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A Comparative Study of Preoperative Dexmedetomidine and Fentanyl on Anaesthetic Requirement and Perioperative Hemodynamic Stress Response

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ABSTRACT

Background: Laryngoscopy and endotracheal intubation produce marked sympathetic stimulation, resulting in transient tachycardia and hypertension. Dexmedetomidine and fentanyl are commonly used to attenuate these responses, but their comparative efficacy remains clinically relevant.

Methods: This prospective, randomized comparative study included 90 adult patients (ASA I–II) undergoing elective surgery under general anesthesia. Patients were allocated into two groups of 45 each. Group D received intravenous dexmedetomidine 1 µg/kg, while Group F received intravenous fentanyl 2 µg/kg, administered 10 minutes before induction. Hemodynamic parameters, Bispectral Index (BIS), anesthetic requirements, postoperative recovery profile, and adverse events were recorded and compared.

Results: Baseline demographic characteristics were comparable between the groups. Dexmedetomidine produced significantly lower maximum heart rate (88.2 ± 8.1 vs. 101.6 ± 9.4 bpm; $p<0.001$) and mean arterial pressure (96.5 ± 8.4 vs. 108.7 ± 9.6 mmHg; $p<0.001$) following intubation. Isoflurane consumption (9.8 ± 1.9 vs. 12.4 ± 2.2 mL/h; $p<0.001$) and vecuronium requirement (6.8 ± 1.2 vs. 7.5 ± 1.3 mg; $p=0.009$) were significantly reduced in the dexmedetomidine group. BIS values after induction and intubation were significantly lower, indicating adequate anesthetic depth. Patients receiving dexmedetomidine had lower postoperative pain scores, longer time to first rescue analgesia, and reduced rescue analgesic requirement. Although bradycardia and hypotension occurred more frequently with dexmedetomidine, the differences were not statistically significant.

Conclusion: A single pre-operative dose of dexmedetomidine provided superior attenuation of the peri-operative hemodynamic stress response, reduced anesthetic requirements, improved postoperative analgesia, and maintained adequate depth of anesthesia compared with fentanyl. Dexmedetomidine can be considered an effective and safe anesthetic adjuvant for elective surgical procedures under general anesthesia.

Keywords*: Dexmedetomidine; Fentanyl; General anesthesia; Hemodynamic stress response; Bispectral Index; Laryngoscopy; Endotracheal intubation; Peri-operative analgesia.*

INTRODUCTION

General anaesthesia is an essential component of modern surgical practice, enabling the safe conduct of elective and emergency surgical procedures. A primary objective of balanced anaesthesia is to maintain adequate depth of anaesthesia while preserving cardiovascular stability. However, airway manipulation, laryngoscopy, endotracheal intubation, and surgical stimulation activate the sympathetic nervous system, producing transient increases in heart rate, arterial blood pressure, and circulating catecholamines. Although these responses are usually well tolerated in healthy individuals, they may precipitate myocardial ischemia, arrhythmias, or cerebrovascular complications in patients with limited cardiovascular

reserve. Therefore, attenuation of the perioperative haemodynamic stress response remains a key objective of modern anaesthetic practice.[1The perioperative stress response involves activation of the hypothalamic–pituitary–adrenal axis and sympathetic nervous system, leading to the release of catecholamines, cortisol, and other stress mediators that increase myocardial oxygen demand and metabolic activity. During laparoscopic surgery, carbon dioxide (CO_2) pneumoperitoneum further exaggerates these changes by increasing systemic vascular resistance and arterial pressure while reducing cardiac output. Effective suppression of these responses improves haemodynamic stability, decreases anaesthetic requirements, and enhances postoperative recovery.[2,3]Balanced anaesthesia combines hypnotics, opioids, inhalational agents, neuromuscular blockers, and adjuvant drugs to achieve hypnosis, analgesia, muscle relaxation, and autonomic stability. Premedication is an important component of this approach, reducing anxiety, blunting sympathetic responses, decreasing anaesthetic requirements, and improving perioperative comfort. Various agents, including opioids, β-blockers, calcium channel blockers, intravenous lignocaine, and α_2-adrenergic agonists, have been used to attenuate these responses.[4]Fentanyl, a potent synthetic μ-opioid receptor agonist, is widely used during induction because of its rapid onset, effective analgesia, and ability to suppress haemodynamic responses to laryngoscopy and surgical stimulation. However, its use is associated with dose-dependent adverse effects such as respiratory depression, postoperative nausea and vomiting, chest wall rigidity, delayed recovery, and opioid-related hyperalgesia, prompting the search for opioid-sparing alternatives.[5,6]Dexmedetomidine is a highly selective α_2-adrenergic receptor agonist with potent sympatholytic, sedative, and analgesic properties. By reducing central sympathetic outflow and norepinephrine release, it effectively attenuates cardiovascular responses to laryngoscopy and surgery while preserving respiratory function. In addition, dexmedetomidine provides cooperative sedation, reduces anaesthetic and opioid requirements, prolongs postoperative analgesia, minimizes emergence agitation, and improves perioperative haemodynamic stability with minimal respiratory depression.[7–10]Although both fentanyl and dexmedetomidine are widely used to attenuate perioperative stress responses, their comparative effectiveness in reducing anaesthetic requirements and maintaining haemodynamic stability remains an area of clinical interest. Therefore, the present study was undertaken to compare the effects of a single preoperative dose of dexmedetomidine and fentanyl on anaesthetic requirement and perioperative haemodynamic stress response in adult patients undergoing elective surgery under general anaesthesia, while also evaluating intraoperative haemodynamic stability, anaesthetic drug consumption, postoperative recovery, and safety profile.

MATERIALS AND METHODS

This prospective, randomized, comparative, hospital-based interventional study was conducted to evaluate the effect of a single pre-operative dose of dexmedetomidine versus fentanyl on anesthetic requirement and peri-operative hemodynamic stress response in patients undergoing elective surgery under general anesthesia.The study was conducted in the Department of Anaesthesiology

Sample Size

A total of **90 patients** were enrolled in the study. Participants were randomly allocated into two equal groups:

- **Group D (Dexmedetomidine group):** 45 patients received intravenous dexmedetomidine 1 μg/kg.
- **Group F (Fentanyl group):** 45 patients received intravenous fentanyl 2 μg/kg.

Study Population

Adult patients of either sex aged 18–60 years, belonging to American Society of Anesthesiologists (ASA) physical status I and II, and scheduled for elective surgery under general anesthesia were included in the study.

Inclusion Criteria

- Age between 18 and 60 years.
- ASA physical status I or II.
- Patients scheduled for elective surgery under general anesthesia with endotracheal intubation.
- Patients who provided written informed consent.

Exclusion Criteria

- ASA physical status III or IV.
- Anticipated difficult airway.
- History of cardiovascular, hepatic, renal, or neurological disorders.
- Patients receiving β-blockers, calcium channel blockers, or other drugs affecting cardiovascular responses.
- Known allergy to study medications.
- Pregnancy or lactation.
- Patients refusing participation.

Pre-operative Assessment

All patients underwent a detailed pre-anaesthetic evaluation, including history taking, physical examination, airway assessment, and routine laboratory investigations such as complete blood count, blood sugar, renal function tests,

electrocardiography, and chest radiography where indicated. Patients were kept nil per oral according to standard fasting guidelines.

Randomization and Study Groups
Patients were randomly assigned into two equal groups using a computer-generated randomization sequence.

- Group D (n = 45): Received intravenous dexmedetomidine 1 µg/kg diluted in normal saline and infused over 10 minutes before induction of anesthesia.
- Group F (n = 45): Received intravenous fentanyl 2 µg/kg administered 10 minutes before induction of anesthesia.

Anaesthetic Technique
All patients were premedicated with intramuscular glycopyrrolate 5–10 µg/kg approximately 30 minutes before induction. In the operating room, baseline heart rate, systolic blood pressure, diastolic blood pressure, mean arterial pressure, oxygen saturation (SpO_2), and Bispectral Index (BIS) values were recorded before administration of the study drug.

Following preoxygenation with 100% oxygen for 3 minutes, anesthesia was induced using intravenous sodium thiopentone (2.5%) at a dose of 4–6 mg/kg until loss of the eyelash reflex. Neuromuscular blockade was achieved with succinylcholine 1.5–2 mg/kg, and tracheal intubation was performed using an appropriately sized cuffed Portex endotracheal tube.Anesthesia was maintained with oxygen (66%), nitrous oxide (33%), isoflurane, and intravenous vecuronium bromide (0.1 mg/kg initial dose followed by 0.02 mg/kg maintenance doses as required). Controlled ventilation was provided using intermittent positive-pressure ventilation (IPPV). Isoflurane concentration was adjusted to maintain a Bispectral Index (BIS) between 40 and 60, indicating an adequate surgical plane of anesthesia.At the completion of surgery, residual neuromuscular blockade was reversed with intravenous glycopyrrolate 0.008 mg/kg and neostigmine 0.05 mg/kg, followed by extubation after adequate recovery.

Outcome Measures
Primary Outcome

- Peri-operative hemodynamic stress response, assessed by changes in:
    - Heart rate (HR)
    - Systolic blood pressure (SBP)
    - Diastolic blood pressure (DBP)
    - Mean arterial pressure (MAP)

Secondary Outcomes

- Intraoperative anesthetic requirement (isoflurane consumption).
- Total dose of vecuronium used.
- Duration of surgery.
- Duration of anesthesia.
- Bispectral Index (BIS) values.
- Ramsay Sedation Score.
- Visual Analogue Scale (VAS) for postoperative pain.
- Incidence of adverse events including bradycardia, hypotension, nausea, and vomiting.

Data Collection
Hemodynamic variables (HR, SBP, DBP, MAP), SpO_2, and BIS values were recorded at baseline before administration of the study drug, during laryngoscopy, every minute for the first 5 minutes after endotracheal intubation, and subsequently at 10-minute intervals until extubation. Isoflurane consumption was estimated using the Ehrenwerth and Eisenkraft formula. Postoperative vital signs, Ramsay Sedation Score, Visual Analogue Scale scores, and adverse events were recorded during the recovery period.

Statistical Analysis
The collected data were entered into Microsoft Excel and analyzed using Statistical Package for the Social Sciences (SPSS) software (version 25.0). Continuous variables were expressed as mean ± standard deviation (SD), whereas categorical variables were presented as frequency and percentage. Comparisons between groups were performed using the independent Student's t-test for continuous variables and the Chi-square test or Fisher's exact test for categorical variables. Repeated measurements of hemodynamic parameters were analyzed using repeated-measures analysis of variance (ANOVA) with appropriate post-hoc comparisons. A p-value <0.05 was considered statistically significant.

RESULTS
A total of 90 patients were enrolled and equally allocated to the Dexmedetomidine group (Group D, $n = 45$) and the Fentanyl group (Group F, $n = 45$). Baseline demographic and clinical characteristics, including age, sex distribution, body weight,

body mass index (BMI), and ASA physical status, were comparable between the two groups, with no statistically significant differences (all $p > 0.05$), indicating successful randomization (Table 1).
The comparison of perioperative hemodynamic parameters demonstrated that baseline heart rate (HR), mean arterial pressure (MAP), and oxygen saturation (SpO_2) were similar between the groups. However, following endotracheal intubation, Group D exhibited significantly lower maximum HR (88.2 ± 8.1 vs. 101.6 ± 9.4 bpm, $p < 0.001$) and maximum MAP (96.5 ± 8.4 vs. 108.7 ± 9.6 mmHg, $p < 0.001$) compared with Group F, indicating superior attenuation of the hemodynamic stress response. The lowest intraoperative SpO_2 values remained comparable between groups ($p = 0.312$) (Table 2, Figure 1).

Assessment of intraoperative anaesthetic requirements revealed significantly lower isoflurane consumption in Group D than in Group F (9.8 ± 1.9 vs. 12.4 ± 2.2 mL/h, $p < 0.001$). Similarly, the total vecuronium requirement was significantly reduced in the dexmedetomidine group (6.8 ± 1.2 vs. 7.5 ± 1.3 mg, $p = 0.009$). No significant differences were observed in the duration of anaesthesia or surgery between the two groups ($p > 0.05$) (Table 3).

Bispectral Index (BIS) monitoring showed comparable baseline values between the groups. Following induction and intubation, BIS values were significantly lower in Group D, reflecting deeper anaesthetic depth with dexmedetomidine. The mean maintenance BIS also remained significantly lower in Group D than in Group F (44.8 ± 2.8 vs. 46.9 ± 3.4, $p = 0.002$) (Table 4, Figure 2).

Postoperative recovery assessment demonstrated significantly higher Ramsay Sedation Scores at 30 minutes in Group D (2.9 ± 0.6 vs. 2.3 ± 0.5, $p < 0.001$). Patients receiving dexmedetomidine also experienced significantly lower pain scores at 2 hours (VAS: 2.8 ± 1.1 vs. 4.1 ± 1.2, $p < 0.001$), a longer time to first rescue analgesia (6.9 ± 1.8 vs. 4.5 ± 1.4 hours, $p < 0.001$), and a significantly lower proportion requiring rescue analgesia (31.1% vs. 64.4%, $p = 0.002$) (Table 5).
The incidence of adverse events was low and comparable between the two groups. Bradycardia and hypotension occurred more frequently in Group D, whereas nausea, vomiting, and respiratory depression were observed more commonly in Group F; however, none of these differences reached statistical significance ($p > 0.05$) (Table 6, Figure 3). Overall, both study drugs demonstrated acceptable safety profiles.

Table 1. Baseline Demographic and Clinical Characteristics

Variable	Group D (Dexmedetomidine) (n=45)	Group F (Fentanyl) (n=45)	p-value
Age (years), Mean ± SD	39.8 ± 10.6	40.7 ± 11.2	0.691
Male/Female, n	27/18	25/20	0.664
Weight (kg), Mean ± SD	64.9 ± 8.3	65.6 ± 7.8	0.684
BMI (kg/m²), Mean ± SD	24.3 ± 2.7	24.8 ± 2.9	0.423
ASA I, n (%)	27 (60.0)	26 (57.8)	0.829
ASA II, n (%)	18 (40.0)	19 (42.2)	

Table 2. Comparison of Hemodynamic Parameters

Parameter	Group D	Group F	p-value
Baseline HR (bpm)	82.4 ± 7.6	81.8 ± 7.3	0.708
Maximum HR after Intubation (bpm)	88.2 ± 8.1	101.6 ± 9.4	<0.001
Baseline MAP (mmHg)	92.4 ± 7.8	91.8 ± 8.2	0.731
Maximum MAP after Intubation (mmHg)	96.5 ± 8.4	108.7 ± 9.6	<0.001
Lowest SpO_2 (%)	99.0 ± 0.8	98.8 ± 0.9	0.312

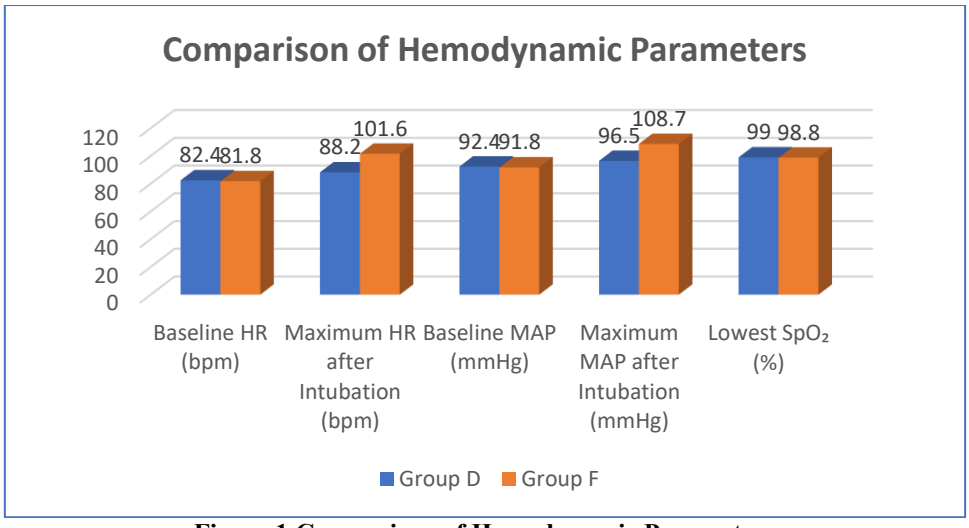

Figure 1 Comparison of Hemodynamic Parameters

Table 3. Comparison of Intraoperative Anaesthetic Requirement

Variable	Group D	Group F	p-value
Isoflurane Consumption (mL/h), Mean ± SD	9.8 ± 1.9	12.4 ± 2.2	<0.001
Total Vecuronium Requirement (mg), Mean ± SD	6.8 ± 1.2	7.5 ± 1.3	0.009
Duration of Anaesthesia (minutes), Mean ± SD	104.8 ± 18.2	107.6 ± 19.1	0.476
Duration of Surgery (minutes), Mean ± SD	89.6 ± 17.5	91.8 ± 18.3	0.561

Table 4. Comparison of Bispectral Index (BIS) Values

Time Point	Group D	Group F	p-value
Baseline	97.4 ± 1.5	97.2 ± 1.6	0.541
After Induction	48.6 ± 4.2	50.8 ± 4.6	0.020
After Intubation	46.8 ± 3.9	51.4 ± 4.8	<0.001
Maintenance (Mean)	44.8 ± 2.8	46.9 ± 3.4	0.002

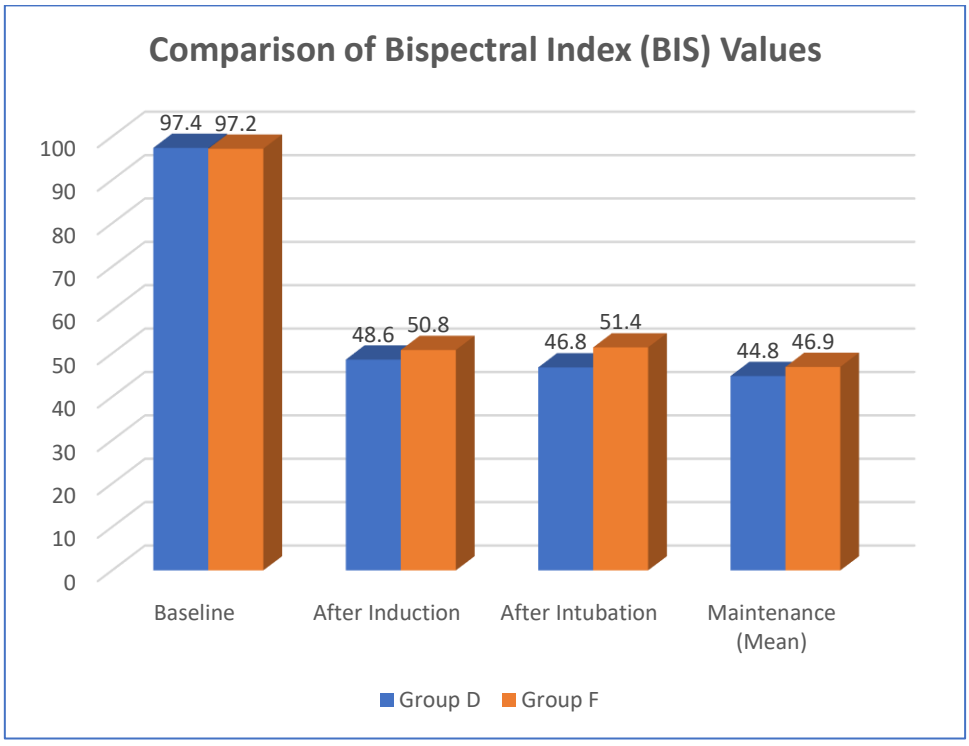

Figure 2 Comparison of Bispectral Index (BIS) Values

Table 5. Postoperative Recovery Profile

Variable	Group D	Group F	p-value
Ramsay Sedation Score (30 min)	2.9 ± 0.6	2.3 ± 0.5	<0.001

VAS Score at 2 hours	2.8 ± 1.1	4.1 ± 1.2	<0.001
Time to First Rescue Analgesia (hours)	6.9 ± 1.8	4.5 ± 1.4	<0.001
Rescue Analgesia Required, n (%)	14 (31.1)	29 (64.4)	0.002

Table 6. Incidence of Adverse Events

Adverse Event	Group D (n=45)	Group F (n=45)	p-value
Bradycardia, n (%)	5 (11.1)	1 (2.2)	0.091
Hypotension, n (%)	4 (8.9)	2 (4.4)	0.398
Nausea, n (%)	3 (6.7)	6 (13.3)	0.294
Vomiting, n (%)	2 (4.4)	5 (11.1)	0.238
Respiratory Depression, n (%)	0 (0.0)	1 (2.2)	0.315

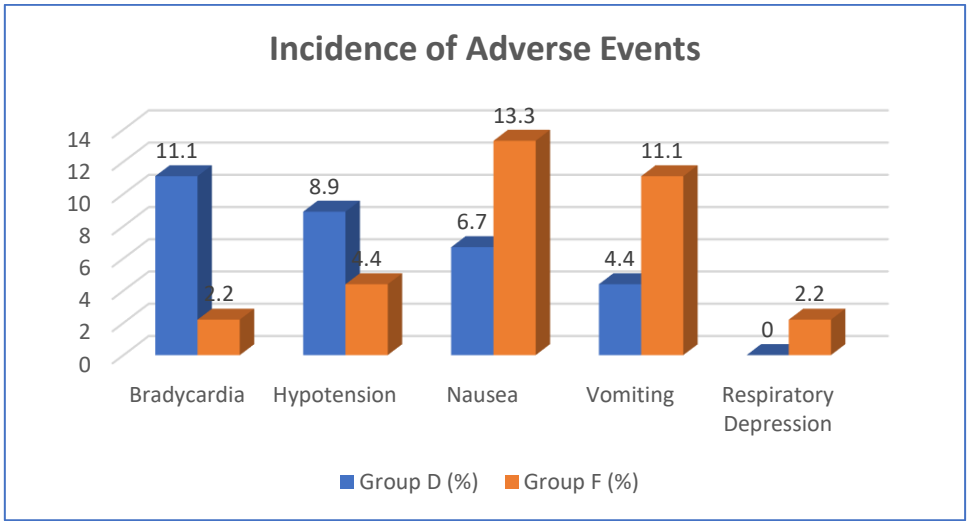

Figure 3 Incidence of Adverse Events

DISCUSSION

Our study demonstrated significantly better attenuation of the haemodynamic stress response with dexmedetomidine than fentanyl. The maximum heart rate after intubation was significantly lower in the dexmedetomidine group than in the fentanyl group (88.2 ± 8.1 vs. 101.6 ± 9.4 bpm; p<0.001), while the maximum mean arterial pressure was also significantly reduced (96.5 ± 8.4 vs. 108.7 ± 9.6 mmHg; p<0.001). These findings are consistent with those of Lovina Neil and Patel,[11] who reported superior perioperative haemodynamic stability with dexmedetomidine compared with fentanyl during laparoscopic surgery. Similar observations were reported by Vaswani et al.,[12] who demonstrated significantly smaller increases in heart rate and mean arterial pressure during laryngoscopy, pneumoperitoneum, and surgery with dexmedetomidine. Mahiswar, Dubey and Ranjan[13] further showed that dexmedetomidine was at least as effective as fentanyl in attenuating the haemodynamic response to laryngoscopy while maintaining stable cardiovascular parameters. Likewise, the meta-analysis by Khan et al.[14] involving eight randomized controlled trials confirmed significantly lower post-intubation heart rates with dexmedetomidine.Dexmedetomidine significantly reduced intraoperative anaesthetic requirements in our study. Isoflurane consumption (9.8 ± 1.9 vs. 12.4 ± 2.2 mL/h; p<0.001) and vecuronium requirement (6.8 ± 1.2 vs. 7.5 ± 1.3 mg; p=0.009) were significantly lower than with fentanyl. These findings agree with Bajwa et al.,[15] who demonstrated reduced inhalational anaesthetic and opioid requirements with improved haemodynamic stability following preoperative dexmedetomidine administration. Similarly, Laha et al.[16] reported that dexmedetomidine decreased anaesthetic requirements by attenuating the sympathoadrenal response during surgery.Our study also demonstrated significantly lower BIS values after induction, after intubation, and during maintenance of anaesthesia, indicating deeper yet well-controlled anaesthesia with dexmedetomidine. These findings are comparable with those of Vora et al.,[17] who reported that dexmedetomidine maintained adequate depth of anaesthesia while reducing volatile anaesthetic requirements during laparoscopic procedures.Postoperative recovery was superior in the dexmedetomidine group, with higher Ramsay Sedation Scores, lower VAS pain scores, prolonged time to first rescue analgesia (6.9 ± 1.8 vs. 4.5 ± 1.4 hours), and fewer patients requiring rescue analgesia (31.1% vs. 64.4%). These findings closely parallel those of Lovina Neil et al.,[11] who observed lower postoperative pain scores and prolonged analgesia with dexmedetomidine. Bajwa et al.[15] similarly demonstrated reduced postoperative opioid consumption and improved analgesia attributable to the analgesic and sympatholytic properties of dexmedetomidine.Although bradycardia (11.1%) and hypotension (8.9%) were numerically more frequent with dexmedetomidine, these differences were not statistically significant. In contrast, nausea, vomiting, and respiratory depression occurred more frequently in the fentanyl group. Comparable findings were reported by Tanskanen et al.,[18] who observed a modest increase in bradycardia with dexmedetomidine but fewer opioid-related adverse effects, including postoperative nausea, vomiting, and respiratory depression.

Overall, our findings are in agreement with previous randomized studies by Neil et al.,[11] Vaswani et al.,[12] Mahiswar et al.,[13] Khan et al.,[14] Bajwa et al.,[15] Laha et al.,[16] Vora et al.,[17] and Tanskanen et al.,[18] supporting dexmedetomidine as a superior alternative to fentanyl for achieving better perioperative haemodynamic stability, reducing anaesthetic and analgesic requirements, improving postoperative recovery, and maintaining an acceptable safety profile.

CONCLUSION

The present study demonstrated that a single pre-operative dose of dexmedetomidine (1 µg/kg) provided superior attenuation of the peri-operative hemodynamic stress response compared with fentanyl (2 µg/kg) in patients undergoing elective surgery under general anesthesia. Dexmedetomidine significantly reduced intraoperative anesthetic and muscle relaxant requirements, maintained an adequate depth of anesthesia with lower BIS values, and improved postoperative analgesia while prolonging the time to first rescue analgesia. Although bradycardia and hypotension were observed more frequently with dexmedetomidine, these adverse effects were infrequent and clinically manageable. Overall, dexmedetomidine proved to be a safe and effective anesthetic adjuvant for achieving better hemodynamic stability and enhanced peri-operative outcomes.

Limitations

This study was conducted at a single tertiary care center with a relatively small sample size, which may limit the generalizability of the findings. Only ASA I and II patients undergoing elective surgery were included; therefore, the results may not be applicable to high-risk patients or emergency procedures. Additionally, postoperative outcomes were assessed only during the early postoperative period, and long-term recovery and patient satisfaction were not evaluated.

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