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Original Research Article

A Comparative Evaluation of Dexmedetomidine Infusion versus Normal Saline on Intraoperative Hemodynamic Stability in Laparoscopic Cholecystectomy

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Conflict of interest: Nil

Abstract:

Background: Dexmedetomidine, an α2-adrenergic agonist, is widely used for its sedative, analgesic, and sympatholytic properties. This study aimed to compare the effects of dexmedetomidine infusion versus normal saline on intraoperative hemodynamic stability in patients undergoing laparoscopic cholecystectomy.

Material and Methods: A prospective, randomized, double-blinded study was conducted over one year at a tertiary care center in Western Gujarat involving 63 patients undergoing elective laparoscopic cholecystectomy. Patients were divided into two groups: Group 1 received dexmedetomidine infusion (0.2 µg/kg/hr in 100 ml saline), while Group 2 received 100 ml normal saline. Hemodynamic parameters—heart rate (HR), systolic blood pressure (SBP), diastolic blood pressure (DBP), mean arterial pressure (MAP), and oxygen saturation (SpO_2)—were recorded at predefined intraoperative intervals.

Results: Baseline HR was 87.97 ± 15.24 bpm in Group 1 and 83.87 ± 12.42 bpm in Group 2 ($p = 0.249$), which increased post-intubation to 96.94 ± 14.21 and 103.27 ± 14.05 bpm, respectively ($p = 0.081$). SBP peaked at 137.70 ± 15.67 mmHg in Group 1 and 141.93 ± 23.38 mmHg in Group 2 post-intubation ($p = 0.398$). MAP was consistently lower in the dexmedetomidine group, notably at 30 minutes (93.46 ± 9.65 mmHg vs. 98.43 ± 11.35 mmHg, $p = 0.104$). SpO_2 remained above 99% in both groups throughout, with no episodes of desaturation. No statistically significant differences were found between groups in any parameter, but the dexmedetomidine group showed consistently lower and more stable values.

Conclusion: Dexmedetomidine infusion during laparoscopic cholecystectomy provided smoother hemodynamic control, attenuating intraoperative HR and BP elevations more effectively than saline. Though the differences were not statistically significant, the trends favor dexmedetomidine as a safe and effective adjunct to general anesthesia in minimally invasive surgeries.

Keywords: Dexmedetomidine, Laparoscopic Cholecystectomy, Hemodynamic Stability, Intraoperative Monitoring, Alpha-2 Agonist.

Introduction

Laparoscopic cholecystectomy has emerged as the gold standard for treating symptomatic gallbladder disease, particularly cholelithiasis, due to its minimally invasive nature and superior patient outcomes. [1] Compared to traditional open surgery, laparoscopic techniques provide significant benefits, such as smaller incisions, reduced postoperative pain, faster recovery times, and shorter hospital stays. However, despite these advantages, the procedure is not without its challenges, especially concerning its impact on cardiovascular and respiratory functions. These changes, such as the release of catecholamines like norepinephrine and epinephrine, elevate heart rate, blood pressure, and vascular resistance, all of which complicate intraoperative management. [2] Therefore, finding effective medications to mitigate these effects remains a critical aspect of surgical care. [3] Dexmedetomidine, a highly selective alpha2-adrenergic receptor agonist, has gained attention for its potential to maintain hemodynamic stability during surgeries like laparoscopic cholecystectomy. [4] Its pharmacological properties include sedation, analgesia, and sympatholytic effects, making it particularly useful in counteracting the stress responses induced by the procedure. Dexmedetomidine reduces the release of stress hormones that are responsible for cardiovascular instability during surgery, helping to maintain steady blood pressure and heart rate. [5]

Laparoscopic cholecystectomy, although minimally invasive, creates significant hemodynamic changes due to the increased intra-abdominal pressure from CO_2 insufflation. [6] This pressure compresses the diaphragm and reduces venous return to the heart, resulting in decreased cardiac output and increased systemic vascular resistance. These effects are exacerbated by the stress response to surgical manipulation, which releases catecholamines and increases blood pressure and heart rate. Traditional anesthetic agents such as opioids and volatile anesthetics are effective in controlling these responses but come with side effects, including respiratory depression and delayed recovery. [7] Dexmedetomidine, with its unique action on alpha2-adrenergic receptors, offers a potential solution by providing both sedation and hemodynamic control without causing respiratory depression. [8] Existing studies have explored dexmedetomidine's benefits in various surgical contexts, with results indicating improved intraoperative stability and reduced postoperative complications. [9,10] This study aims to contribute to the growing body of literature on dexmedetomidine by providing a direct comparison with normal saline, with the goal of improving intraoperative management and postoperative outcomes for patients undergoing laparoscopic cholecystectomy.

Material and Methods

This study was conducted as a prospective, randomized, double-blinded controlled trial over a period of one year at a tertiary care hospital in Western Gujarat. Ethical clearance was obtained from the institutional ethics committee, and written informed consent was obtained from all participants after explaining the nature, purpose, benefits, and risks of the study. The study enrolled a total of 60 patients undergoing elective laparoscopic cholecystectomy under general anesthesia. Patients were randomly assigned to two groups: Group A received dexmedetomidine infusion, while Group B received an equal volume of normal saline. The study was conducted in compliance with the Declaration of Helsinki and good clinical practice guidelines.

Participants included patients aged 18 to 60 years, with American Society of Anesthesiologists (ASA) physical status I or II, scheduled for laparoscopic cholecystectomy. Exclusion criteria included patients with ASA grade III and IV, known contraindications to spinal anesthesia, chronic cardiac or respiratory illnesses, chronic kidney or liver disease, pregnancy, lactation, chronic pain disorders, and those on antihypertensives or antidepressants. Patients undergoing conversion from laparoscopic to open surgery were also excluded. Following randomization through a sealed envelope technique, Group A received dexmedetomidine at 0.2 µg/kg/hr diluted in 100 ml normal saline, while Group B received only 100 ml saline. Drug preparation was carried out by an anesthesiologist not involved in intraoperative or postoperative assessment, ensuring blinding of both participants and observers.

All patients underwent a detailed pre-anesthetic evaluation. In the operating room, standard ASA monitors were attached, and baseline hemodynamic parameters were recorded. Pre-medication included intravenous glycopyrrolate (0.005 mg/kg), midazolam (0.05 mg/kg), and fentanyl (2 µg/kg). Anesthesia was induced with intravenous propofol (2 mg/kg) and vecuronium (0.1 mg/kg) to facilitate endotracheal intubation, performed by an experienced anesthesiologist. Following intubation, anesthesia was maintained with isoflurane, nitrous oxide, oxygen, and intermittent doses of vecuronium. Dexmedetomidine or saline infusion was initiated just after induction in the respective groups. Intraoperative analgesia was supplemented with fentanyl boluses as needed. Intracuff pressure was maintained between 18–22 cm H_2O using a handheld manometer to avoid tracheal mucosal injury.

Hemodynamic parameters including heart rate (HR), systolic blood pressure (SBP), diastolic blood pressure (DBP), mean arterial pressure (MAP), and oxygen saturation (SpO_2) were recorded at specific intervals: baseline (T0), after completion of infusion (T1), immediately post-extubation (T2), and five minutes post-extubation (T3). Postoperative recovery was monitored in the PACU using the Ramsay Sedation Scale and the Numeric Rating Scale (NRS) for pain at multiple time intervals up to 48 hours. Intravenous paracetamol was administered as first-line analgesia when NRS $\geq$ 3, followed by intravenous diclofenac if pain persisted. Any adverse effects such as nausea, vomiting, pruritus, hypotension, bradycardia, respiratory depression, or urinary retention were recorded meticulously.

Primary outcomes assessed were intraoperative hemodynamic stability and efficacy of dexmedetomidine in attenuating stress responses. Secondary outcomes included postoperative pain scores, sedation levels, time to first analgesic, and incidence of adverse events. Data were entered in Microsoft Excel and analyzed using SPSS version 22. Quantitative variables were expressed as mean ± standard deviation, and qualitative variables as counts and percentages. Group comparisons were conducted using ANOVA for continuous variables and Chi-square or Fisher's exact test for categorical data. A p-value <0.05 was considered statistically significant at 95% confidence intervals.

Results

The baseline characteristics of the study population indicate a well-matched distribution between the two groups, ensuring the validity of the comparative outcomes. The mean age of participants in both groups was similar (Group 1: 37.88 ± 14.69 years vs. Group 2: 37.47 ± 9.52 years), with no statistically significant difference (p = 0.896), suggesting age-related confounding is unlikely. Gender distribution was also comparable, with females comprising the majority (79.4%) and no significant difference between Group 1 and Group 2 (75.8% vs. 83.3%, p = 0.458). (Table 1)

In terms of ASA classification, most patients were ASA Grade I (82.5%), indicating a generally healthy population. The ASA Grade distribution between the two groups was statistically insignificant (p = 0.242), further supporting the clinical equivalence of the groups before intervention. The diagnostic profile also showed a predominance of gallstone disease (GSD), accounting for 87.3% of the total cases, with a slightly higher representation in Group 2 (96.7%) compared to Group 1 (78.8%), though this was not statistically significant (p = 0.081). This uniformity suggests that variations in the type of biliary pathology are unlikely to influence the study results significantly. The presence of comorbidities was observed in 79.4% of the total cohort, distributed similarly between both groups (Group 1: 81.8%, Group 2: 76.7%; p = 0.303). Common comorbid conditions included hypertension and Hepatitis C, while other conditions like hypothyroidism, HIV positivity, and smoking were rare and evenly dispersed. (Table 1) The comparison of preoperative medications and airway characteristics between the two groups revealed no statistically significant differences, thereby ensuring a balanced baseline. A majority of patients (87.3%) were on some form of medication, with similar proportions across Group 1 (87.9%) and Group 2 (86.7%), and the difference was not statistically significant (p = 0.235). The medications most commonly noted included antihypertensives such as Amlodipine and Telmisartan, with occasional prescriptions like ART and Thyroxin also observed, though in very small numbers. This minimal variability in medication usage between groups reduces the likelihood of drug-related confounding on intraoperative outcomes. Furthermore, airway assessment showed that nearly all patients had an "easy" airway (98.4%), with only one case of difficulty reported in Group 1. The airway condition was statistically similar across both groups (p = 0.336), confirming that intubation and airway-related factors were uniformly distributed, allowing for a fair comparison of anesthetic effects.

In our study, the SBP consistently remained the highest among the three, with MAP values predictably positioned between SBP and DBP. All three parameters showed mild fluctuations, particularly after intubation and towards the later intraoperative stages, yet remained within normal clinical ranges. The absence of sharp deviations suggests stable hemodynamic control during the procedure in both groups, reinforcing the safety profile of the anesthetic regimens used.

Table 1: Baseline Demographic and Clinical Characteristics of Study Participants (N = 63)

Parameter	Group 1 (Dex) (n= 33)	Group 2 (NS) (n=30)	Total (N = 63)	p-value
Mean Age (years)	37.88 ± 14.69	37.47 ± 9.52	37.68 ± 12.40	0.896
Female (%)	25 (75.8%)	25 (83.3%)	50 (79.4%)	0.458
Male (%)	8 (24.2%)	5 (16.7%)	13 (20.6%)	
ASA Grade Grade I (%)	29 (87.9%)	23 (76.7%)	52 (82.5%)	0.242
ASA Grade Grade II (%)	4 (12.1%)	7 (23.3%)	11 (17.5%)	
Gallstone Disease	26 (78.8%)	29 (96.7%)	55 (87.3%)	0.081
Cholelithiasis	4 (12.1%)	0 (0.0%)	4 (6.3%)	
Gallbladder Polyp	3 (9.1%)	1 (3.3%)	4 (6.3%)	
Comorbidities +	27 (81.8%)	23 (76.7%)	50 (79.4%)	0.303
Hypertension	3 (9.1%)	3 (10.0%)	6 (9.5%)	
Hepatitis C	2 (6.1%)	2 (6.7%)	4 (6.4%)	
Hypothyroidism	1 (3.0%)	0 (0.0%)	1 (1.6%)	
HIV Positive	0 (0.0%)	1 (3.3%)	1 (1.6%)	
Smoker	0 (0.0%)	1 (3.3%)	1 (1.6%)	
Preoperative Medication Use	29 (87.9%)	26 (86.7%)	55 (87.3%)	0.235

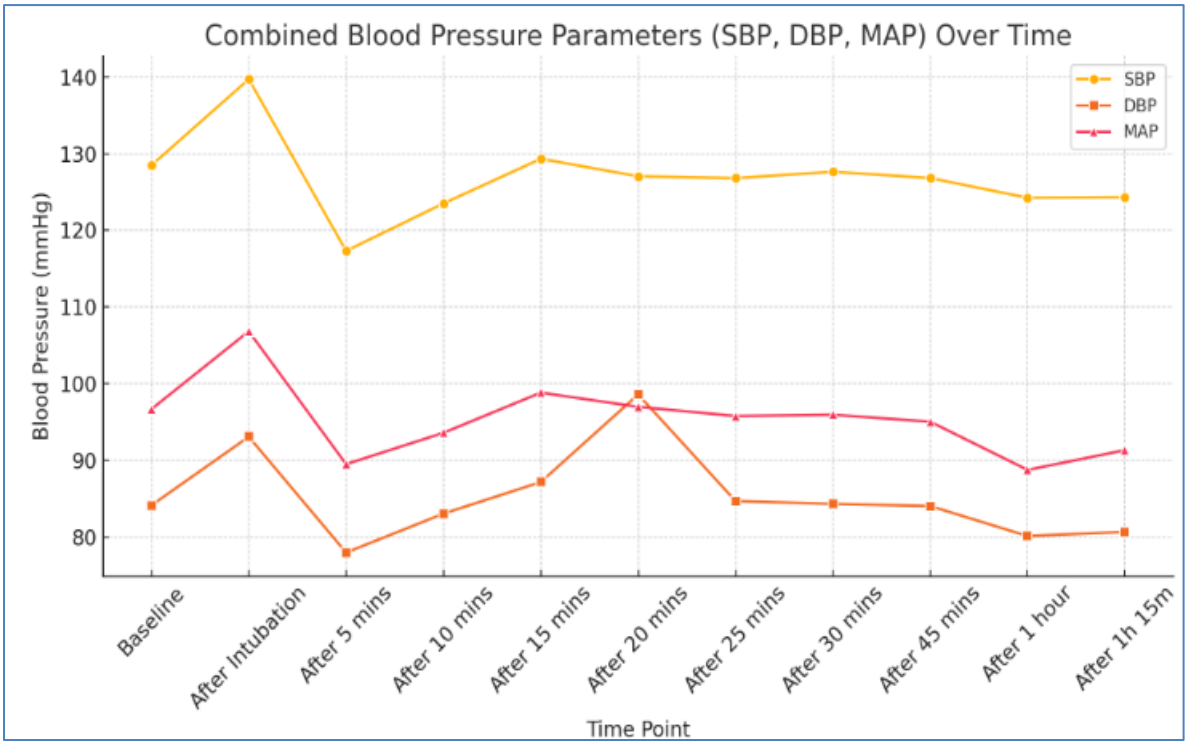

Figure 1:

In our study, the combined chart comparing Heart Rate (HR) and Oxygen Saturation (SpO_2) across various intraoperative intervals revealed that Group 2 (Normal Saline) demonstrated higher peaks in heart rate, especially following intubation and around the 1-hour mark. In contrast, Group 1 (Dexmedetomidine) maintained a more stable and controlled heart rate throughout the procedure. SpO_2 levels remained consistently above 99% in both groups at all recorded time points, with minimal variability.

These findings suggest that Dexmedetomidine was effective in attenuating sympathetic cardiovascular responses during surgery, without adversely affecting respiratory function or oxygen saturation.

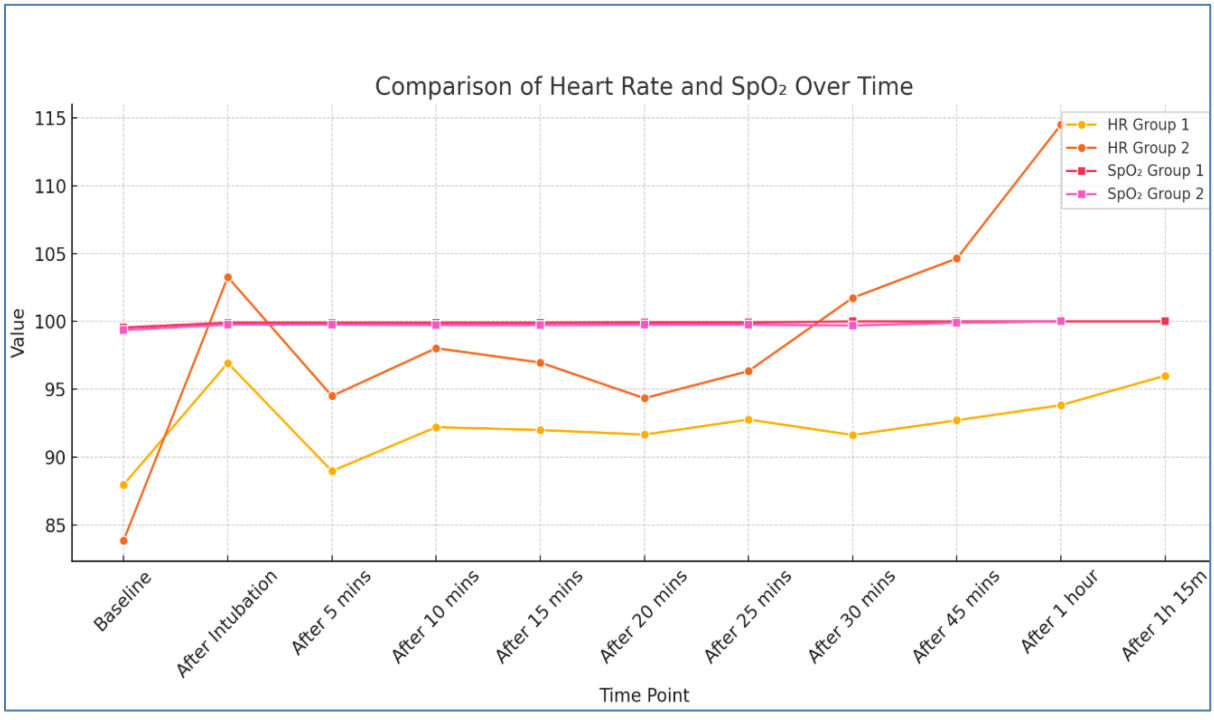

Figure 2:

Discussion

In our study comparing dexmedetomidine infusion with normal saline during laparoscopic cholecystectomy, both groups were clinically comparable at baseline, enabling a fair assessment of intraoperative and postoperative effects of the intervention. The vast majority of cases were related to gallstone disease, and the distribution of diagnoses and comorbidities was balanced. This similarity ensured that the observed differences in intraoperative parameters could be reliably attributed to the effects of dexmedetomidine. Prior studies by Verma et al.11 and Chavan et al. [12] have reported similar diagnostic profiles in comparable surgical populations, further reinforcing the external validity of our study. Additionally, the prevalence of common comorbidities such as hypertension was evenly distributed, similar to findings by Jan et al. [13], who emphasized that dexmedetomidine retains efficacy even in patients with underlying metabolic or cardiovascular conditions.

Hemodynamic parameters, particularly heart rate (HR), exhibited a notable pattern. While no statistically significant difference was observed at any time point, the dexmedetomidine group consistently showed lower HR values, especially following intubation and during pneumoperitoneum. This trend reflects dexmedetomidine's sympatholytic properties, which attenuate stress-induced cardiovascular responses. Rabie and Abdelfattah [14] and Yang and Gao [15] also reported similar findings, where dexmedetomidine infusion led to reduced HR variability and suppression of stress biomarkers such as cortisol and norepinephrine. Prashantha et al. [16] and Mercanoglu et al. [17] further supported the role of dexmedetomidine in achieving stable intraoperative HR, even during stress-inducing periods like pneumoperitoneum. Although HR differences in our study did not reach statistical significance, the clinical trend mirrors outcomes from these comparative trials.

Blood pressure parameters—including systolic (SBP), diastolic (DBP), and mean arterial pressure (MAP)—followed a similar pattern, with the dexmedetomidine group demonstrating slightly lower values throughout surgery. While again not statistically significant, these reductions reflect clinically meaningful hemodynamic stability. Studies by Yang and Gao [15], Jan et al. [13], and Rabie and Abdelfattah [14] have all shown dexmedetomidine’s role in blunting perioperative BP fluctuations, especially during intubation and insufflation.

Our findings at the 30-minute mark, where MAP was lower in the dexmedetomidine group, support its use in attenuating transient hypertensive responses during surgical manipulation. Madhuri et al. and Mercanoglu et al. [17] also emphasized that dexmedetomidine is effective at maintaining blood pressure without causing hypotension, making it suitable even in patients at risk of hemodynamic instability.

Importantly, oxygen saturation (SpO_2) was preserved in both groups across all time points, with no evidence of desaturation or respiratory compromise in patients receiving dexmedetomidine. This finding is consistent with Yang and Gao [15], Prashantha et al. [16], and Mercanoglu et al. [17], who observed that dexmedetomidine's sedative properties do not impair oxygenation, even when used as an adjunct in general anesthesia. These studies, along with our findings, affirm that dexmedetomidine can safely be incorporated into intraoperative anesthetic regimens without impacting ventilation or respiratory parameters. Overall, our study adds to a growing body of evidence supporting dexmedetomidine's role as a reliable agent for hemodynamic control in laparoscopic cholecystectomy, without compromising safety or respiratory function.

Despite its strengths, our study had certain limitations. The sample size was relatively small, which may have limited the statistical power to detect subtle differences between groups, particularly in hemodynamic parameters. Additionally, the study was conducted at a single center over a fixed period, which may affect the generalizability of the findings to broader populations or different surgical settings. Variations in individual anesthetic sensitivity, intraoperative stress levels, and surgeon technique could not be fully controlled. Furthermore, postoperative outcomes such as recovery time, pain scores, and long-term analgesic needs were not extensively analyzed, which may have provided additional insights into the benefits of dexmedetomidine.

Conclusion

Our study demonstrates that dexmedetomidine infusion, when used during laparoscopic cholecystectomy, provides favorable hemodynamic stability without causing significant adverse effects or compromising oxygen saturation. While differences in heart rate, blood pressure, and mean arterial pressure between the dexmedetomidine and normal saline groups were not statistically significant, the consistent trend toward lower values in the dexmedetomidine group suggests a beneficial clinical effect. These findings, supported by previous literature, highlight dexmedetomidine’s potential as a safe and effective adjunct in anesthesia for laparoscopic procedures, contributing to more stable intraoperative

conditions and possibly enhancing perioperative patient outcomes.

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