effects by reducing central sympathetic outflow through action on the locus coeruleus, resulting in sedation, analgesia, and significant attenuation of stress responses without respiratory depression. It also decreases anesthetic and opioid requirements, contributing to improved hemodynamic stability.[10-13] In contrast, magnesium sulphate acts as an NMDA receptor antagonist and calcium channel blocker, reducing catecholamine release and inducing vasodilation through prostacyclin enhancement and inhibition of angiotensin-converting enzyme activity.[5,14-16] It has also been shown to reduce anesthetic requirements and provide adjunctive analgesic benefits.[17-19]

Given that hemodynamic responses to pneumoperitoneum, intubation, and extubation contribute significantly to perioperative morbidity, effective pharmacological attenuation is essential. Previous studies, including those by Karla NK et al.[20] and Ghodki PS et al.[21], have demonstrated the role of magnesium sulphate in reducing pressor responses during laparoscopic procedures; however, comparative data with dexmedetomidine remain limited.

Therefore, the present study was undertaken to compare the efficacy of dexmedetomidine and magnesium sulphate in attenuating the hemodynamic response to CO_2 pneumoperitoneum in patients undergoing laparoscopic surgeries.

MATERIALS AND METHOD

This prospective, randomized, comparative, double-blinded clinical study was conducted in the Department of Anaesthesiology at the School of Medical Science and Research, Sharda Hospital, Greater Noida, over a period extending from April 2024 to November 2025. The study protocol was approved by the Institutional Ethics Committee, and all procedures were carried out in accordance with established ethical standards for research involving human subjects. Written informed consent was obtained from all participants in their vernacular language after a detailed explanation of the study objectives and procedures.

A total of 150 patients scheduled to undergo elective laparoscopic surgeries under general anaesthesia were enrolled in the study. Sample size estimation was based on data derived from previous studies, considering comparable mean and standard deviation values, which indicated that a minimum of 50 patients per group would provide adequate statistical power. Eligible participants were adult patients aged between 18 and 55 years, belonging to American Society of Anesthesiologists (ASA) physical status I or II, and willing to participate in the study. Patients were excluded if they refused consent, were pregnant, had morbid obesity, full stomach, or required emergency surgery, or had a history of hypersensitivity to study drugs or significant comorbid conditions including cardiovascular, respiratory, neuromuscular, endocrine, hepatic, or renal disorders.

Participants were randomly allocated into three groups of 50 patients each using a computer-generated randomization sequence. Group C received normal saline and served as the control group, Group D received dexmedetomidine, and Group M received magnesium sulphate. To maintain the double-blind nature of the study, drug preparation was performed by an anesthesiologist not involved in intraoperative monitoring or data collection, and both the investigator and the patient were blinded to group allocation.

All patients underwent a detailed pre-anaesthetic evaluation prior to surgery. Standard premedication consisting of oral alprazolam 0.5 mg and ranitidine 150 mg was administered the night before surgery. In the operating room, standard ASA monitoring was instituted, including continuous electrocardiography, pulse oximetry, non-invasive blood pressure monitoring, and end-tidal carbon dioxide measurement. Baseline hemodynamic parameters were recorded prior to induction of anaesthesia. An intravenous line was secured, and patients were preoxygenated with 100% oxygen at 6 L/min for three minutes.

The study drugs were administered as a loading dose over 15 minutes prior to laryngoscopy and establishment of pneumoperitoneum. Group C received 20 mL of normal saline, Group D received dexmedetomidine at a dose of 1 µg/kg diluted in 20 mL normal saline followed by a maintenance infusion of 0.4 µg/kg/h, and Group M received magnesium sulphate at a dose of 50 mg/kg diluted in 20 mL normal saline followed by a maintenance infusion of 15 µg/kg/min. General anaesthesia was induced using intravenous fentanyl 2 µg/kg, propofol 2 mg/kg, and vecuronium 0.1 mg/kg to facilitate endotracheal intubation. Correct placement of the endotracheal tube was confirmed by auscultation and capnography.

Anaesthesia was maintained using a mixture of oxygen and nitrous oxide in a 50:50 ratio along with sevoflurane titrated to maintain an adequate depth of anaesthesia. Intermittent doses of vecuronium were administered to ensure adequate muscle relaxation throughout the procedure. Mechanical ventilation was adjusted to maintain end-tidal CO_2 between 36 and 42 mmHg. The assigned study drug infusion was continued intraoperatively according to group allocation. Intravenous fluids were administered as per patient requirement, and any hemodynamic instability was managed appropriately without compromising study blinding.

At the conclusion of surgery, residual neuromuscular blockade was reversed using neostigmine and glycopyrrolate in appropriate doses. Following the return of adequate spontaneous respiration and protective airway reflexes, extubation was performed. Patients were subsequently transferred to the post-anaesthesia care unit for monitoring. Postoperative analgesia was provided with intravenous paracetamol 1 g, and prophylaxis against postoperative nausea and vomiting was achieved with intravenous ondansetron 4 mg administered approximately 30 minutes prior to extubation.

The primary outcome measures included intraoperative hemodynamic parameters, specifically heart rate, systolic blood pressure, diastolic blood pressure, and mean arterial pressure. These parameters were recorded at predefined intervals, including baseline (before induction), prior to pneumoperitoneum, at 5, 10, 20, 30, 40, 50, 60, and 75 minutes following CO_2 insufflation, and immediately before and after extubation. Secondary outcome measures included postoperative pain assessed using the Visual Analog Scale (VAS), sedation levels evaluated using a standardized sedation scoring system, and the incidence of adverse effects such as hypotension, bradycardia, shivering, and postoperative nausea and vomiting. Postoperative assessments were conducted at 0, 5, 15, 30, 45, and 60 minutes following extubation.

Statistical Analysis

All data were systematically compiled and analyzed using the Statistical Package for the Social Sciences (SPSS) software, version 26.0 (IBM Corp., Chicago, IL, USA). Continuous variables were expressed as mean ± standard deviation (SD), while categorical variables were presented as frequencies and percentages. Baseline intergroup comparisons for continuous variables were performed using one-way analysis of variance (ANOVA), whereas categorical variables were analyzed using the Chi-square test or Fisher's exact test, as appropriate.

Intraoperative hemodynamic parameters (heart rate, systolic blood pressure, diastolic blood pressure, and mean arterial pressure) measured at multiple time intervals were analyzed using repeated measures ANOVA to assess both within-group and between-group variations over time. When overall statistical significance was observed, post-hoc pairwise comparisons were performed using Tukey's test to identify intergroup differences.

Postoperative variables such as Visual Analogue Scale (VAS) scores and sedation scores across different time points were also analyzed using repeated measures ANOVA followed by Tukey's post-hoc test for multiple comparisons. A p-value of less than 0.05 was considered statistically significant.

RESULTS

Demographic Characteristics

A total of 150 patients scheduled for elective laparoscopic surgery under general anesthesia were enrolled and randomly allocated into three equal groups of fifty patients each: Group C (Control), Group D (Dexmedetomidine), and Group M (Magnesium Sulphate). The demographic variables including age, weight, gender distribution, and ASA physical status classification were statistically comparable across all three groups, thereby ensuring baseline homogeneity and eliminating selection bias for outcome assessment.

The baseline demographic and perioperative characteristics were comparable across all three groups, demonstrating effective randomization and homogeneous study population distribution. The mean age of patients in Group C, Group D, and Group M was 36.8 ± 8.5, 35.9 ± 7.8, and 37.1 ± 9.1 years, respectively, with no statistically significant difference (p = 0.78).

A similar male predominance was observed in all groups, with males comprising 58% in Group C, 54% in Group D, and 56% in Group M (p = 0.93).

The anthropometric parameters of patients remained consistent between groups, with mean height ranging from 164.6 ± 6.9 cm to 165.9 ± 7.1 cm, weight between 63.7 ± 7.4 kg to 65.1 ± 6.9 kg, and BMI values ranging from 23.4 ± 2.3 to 23.7 ± 2.0 kg/m², with no significant variation (p > 0.05).

Preoperative physical status based on ASA grading revealed a similar distribution of Grade I/II patients in Group C (62%/38%), Group D (60%/40%), and Group M (64%/36%) (p = 0.89), indicating comparable anesthetic risk levels.

The distribution of Mallampati (MP) grades was comparable, with no statistically significant difference observed (p = 0.97). In Group A, MP Grades I, II, and III were recorded in 12 (24%), 26 (52%), and 12 (24%) patients respectively. Group B showed a similar pattern, with 13 (26%) patients in Grade I, 25 (50%) in Grade II, and 12 (24%) in Grade III. Group C also demonstrated close alignment, reporting 11 (22%) in Grade I, 27 (54%) in Grade II, and 12 (24%) in Grade III.

The number of intubation attempts was likewise consistent between groups, with no significant intergroup variation (p = 0.81). Single-attempt intubation was successful in the majority of patients: 48 (96%) in Group A, 49 (98%) in Group B, and 47 (94%) in Group C. Only a small proportion required a second attempt—2 (4%), 1 (2%), and 3 (6%) patients in the respective groups. (table 1)

Parameter	Group C (n = 50)	Group D (n = 50)	Group M (n = 50)	p-value	Significance
Age (years) (Mean ± SD)	36.8 ± 8.5	35.9 ± 7.8	37.1 ± 9.1	0.78	NS
Sex (M/F)	29 (58%) / 21 (42%)	27 (54%) / 23 (46%)	28 (56%) / 22 (44%)	0.93	NS
Height (cm) (Mean ± SD)	165.2 ± 7.3	164.6 ± 6.9	165.9 ± 7.1	0.81	NS
Weight (kg) (Mean ± SD)	64.3 ± 6.5	63.7 ± 7.4	65.1 ± 6.9	0.62	NS
BMI (kg/m²) (Mean ± SD)	23.5 ± 2.1	23.4 ± 2.3	23.7 ± 2.0	0.74	NS
ASA Grade I/II	31 (62%) / 19 (38%)	30 (60%) / 20 (40%)	32 (64%) / 18 (36%)	0.89	NS
MP Grade I / II / III	12 (24%) / 26 (52%) / 12 (24%)	13 (26%) / 25 (50%) / 12 (24%)	11 (22%) / 27 (54%) / 12 (24%)	0.97	NS
Intubation Attempts: 1 / 2	48 (96%) / 2 (4%)	49 (98%) / 1 (2%)	47 (94%) / 3 (6%)	0.81	NS

Intraoperative Hemodynamics

HEART RATE VARIATION ACROSS GROUPS DURING STUDIED TIME INTERVALS

The baseline heart rate values were comparable among the three study groups, with mean HRs of 82 ± 7 bpm in Group C, 82 ± 7 bpm in Group D, and 82 ± 6 bpm in Group M, showing no statistically significant difference ($p = 0.92$). Before CO_2 insufflation, there was still no significant variation between the groups ($p = 0.08$), confirming comparable pre-insufflation physiological conditions.

Following pneumoperitoneum creation, a statistically significant rise in heart rate was observed in the Control group, whereas both Dexmedetomidine and Magnesium Sulphate attenuated this sympathetic response effectively. At T5, HR increased markedly in Group C to 98 ± 8 bpm, compared to 85 ± 7 bpm in Group D and 89 ± 7 bpm in Group M ($p < 0.001$). This trend continued throughout pneumoperitoneum, with Group C demonstrating the highest HR values at every interval. The peak tachycardic response occurred at T30, where Group C recorded a mean HR of 108 ± 10 bpm, significantly higher than Group D (88 ± 6 bpm) and Group M (96 ± 7 bpm) with a highly significant $p < 0.001$.

Even during later intraoperative periods such as T60 and T75, Group C persisted with elevated HR values (103 ± 10 bpm and 101 ± 9 bpm, respectively), whereas Group D maintained near-baseline control (85 ± 6 bpm and 84 ± 6 bpm) and Group M reflected moderate suppression (93 ± 7 bpm and 92 ± 7 bpm), all comparisons yielding $p < 0.001$. During recovery phases, immediately before extubation (96 ± 8 bpm vs 83 ± 7 bpm vs 90 ± 7 bpm; $p < 0.001$) and immediately after extubation (104 ± 10 bpm vs 86 ± 7 bpm vs 94 ± 7 bpm; $p < 0.001$), Group C continued to show a sympathetic surge while Group D remained hemodynamically stable.

The post-hoc Tukey analysis confirmed this pattern. Significant differences were consistently observed between Group C and Group D ($p < 0.001$ at all post-insufflation time points), while Group C also differed significantly from Group M ($p \leq 0.004$ across majority time points). Comparisons between Group D and Group M showed milder but still statistically significant differences ($p \approx 0.03–0.05$), confirming the superior HR attenuation with Dexmedetomidine followed by Magnesium Sulphate.(Figure1)

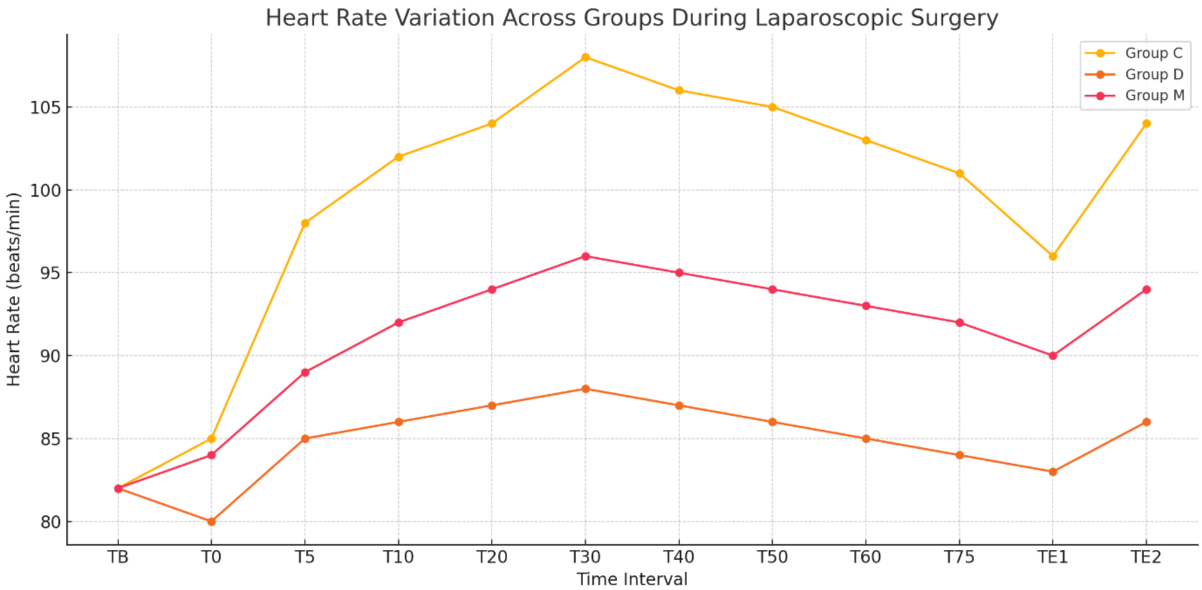

Figure 1 Heart Rate Variation Across Groups During Laparoscopic Surgery

SYSTOLIC BLOOD PRESSURE (SBP) VARIATION ACROSS GROUPS DURING STUDIED TIME INTERVALS

The baseline systolic blood pressure values were well-comparable between the groups, with means of 122 ± 9 mmHg in Group C, 121 ± 9 mmHg in Group D, and 121 ± 9 mmHg in Group M, and no significant difference observed ($p = 0.88$). Even prior to pneumoperitoneum (T0), the SBP values across the groups did not differ significantly ($p = 0.07$), indicating uniform pre-insult hemodynamic status.

A significant hypertensive response was consistently observed following CO_2 insufflation in the Control group. At T5, SBP rose markedly to 138 ± 12 mmHg in Group C, while SBP was significantly lower in Group D (124 ± 9 mmHg) and Group M (129 ± 10 mmHg) ($p < 0.001$). The hypertensive effect continued to intensify, reaching its peak at T30, where Group C recorded 146 ± 14 mmHg, as compared to 128 ± 9 mmHg in Group D and 136 ± 12 mmHg in Group M ($p < 0.001$). This reflects a substantially greater sympathetic stimulation in the absence of attenuation strategy.

Throughout the remainder of pneumoperitoneum—from T40 to T75—Group C remained within an elevated hypertensive range (145 ± 13 mmHg at T40 and 140 ± 11 mmHg at T75), whereas Group D consistently maintained near-baseline levels (127 ± 9 mmHg at T40; 123 ± 9 mmHg at T75), demonstrating superior stability in SBP. Group M continued to show moderate control (135 ± 11 mmHg at T40; 131 ± 10 mmHg at T75), falling between the Dexmedetomidine and Control groups.

The hypertensive surge persisted during airway manipulation phases as well. Immediately before extubation (TE1), Group C showed an SBP of 136 ± 10 mmHg, while Group D and Group M maintained lower values (122 ± 9 mmHg and 129 ± 10 mmHg, respectively; $p < 0.001$). After extubation (TE2), the stress response was again more pronounced in the Control group (145 ± 12 mmHg) compared with 126 ± 9 mmHg in Group D and 133 ± 11 mmHg in Group M ($p < 0.001$).

Post-hoc Tukey analysis confirmed Dexmedetomidine (Group D) to have the strongest attenuation compared to Control ($p < 0.001$ at all critical periods). Group M also demonstrated significant superiority over Group C at multiple time points (p = 0.003–0.008), while the comparison between Group D and Group M remained statistically significant but milder (p = 0.036–0.050), indicating partial efficacy of Magnesium Sulphate.(Figure 2)

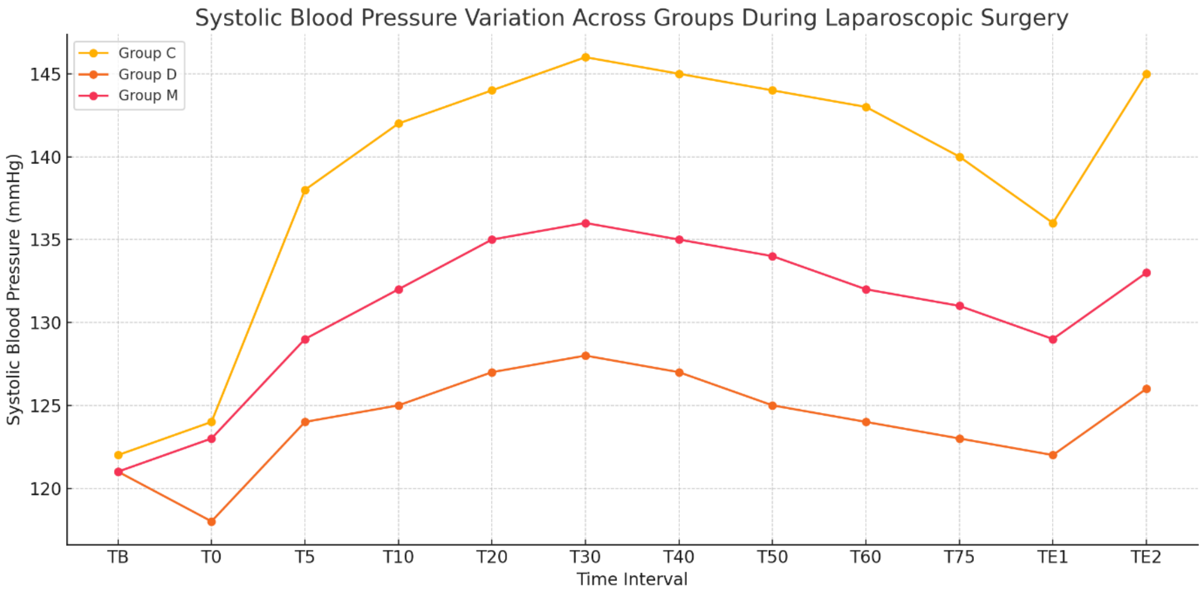

Figure 2 Systolic blood pressure Variation Across Groups During Laparoscopic Surgery

DIASTOLIC BLOOD PRESSURE (DBP) VARIATION ACROSS GROUPS DURING STUDIED TIME INTERVALS

The baseline diastolic blood pressure values were comparable across all groups, with Group C showing 78 ± 7 mmHg, Group D 78 ± 7 mmHg, and Group M 79 ± 7 mmHg, and no statistically significant difference (p = 0.92). Before insufflation (T0), DBP values remained statistically similar (p = 0.13), confirming homogeneous preoperative hemodynamic status.

With pneumoperitoneum initiation, Group C demonstrated a noticeable sympathetic response with a significant and progressive rise in DBP, whereas patients in Group D and Group M exhibited blunted DBP increases, reflecting the beneficial effects of Dexmedetomidine and Magnesium Sulphate. At T5, Group C recorded 88 ± 8 mmHg, significantly higher compared to 79 ± 7 mmHg in Group D and 84 ± 7 mmHg in Group M ($p < 0.001$).

The difference became more prominent by T30, marking the peak diastolic response, where Group C reached 94 ± 9 mmHg, followed by 89 ± 8 mmHg in Group M and 83 ± 7 mmHg in Group D ($p < 0.001$). Throughout subsequent intervals (T40 to T75), Group C persisted at elevated DBP levels (92–89 mmHg), whereas Group D remained significantly more stable (82–79 mmHg), showing strong attenuation of pneumoperitoneum-induced sympathetic effects. Group M served as an intermediate response category (88–85 mmHg), demonstrating moderate diastolic control.

During emergence and extubation, both TE1 and TE2 revealed a recurrence of sympathetic stimulation with DBP increase in all groups. However, the elevation was markedly higher in Group C (e.g., 92 ± 8 mmHg at TE2), compared with 81 ± 7 mmHg in Group D and 87 ± 7 mmHg in Group M ($p < 0.001$), indicating Dexmedetomidine's continued effectiveness even during recovery—a crucial phase for stress reduction.

Post-hoc Tukey analysis highlighted highly significant differences between Group C vs Group D throughout major hemodynamic stress periods ($p < 0.001$) and also demonstrated significant differences between Group C vs Group M (p = 0.008–0.019), confirming superior attenuation in the intervention groups. While differences between Group D and Group M were less pronounced, they remained statistically significant, indicating that Dexmedetomidine provided the highest level of DBP control.(Figure 3)

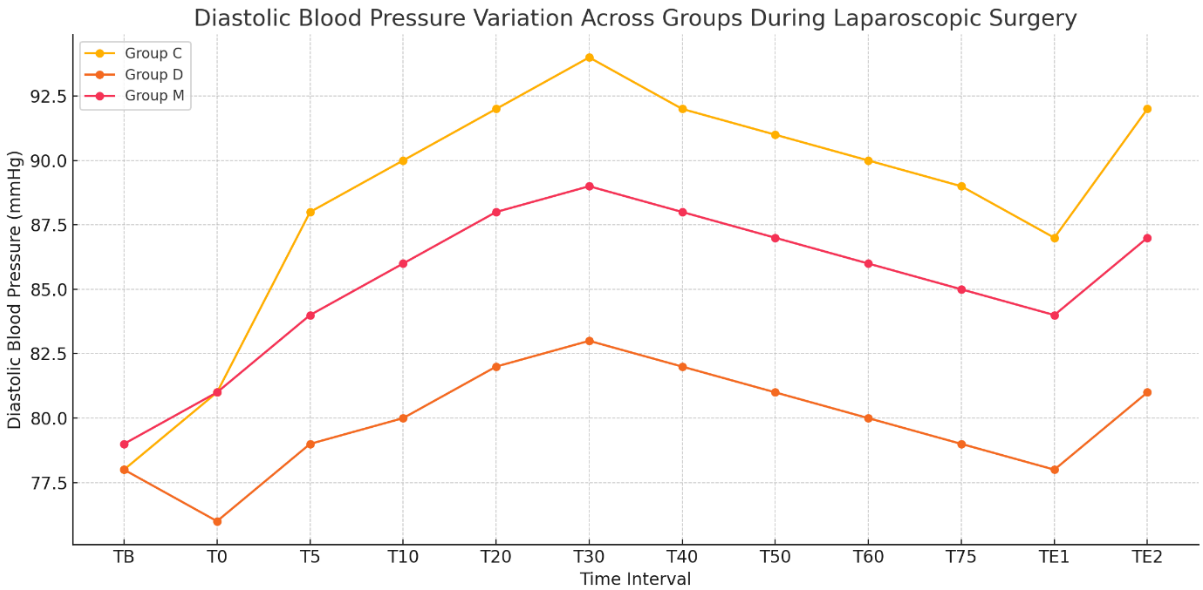

Figure 3 .DIASTOLIC BLOOD PRESSURE (DBP) VARIATION ACROSS GROUPS DURING STUDIED TIME INTERVALS

MEAN ARTERIAL PRESSURE (MAP) VARIATION ACROSS GROUPS DURING STUDIED TIME INTERVALS

The baseline MAP values were comparable among the three groups with no statistically significant differences (Group C: 92 ± 7 mmHg, Group D: 92 ± 7 mmHg, Group M: 92 ± 7 mmHg, p = 0.95). Prior to insufflation (T0), although Group D showed a slightly lower MAP (90 ± 7 mmHg), the variation remained statistically insignificant (p = 0.06), confirming uniform pre-pneumoperitoneum hemodynamic status between the groups.

Following CO_2 insufflation, a highly statistically significant increase in MAP was noted in the Control group, while the Dexmedetomidine and Magnesium groups demonstrated effective suppression of this rise. At T5, MAP increased to 103 ± 8 mmHg in Group C, compared to 94 ± 7 mmHg in Group D and 97 ± 7 mmHg in Group M ($p < 0.001$). The hypertensive effect intensified as pneumoperitoneum continued, with MAP peaking at T30 in Group C (111 ± 10 mmHg). In contrast, Group D recorded 96 ± 7 mmHg and Group M 101 ± 8 mmHg, again with $p < 0.001$, indicating a clear attenuation of sympathetic response in the intervention groups.

Throughout the intraoperative monitoring period (T40–T75), Group C maintained elevated MAP values (110–106 mmHg), whereas Group D consistently maintained MAP close to baseline (95–93 mmHg), demonstrating excellent hemodynamic stability. Group M showed moderate control with MAP values between 100–97 mmHg, positioned between Groups C and D.

During extubation—a well-established stress-inducing period—Group C again demonstrated a marked surge in MAP (110 ± 9 mmHg at TE2), whereas Group D (94 ± 7 mmHg) and Group M (99 ± 7 mmHg) maintained significantly lower MAP values ($p < 0.001$), reinforcing the role of study drugs in blunting extubation-related hemodynamic stress.

The post-hoc Tukey pairwise comparison analysis for Mean Arterial Pressure (MAP) demonstrated that the differences between Group C and Group D were highly statistically significant at all key intraoperative time intervals, including T10, T20, T30, and T40 ($p < 0.001$), Significant differences were also observed between Group C and Group M during the same periods (p = 0.003–0.005),. Comparisons between Group D and Group M showed borderline yet statistically significant differences (p = 0.039–0.048), confirming that while both drugs mitigated MAP elevation, Dexmedetomidine remained superior. During extubation (TE2) as well, all inter-group differences persisted with significance (p = 0.001–0.048), demonstrating that Dexmedetomidine continued to maintain the most stable MAP during recovery, followed by Magnesium Sulphate, whereas the Control group exhibited the most pronounced hypertensive responses throughout.(Figure 4)

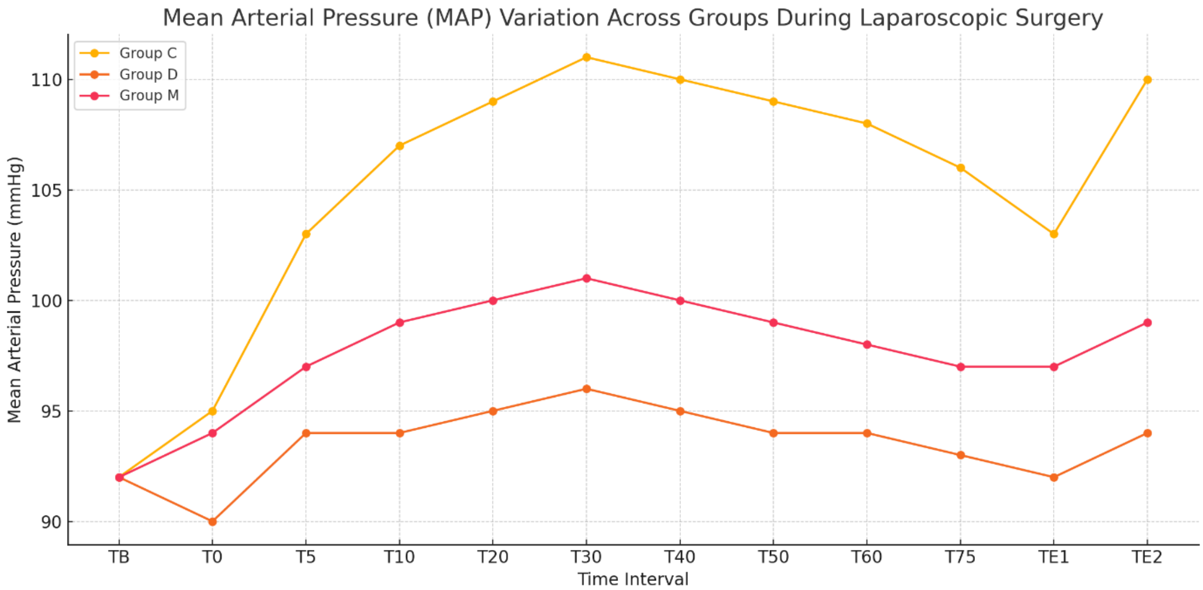

Figure 4 .MEAN ARTERIAL PRESSURE (MAP) VARIATION ACROSS GROUPS DURING STUDIED TIME INTERVALS

Sevoflurane % Comparison Between Group

Sevoflurane concentration across all three study groups was titrated within a standard clinically permitted range of 0.5–2.5%, ensuring adequate depth of anesthesia during laparoscopic surgery. The mean concentration remained close to 1.0% in all groups, with minimal variability (SD ≤ 0.10), indicating uniformly controlled anesthetic delivery.

Although Group D (Dexmedetomidine) required slightly lower sevoflurane concentration (0.90 ± 0.10%) compared to Group C and Group M (both 1.00 ± 0.00%), the difference did not reach statistical significance (p = 0.09).

End-Tidal CO_2 ($EtCO_2$ mmHg) Comparison Between Groups

End-tidal CO_2 levels were well controlled and maintained within a physiological range of 36–42 mmHg in all study groups throughout laparoscopic procedures. The mean $EtCO_2$ values demonstrated minimal variability: 39.1 ± 1.8 mmHg in Group C, 38.9 ± 1.7 mmHg in Group D, and 39.0 ± 1.6 mmHg in Group M. Median values remained identical (39 mmHg) in all groups. Statistical testing showed no significant difference between groups (p = 0.78), confirming that ventilation strategies and CO_2 clearance were uniformly maintained.

Intra-Abdominal Pressure (IAP mmHg) Comparison Between Groups

Intra-abdominal pressure fluctuated within the clinically recommended range of 5–15 mmHg in all patients throughout pneumoperitoneum. The mean IAP values remained comparable across the three study groups, measuring 12.4 ± 1.9 mmHg in Group C, 12.1 ± 1.7 mmHg in Group D, and 12.3 ± 1.8 mmHg in Group M, with no statistically significant difference between them (p = 0.88). Median IAP remained constant at 12 mmHg in all groups, indicating that brief variations above or below this level did not significantly influence distribution.

VAS Scores

Postoperative pain intensity was assessed using the Visual Analogue Scale (VAS) at predefined recovery intervals, and a statistically significant difference in pain scores was observed among the three groups throughout the study period (**p < 0.001**, ANOVA at all time points). Immediately after extubation (0 hr), patients in the Control group (Group C) experienced the highest pain (48.0 ± 9.2), whereas those receiving Dexmedetomidine (Group D) demonstrated substantially lower pain levels (32.0 ± 7.4), followed by the Magnesium group (37.0 ± 8.2). This trend persisted at 1 hour, where Group C recorded a mean score of 52.0 ± 11.0, significantly higher than Group D (34.0 ± 9.1) and Group M (39.0 ± 9.0). As recovery progressed, VAS scores steadily reduced in all groups; however, Group D consistently maintained the lowest pain perception. At 2 hours, the values were 46.0 ± 10.1, 30.0 ± 8.7 and 35.0 ± 8.3 in Groups C, D and M respectively. By 4 hours, pain scores decreased to 41.0 ± 8.8 in Group C, compared with 28.0 ± 7.3 in Group D and 32.0 ± 8.5 in Group M. At 6 hours, although pain was notably reduced, patients in Group C still reported the highest pain (38.0 ± 7.6), whereas Group D remained significantly lower (25.0 ± 7.2) with Group M showing intermediate levels (29.0 ± 7.0).

Post-hoc Tukey analysis further confirmed the superiority of Dexmedetomidine in postoperative analgesia. Group D demonstrated significantly lower VAS scores than Group C at all time intervals (**p < 0.001**), while Group M also showed significantly better pain relief compared with Control (**p = 0.002–0.008**). Although Group D outperformed Group M consistently, the differences, while statistically significant (**p = 0.038–0.049**), were clinically moderate. Overall, Dexmedetomidine provided the most effective postoperative pain attenuation, followed by Magnesium Sulphate, with the Control group showing the highest need for additional analgesia.(Figure 5)

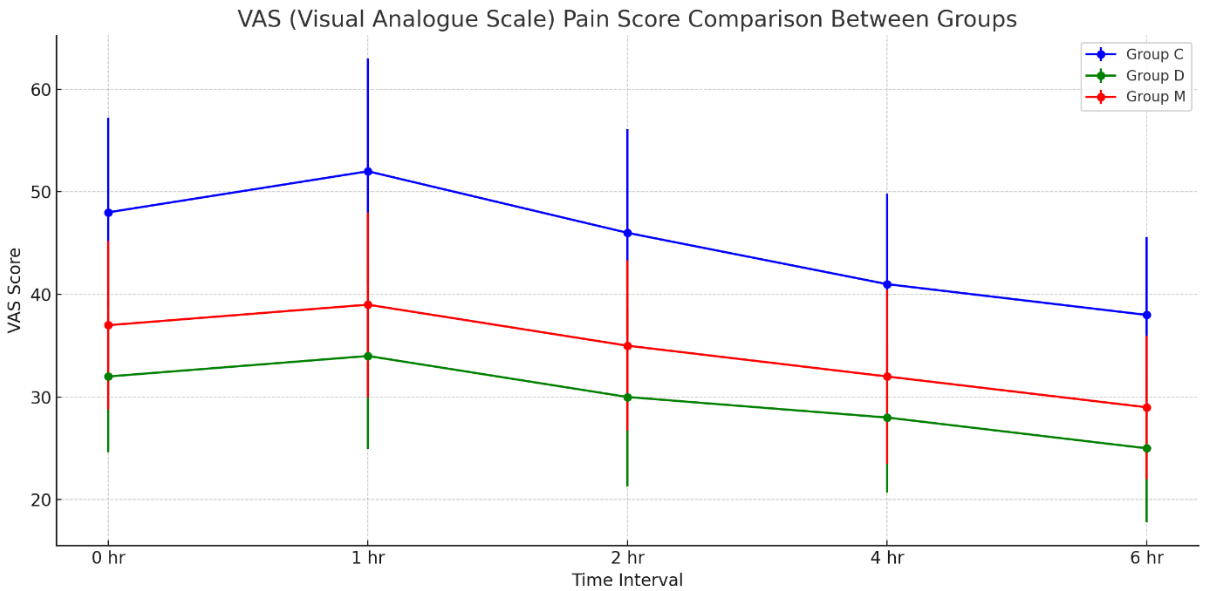

Figure 5 .VAS (Visual Analogue Scale) Pain Score Comparison Between Groups

Comparison of Sedation Scores Between Groups

Postoperative sedation scores were compared between the three study groups at predefined recovery intervals to assess the residual sedative effects of the administered drugs. A statistically significant inter-group difference was observed only at T0 (just after extubation), where Group D (Dexmedetomidine) demonstrated higher sedation (1.6 ± 0.4) compared to Group C and Group M, both of which recorded minimal sedation (1.0 ± 0.0) (p < 0.001, ANOVA). Post-hoc Tukey testing confirmed that the difference between Group D vs Group C and Group D vs Group M at T0 remained highly significant (p < 0.001 for both comparisons), indicating the expected sedative influence of Dexmedetomidine during immediate recovery.

At T5, although the sedation score was slightly higher in Group D (1.1 ± 0.2) compared to Group C and Group M (1.0 ± 0.0), this variation did not reach statistical significance (p = 0.067). From T15 through T60, sedation scores were identical across all groups (1.0 ± 0.0), and no significant difference was demonstrated (p = 1.000), indicating complete and comparable recovery of consciousness in all patients during the subsequent postoperative period.

Comparison of Adverse Events Between Groups

Adverse events were compared between the three study groups using Chi-square or Fisher's Exact test where appropriate. Hypotension was more frequently observed in Group D (6 patients; 12%) and Group M (5 patients; 10%) compared to Group C (2 patients; 4%), although this difference did not reach statistical significance (p = 0.18). Bradycardia showed a distinct pattern, with a significantly higher incidence in Group D (7 patients; 14%) compared to Group M (3 patients; 6%) and Group C (1 patient; 2%) (p = 0.03), consistent with the known sympatholytic and vagotonic effects of Dexmedetomidine. In contrast, PONV occurred most commonly in Group C (6 patients; 12%) followed by Group M (4 patients; 8%) and Group D (3 patients; 6%), but this variation was not statistically significant (p = 0.41). Similarly, postoperative shivering was more prevalent in the control group (5 patients; 10%), while lower rates were seen in Group M (3 patients; 6%) and Group D (2 patients; 4%), again without significant statistical difference (p = 0.47). These findings suggest that while Dexmedetomidine contributed to a statistically significant increase in bradycardia, it also led to a reduction in stress-related adverse effects such as PONV and shivering. Magnesium sulphate demonstrated a balanced and favorable safety profile.(Figure 6)

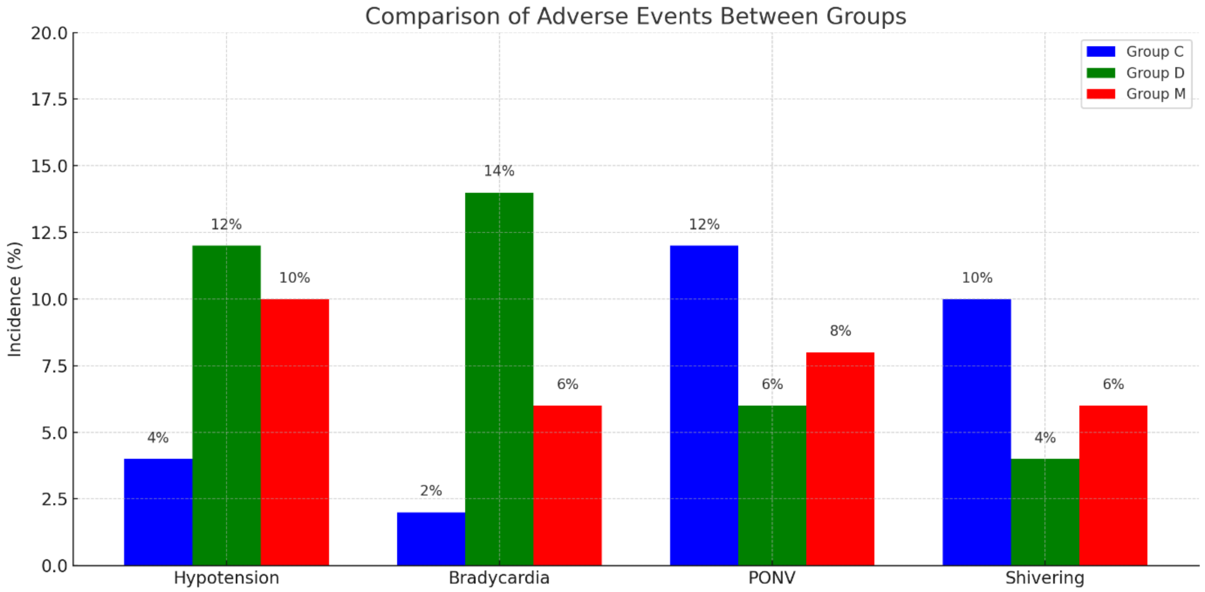

Figure 6 Comparison of Adverse Events Between Groups

DISCUSSION

The present prospective, randomized, double-blinded study demonstrated that the three groups were comparable with respect to baseline demographic characteristics, thereby minimizing confounding variables and ensuring internal validity. The mean age of patients ranged between 36–37 years with a slight male predominance and majority belonging to ASA physical status I, findings that are consistent with earlier studies. Chandrasekaran R & Jayaraj R et al. (2017)[22] reported a relatively younger cohort with male predominance, whereas Kaur U et al. (2018)[23] and Ninan A & Anand P et al. (2023)[24] observed comparable demographic distributions, reinforcing the generalizability of the present findings. Similarly, Jaisawal S et al. (2024)[25] and Kaasat A et al. (2025)[26] demonstrated homogeneous baseline characteristics, supporting the validity of comparative analysis across intervention groups .

The choice of anesthetic technique plays a crucial role in modulating hemodynamic responses during laparoscopic procedures. In the present study, the use of sevoflurane was associated with improved hemodynamic stability, particularly in the dexmedetomidine group, which maintained parameters close to baseline values. This finding aligns with the observations of Kaasat A et al. (2025)[26], who demonstrated that dexmedetomidine significantly reduces volatile anesthetic requirement, although their study utilized isoflurane. The superior performance observed in the present study may be attributed to the inherent vasodilatory and cardiostable properties of sevoflurane, which, when combined with the central sympatholytic action of dexmedetomidine, results in enhanced attenuation of the hemodynamic stress response. Magnesium sulphate also exhibited a moderate anesthetic-sparing effect, likely mediated through its calcium channel blocking properties, although its effect was less pronounced compared to dexmedetomidine.[9,14-17,23,26]

Heart rate response to CO_2 pneumoperitoneum is a sensitive indicator of sympathetic activation. In the present study, dexmedetomidine demonstrated the most effective attenuation of heart rate increase, with only a minimal rise compared to significant tachycardia observed in the control group. These findings are consistent with those reported by Chandrasekaran R & Jayaraj R et al. (2017)[22], who observed stable intraoperative heart rate in the dexmedetomidine group, and Kaur U et al. (2018)[23], who reported significantly lower heart rates with dexmedetomidine administration. Furthermore, Mallick S et al. (2019)[9], Ninan A & Anand P et al. (2023)[24], and Kaasat A et al. (2025)[26] consistently demonstrated a trend of dexmedetomidine providing superior control over heart rate compared to magnesium sulphate and control groups. The mechanism underlying this effect is primarily due to activation of central α2-adrenoceptors, leading to decreased norepinephrine release and attenuation of sympathetic outflow. Magnesium sulphate, although effective to some extent, produces a comparatively lesser reduction in heart rate due to its indirect action via calcium channel blockade and peripheral vasodilation.[14-17,22-24]

Similarly, systolic blood pressure changes observed in the present study further reinforce the superior efficacy of dexmedetomidine in attenuating the pressor response associated with pneumoperitoneum. The minimal rise in systolic blood pressure in the dexmedetomidine group compared to control and magnesium groups is in agreement with findings reported by Chandrasekaran R & Jayaraj R et al. (2017)[22] and Mallick S et al. (2019)[9], who observed significantly attenuated systolic responses with dexmedetomidine. Kaasat A et al. (2025)[26] also reported early reductions in systolic blood pressure with dexmedetomidine, further supporting its role as an effective agent in blunting perioperative stress responses. The pharmacological basis of this effect lies in the reduction of central sympathetic tone and inhibition of catecholamine release, whereas magnesium sulphate acts by reducing vascular smooth muscle contraction through calcium antagonism, thereby providing moderate but less consistent blood pressure control.

Diastolic blood pressure trends in the present study mirrored those of systolic pressure, with dexmedetomidine providing the greatest stability and minimal rise during pneumoperitoneum. Comparable findings were reported by Chandrasekaran R & Jayaraj R et al. (2017)[22] and Mallick S et al. (2019)[9], who demonstrated lower diastolic pressures in dexmedetomidine groups compared to magnesium and control. Kaasat A et al. (2025)[26] further confirmed that dexmedetomidine consistently maintains lower diastolic pressures intraoperatively. These findings highlight the ability of dexmedetomidine to provide comprehensive hemodynamic control by influencing both systolic and diastolic components of blood pressure.

Mean arterial pressure, being a composite indicator of tissue perfusion, was also best maintained in the dexmedetomidine group in the present study. The minimal increase in MAP compared to control and magnesium groups is in concordance with studies by Chandrasekaran R & Jayaraj R et al. (2017)[22], Mallick S et al. (2019)[9], and Kaasat A et al. (2025)[26], all of which reported superior attenuation of MAP fluctuations with dexmedetomidine. The combined reduction in cardiac output and systemic vascular resistance mediated by central sympatholysis contributes to this effect, making dexmedetomidine particularly advantageous in procedures involving pneumoperitoneum where hemodynamic fluctuations are pronounced .

Postoperative sedation profiles in the present study revealed significantly higher sedation scores in the dexmedetomidine group compared to magnesium and control groups, particularly in the early postoperative period. These findings are consistent with Kaur U et al. (2018)[23] and Ninan A & Anand P et al. (2023)[24], who reported higher Ramsay sedation scores with dexmedetomidine without associated respiratory depression. The sedative effect is mediated through activation of α2-adrenoceptors in the locus coeruleus, resulting in a state of cooperative sedation that enhances patient comfort while preserving airway reflexes. Magnesium sulphate produced moderate sedation, which may be attributed to its central nervous system depressant effects, although less predictable than dexmedetomidine.[14-17]

In contrast, postoperative pain scores assessed using the Visual Analog Scale did not differ significantly among the three groups in the present study, indicating that neither dexmedetomidine nor magnesium sulphate provides substantial independent analgesic benefit in this context. This observation is consistent with findings reported by Mallick S et al. (2019)[9] and Kaasat A et al. (2025)[26], who also reported no statistically significant differences in postoperative pain scores. Although dexmedetomidine possesses some analgesic properties through modulation of nociceptive pathways, its primary clinical benefit appears to be related to sedation and attenuation of sympathetic responses rather than direct analgesia.

The incidence of adverse effects in the present study was minimal, with no clinically significant episodes of hypotension or bradycardia observed. These findings are in agreement with Chandrasekaran R & Jayaraj R et al. (2017)[22] and Kaur U et al. (2018)[23], who reported occasional but manageable bradycardia with dexmedetomidine, and Ninan A & Anand P et al. (2023)[24], who noted mild nausea associated with magnesium sulphate. The favorable safety profile observed suggests that both dexmedetomidine and magnesium sulphate can be used safely as adjuncts in laparoscopic surgeries, with dexmedetomidine offering superior hemodynamic stability and sedation without significant increase in adverse outcomes .

The strengths of the present study include its randomized double-blind design, adequate sample size with equal group distribution, and standardized anesthesia protocol, all of which enhance the internal validity and reliability of the findings. Additionally, the use of multiple time-point hemodynamic measurements allowed for a comprehensive assessment of intraoperative physiological responses to CO_2 pneumoperitoneum. However, certain limitations must be acknowledged. The study was conducted at a single center, which may limit the generalizability of the results to broader populations. The exclusion of patients with significant comorbidities restricts applicability in high-risk surgical groups. Furthermore, biochemical markers of stress response such as plasma catecholamine levels were not measured, which could have provided objective corroboration of sympathetic attenuation. The follow-up period was limited to the immediate postoperative phase, thereby precluding assessment of long-term outcomes and recovery profiles. Future research should focus on multicentric trials with larger and more diverse patient populations, inclusion of high-risk groups, and evaluation of biochemical stress markers. Comparative studies assessing different dosing regimens and combinations of anesthetic agents may further refine optimal protocols. Additionally, long-term postoperative outcomes, including recovery quality and patient satisfaction, should be explored to provide a more holistic evaluation of these pharmacological interventions.

CONCLUSION

The present study demonstrates that dexmedetomidine is significantly more effective than magnesium sulphate in attenuating the hemodynamic response to CO_2 pneumoperitoneum in patients undergoing laparoscopic surgeries. Dexmedetomidine provided superior control of heart rate, systolic and diastolic blood pressure, and mean arterial pressure, along with better sedation profile, while maintaining a favorable safety margin. Magnesium sulphate also exhibited beneficial effects in reducing hemodynamic fluctuations but to a lesser extent compared to dexmedetomidine. Therefore, dexmedetomidine can be considered a preferable pharmacological adjunct for achieving perioperative hemodynamic stability in laparoscopic procedures.Therefore, for optimal perioperative hemodynamic control during laparoscopic surgery, Dexmedetomidine should be considered the preferred adjuvant**,** with Magnesium Sulphate serving as a reasonable secondary option.

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