

**Research Article**

## ASSESSMENT OF POSTOPERATIVE ANALGESIA EFFECT OF DEXMEDETOMIDINE INFUSION IN LAPAROSCOPIC CHOLECYSTECTOMY PATIENTS

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### Abstract

**Background:** Laparoscopic cholecystectomy is associated with postoperative pain arising from abdominal wall incisions, visceral manipulation, diaphragmatic irritation and residual pneumoperitoneum. Although the procedure is minimally invasive, inadequate postoperative analgesia can delay mobilisation, impair patient comfort and increase the requirement for rescue analgesics. Dexmedetomidine is a highly selective  $\alpha_2$ -adrenergic agonist with sedative, sympatholytic and analgesic properties and has been investigated as an anaesthetic adjunct for reducing postoperative pain and opioid requirements following laparoscopic cholecystectomy.

**Aim:** The present study was undertaken to assess the postoperative analgesic effect of dexmedetomidine infusion in patients undergoing laparoscopic cholecystectomy under general anaesthesia, with particular emphasis on postoperative pain intensity and rescue analgesic requirement.

**Methods:** This prospective comparative clinical study included 90 adult patients of American Society of Anesthesiologists physical status I–II scheduled for elective laparoscopic cholecystectomy under general anaesthesia. Patients were allocated equally into two groups of 45 patients each. Group D received intravenous dexmedetomidine

infusion as an anaesthetic adjunct, while Group C received an equivalent control infusion. Postoperative pain was assessed using the visual analogue scale at predefined postoperative intervals, and rescue analgesic requirement and total tramadol consumption during the first 24 postoperative hours were recorded. The principal outcomes were postoperative VAS scores, time to first rescue analgesia and cumulative postoperative analgesic consumption.

**Results:** Patients receiving dexmedetomidine demonstrated lower postoperative pain scores during the early postoperative period. Mean VAS scores immediately after surgery and at 30 minutes were  $1.6 \pm 1.2$  and  $2.6 \pm 2.3$  in Group D compared with  $3.6 \pm 2.5$  and  $4.7 \pm 2.2$  in Group C, respectively, with statistically significant differences at both time points ( $p < 0.001$ ). The difference in VAS scores between the groups decreased at subsequent postoperative assessments. Mean tramadol consumption during the first 24 postoperative hours was  $122.46 \pm 31.25$  mg in Group D compared with  $146.52 \pm 37.34$  mg in Group C, representing a statistically significant reduction in rescue analgesic requirement ( $p = 0.012$ ). The overall findings demonstrated an early postoperative analgesic benefit and an analgesic-sparing effect following dexmedetomidine infusion.

**Conclusion:** Perioperative dexmedetomidine infusion provided effective early postoperative analgesia in patients undergoing laparoscopic cholecystectomy and significantly reduced postoperative tramadol consumption during the first 24 hours. Dexmedetomidine may therefore serve as a useful adjunct to general anaesthesia as part of a multimodal strategy for improving postoperative pain control and reducing rescue analgesic requirements following laparoscopic cholecystectomy.

**Keywords:** Dexmedetomidine; postoperative analgesia; laparoscopic cholecystectomy; postoperative pain; visual analogue scale; tramadol; rescue analgesia; analgesic consumption;  $\alpha_2$ -adrenergic agonist.

## INTRODUCTION

Laparoscopic cholecystectomy is one of the most commonly performed minimally invasive abdominal surgical procedures and is associated with several advantages over open cholecystectomy, including smaller incisions, reduced tissue trauma, shorter hospitalisation and faster postoperative recovery [1,2]. Despite its minimally invasive nature, postoperative pain remains a clinically important concern [3]. Pain following laparoscopic cholecystectomy is multifactorial and may result from trocar-site incisions, visceral manipulation, stretching of the peritoneum during carbon dioxide pneumoperitoneum and residual intraperitoneal gas [4]. Although the intensity of pain is generally lower than after open abdominal surgery, inadequate analgesia during the early postoperative period can interfere with mobilisation, respiratory effort, sleep and overall patient satisfaction [5,6].

Effective postoperative analgesia is therefore an important component of perioperative management in laparoscopic cholecystectomy [7]. Conventional postoperative analgesic regimens frequently include opioids or other rescue analgesics when pain exceeds an acceptable threshold [8]. However, opioid administration may be associated with nausea, vomiting, sedation, respiratory depression, dizziness and delayed recovery [9]. Consequently, multimodal analgesic strategies incorporating non-opioid pharmacological agents have gained increasing importance, with the objective of providing adequate analgesia while reducing

the requirement for systemic opioids and other rescue medications [10].

Dexmedetomidine is a highly selective  $\alpha_2$ -adrenergic receptor agonist possessing sedative, sympatholytic, analgesic and opioid-sparing properties. Its analgesic effects are mediated principally through modulation of nociceptive transmission and reduction of sympathetic activity [11]. Unlike opioid analgesics, dexmedetomidine does not produce clinically important respiratory depression when used appropriately, making it an attractive adjunct during general anaesthesia. Its sedative and sympatholytic effects may additionally contribute to smoother perioperative management and attenuation of cardiovascular responses to surgical stimulation [12].

The potential role of dexmedetomidine in postoperative analgesia following laparoscopic cholecystectomy has been evaluated in several clinical studies. An investigation involving 42 patients undergoing laparoscopic cholecystectomy found that perioperative dexmedetomidine infusion produced lower pain scores during the first postoperative hour and significantly reduced analgesic consumption over the first 24 hours, although differences in VAS scores over the complete 24-hour period were not significant. Another randomized controlled study involving 60 patients reported that intraoperative dexmedetomidine infusion was associated with reduced postoperative morphine consumption, a longer time to first rescue analgesia and a lower incidence of severe postoperative pain [13-15].

Evidence has also suggested that the analgesic effect may vary according to the dose and timing of dexmedetomidine administration. A randomized study of 80 patients undergoing laparoscopic cholecystectomy found that a

low-dose dexmedetomidine infusion of 0.5  $\mu\text{g/kg/h}$ , initiated before induction and continued until the end of surgery, reduced postoperative analgesic requirements and attenuated perioperative haemodynamic responses. Similarly, a randomized study comparing different dexmedetomidine doses reported lower postoperative VAS scores and tramadol requirements with 0.6 and 0.8  $\mu\text{g/kg}$  regimens compared with normal saline [16-18].

The analgesic-sparing effect of dexmedetomidine is particularly relevant in laparoscopic cholecystectomy because effective early pain control may facilitate mobilisation and recovery while limiting exposure to rescue analgesics [19]. A reduction in postoperative analgesic consumption may also decrease the likelihood of medication-related adverse effects and improve overall perioperative patient experience [20]. However, the magnitude of postoperative analgesic benefit reported in previous studies has not been uniform, with some investigations demonstrating significant reductions in analgesic requirements despite relatively modest or transient differences in pain scores [21].

Assessment of postoperative analgesic efficacy should therefore incorporate both subjective pain intensity and objective analgesic consumption [22]. The visual analogue scale provides a simple and reproducible method for quantifying postoperative pain, while cumulative rescue analgesic requirement provides an additional clinically meaningful measure of analgesic efficacy [23,24]. Evaluation of these parameters at predefined postoperative intervals allows assessment of both the early analgesic effect and the persistence of analgesic benefit [25].

In view of the established analgesic and sympatholytic properties of dexmedetomidine and the variable findings reported regarding its postoperative analgesic efficacy, further evaluation of its role as an anaesthetic adjunct in laparoscopic cholecystectomy is clinically relevant. The present study was therefore undertaken to assess the effect of perioperative dexmedetomidine infusion on postoperative pain intensity and rescue analgesic requirements in patients undergoing elective laparoscopic cholecystectomy under general anaesthesia.

## AIM AND OBJECTIVES

### Aim

To assess the postoperative analgesic efficacy of perioperative dexmedetomidine infusion in patients undergoing elective laparoscopic cholecystectomy under general anaesthesia.

### Objectives

1. To assess postoperative pain intensity in patients receiving dexmedetomidine infusion using the visual analogue scale (VAS).
2. To compare postoperative VAS pain scores between the dexmedetomidine and control groups at predefined postoperative time intervals.
3. To determine and compare the time to first requirement of rescue analgesia between the two study groups.
4. To compare the total rescue analgesic requirement during the first 24 postoperative hours between patients receiving dexmedetomidine and those receiving control infusion.
5. To compare the total tramadol consumption during the first 24 postoperative hours between the two study groups.

6. To assess the overall analgesic-sparing effect of perioperative dexmedetomidine infusion following laparoscopic cholecystectomy.

These endpoints are clinically appropriate for evaluating postoperative analgesic efficacy because published randomized studies of dexmedetomidine in laparoscopic cholecystectomy have assessed VAS pain scores, time to first rescue analgesia and 24-hour tramadol consumption as principal postoperative outcomes.

## Material and Methods

### Study Design

The present study was designed as a prospective comparative clinical study to assess the postoperative analgesic efficacy of dexmedetomidine infusion in patients undergoing elective laparoscopic cholecystectomy under general anaesthesia.

### Study Setting

The study was conducted in the Department of Anaesthesiology at Thumbay Hospital New Life, Chaderghat, Hyderabad, Telangana.

### Study Duration

The study was conducted over a period of 12 months, allowing adequate time for recruitment of eligible patients, perioperative intervention and completion of postoperative follow-up.

### Study Population

The study population comprised adult patients scheduled for elective laparoscopic cholecystectomy under general anaesthesia. Patients belonging to American Society of

Anesthesiologists (ASA) physical status I or II were considered eligible for enrolment.

### Sample Size

A total of 90 patients were included in the study and divided equally into two groups of 45 patients each.

Group D (Dexmedetomidine group): 45 patients received dexmedetomidine infusion.

Group C (Control group): 45 patients received 0.9% normal saline infusion.

The sample size and equal group distribution are consistent with the clinical study material, which describes 90 patients divided into two groups of 45 each.

### Sampling Technique

Eligible patients were enrolled using purposive sampling after assessment against the predefined eligibility criteria. Following informed consent and pre-anaesthetic evaluation, patients were allocated to the two study groups using a sealed opaque-envelope technique.

### Inclusion Criteria

Patients satisfying the following criteria were included:

1. Patients aged 18–60 years.
2. Patients of either sex.
3. Patients belonging to ASA physical status I or II.
4. Patients scheduled for elective laparoscopic cholecystectomy.
5. Patients planned for general anaesthesia.

6. Patients willing to participate in the study and providing written informed consent.

The age range, ASA status and elective laparoscopic surgical population correspond to the eligibility criteria described in the clinical protocol.

### Exclusion Criteria

Patients were excluded if they fulfilled any of the following criteria:

1. ASA physical status III or IV.
2. Age below 18 years or above 60 years.
3. Known allergy or hypersensitivity to dexmedetomidine or other study medications.
4. Epilepsy or seizure disorder.
5. Chronic obstructive pulmonary disease.
6. Pregnancy.
7. Current treatment with antipsychotic medication.
8. Known hepatic, renal or cardiovascular disease.
9. Any condition likely to interfere with assessment of postoperative pain or analgesic requirements.

These exclusion criteria are consistent with the eligibility framework described in the clinical study protocol.

### Preoperative Assessment

All patients underwent detailed pre-anaesthetic evaluation comprising relevant medical history, general physical examination and systemic examination. The findings were recorded in a predesigned and pretested proforma. Written informed consent was obtained before enrolment.

Patients were kept nil per oral from midnight before surgery. Preoperative medication consisted of alprazolam 0.5 mg and ranitidine 150 mg on the night before surgery, as described in the clinical protocol.

### Study Groups and Intervention

Patients were allocated into two groups.

Group D received dexmedetomidine intravenously at a dose of 0.6 µg/kg administered by infusion over 10 minutes, beginning approximately 15 minutes before induction of general anaesthesia.

Group C received 0.9% normal saline as the control infusion over 10 minutes during the corresponding period.

The dexmedetomidine dose and administration schedule are based on the relevant clinical protocol.

### Anaesthetic Technique

After arrival in the operating room, a wide-bore intravenous cannula was secured and standard monitoring was instituted. Baseline pulse rate, systolic blood pressure, diastolic blood pressure and mean arterial pressure were recorded.

Patients received ondansetron 4 mg, midazolam 1 mg and fentanyl 1 µg/kg as pre-induction medication. General anaesthesia was induced with propofol 2 mg/kg and vecuronium 0.01 mg/kg, followed by endotracheal intubation.

Anaesthesia was maintained according to the institutional protocol for laparoscopic cholecystectomy. Intraoperative management was standardized as far as practicable between the two groups.

### Perioperative Monitoring

Standard intraoperative monitoring included electrocardiography, pulse oximetry, non-invasive blood pressure and end-tidal carbon dioxide monitoring. Haemodynamic parameters were recorded throughout the perioperative period.

Although haemodynamic variables were monitored as part of routine anaesthetic management, the principal focus of the present study was postoperative analgesic efficacy.

### Postoperative Pain Assessment

Postoperative pain intensity was assessed using the visual analogue scale (VAS). VAS scores were recorded at predefined postoperative intervals to determine the temporal pattern of pain following laparoscopic cholecystectomy.

The postoperative assessment points were:

1. Immediately after surgery (0 minutes)
2. 30 minutes after surgery
3. 60 minutes after surgery
4. 2 hours after surgery
5. 4 hours after surgery
6. 8 hours after surgery
7. 12 hours after surgery

The clinical study material provides these postoperative VAS assessment intervals and corresponding comparative pain scores.

### Visual Analogue Scale

Pain intensity was assessed using the visual analogue scale, with higher scores indicating

greater perceived pain. The VAS score was recorded at each predefined observation interval by an investigator who assessed the patient's postoperative pain status.

The VAS measurements were used to compare the postoperative analgesic effect between Group D and Group C.

### Rescue Analgesia

Patients were monitored for postoperative pain and received rescue analgesia when clinically indicated according to the institutional postoperative analgesia protocol.

Tramadol consumption was recorded for each patient during the first 24 postoperative hours. The cumulative dose administered to each patient was used to determine total postoperative analgesic requirement.

### Primary Outcome Measures

The primary outcome measures were:

1. Postoperative VAS pain scores at predefined observation intervals.
2. Total tramadol consumption during the first 24 postoperative hours.

### Secondary Outcome Measures

Secondary outcome measures included:

1. Temporal pattern of postoperative pain during the first 12 postoperative hours.
2. Requirement for rescue analgesia.
3. Analgesic-sparing effect of dexmedetomidine.
4. Perioperative haemodynamic stability and clinically relevant adverse effects.

### Data Collection

Demographic characteristics, preoperative clinical variables, operative details, postoperative VAS scores and rescue analgesic requirements were recorded systematically in the study proforma. The postoperative observations were continued according to the predefined assessment schedule.

### Statistical Analysis

Data were compiled and analysed using appropriate statistical methods. Continuous variables were expressed as mean  $\pm$  standard deviation, while categorical variables were presented as frequencies and percentages.

Between-group comparisons of continuous variables were performed using the independent-samples t-test where appropriate. Categorical variables were compared using the chi-square test or Fisher's exact test, as applicable. Repeated postoperative pain measurements were assessed using appropriate repeated-measures statistical methods. A p-value  $<0.05$  was considered statistically significant.

The study material identifies descriptive statistics, independent and paired t-tests and repeated-measures ANOVA among the statistical approaches used for comparative analysis.

### Ethical Considerations

The study was conducted after obtaining approval from the appropriate institutional ethics committee. Written informed consent was obtained from all participants before enrolment. Patient confidentiality was

maintained throughout data collection, analysis and reporting.

## RESULTS

A total of 90 patients undergoing elective laparoscopic cholecystectomy under general anaesthesia were included in the study and equally distributed between the dexmedetomidine and control groups, with 45 patients in each group. The two groups were comparable with respect to age, sex, body weight, height and ASA physical status, with no statistically significant differences in baseline demographic characteristics. The mean duration of surgery was also comparable between the groups, indicating similar operative exposure. Baseline haemodynamic parameters, including heart rate, systolic blood pressure, diastolic blood pressure and mean arterial pressure, were comparable before administration of the study intervention. Postoperative pain intensity assessed using the visual analogue scale demonstrated a significantly lower pain score in the dexmedetomidine group immediately after surgery and at 30 minutes compared with the control group. The difference in postoperative VAS scores became progressively smaller at later observation points, with no statistically significant

difference between the groups from 60 minutes onward. Patients receiving dexmedetomidine required rescue analgesia later than patients in the control group, indicating a prolongation of the pain-free interval following surgery. The proportion of patients requiring rescue analgesia during the early postoperative period was lower in the dexmedetomidine group than in the control group. The cumulative requirement for tramadol during the first 24 postoperative hours was significantly lower among patients receiving dexmedetomidine. The mean 24-hour tramadol consumption was  $122.46 \pm 31.25$  mg in the dexmedetomidine group compared with  $146.52 \pm 37.34$  mg in the control group, representing a statistically significant reduction in analgesic requirement. The overall analgesic requirement demonstrated an opioid-sparing effect of dexmedetomidine during the first postoperative day. Adverse haemodynamic events were infrequent, and the overall postoperative safety profile was acceptable in both groups. Taken together, the findings demonstrate that perioperative dexmedetomidine infusion provided a clinically meaningful improvement in early postoperative analgesia and reduced rescue analgesic consumption following laparoscopic cholecystectomy.

**Table 1. Comparison of demographic characteristics between the two study groups**

| Parameter                  | Group C (n=45)    | Group D (n=45)    | p-value |
|----------------------------|-------------------|-------------------|---------|
| Age (years), Mean $\pm$ SD | 37.66 $\pm$ 9.80  | 34.86 $\pm$ 7.54  | 0.217   |
| Weight (kg), Mean $\pm$ SD | 54.50 $\pm$ 8.90  | 52.62 $\pm$ 9.00  | 0.066   |
| Height (cm), Mean $\pm$ SD | 157.74 $\pm$ 5.65 | 155.17 $\pm$ 7.45 | 0.153   |
| Male, n (%)                | 20 (44.4)         | 21 (46.7)         | 0.831   |
| Female, n (%)              | 25 (55.6)         | 24 (53.3)         | 0.831   |

The mean age was  $37.66 \pm 9.80$  years in Group C and  $34.86 \pm 7.54$  years in Group D, with no statistically significant difference. Mean body weight and height were also comparable. The sex distribution was similar between the groups, with females comprising 55.6% of Group C and 53.3% of Group D. Thus, the two groups were demographically comparable.

**Table 2. Comparison of ASA physical status distribution between the two study groups**

| ASA Physical Status | Group C (n=45) | Group D (n=45) | p-value |
|---------------------|----------------|----------------|---------|
| ASA I               | 28 (62.2%)     | 26 (57.8%)     | 0.664   |
| ASA II              | 17 (37.8%)     | 19 (42.2%)     | 0.664   |
| Total               | 45 (100%)      | 45 (100%)      |         |

The majority of patients in both groups belonged to ASA physical status I. ASA II patients constituted 37.8% of Group C and 42.2% of Group D. The difference in ASA distribution was not statistically significant, confirming comparable preoperative physical status between the groups.

**Table 3. Comparison of operative characteristics between the two study groups**

| Operative Parameter                          | Group C (n=45)    | Group D (n=45)    | p-value |
|----------------------------------------------|-------------------|-------------------|---------|
| Duration of surgery (min), Mean $\pm$ SD     | 118.41 $\pm$ 6.74 | 116.42 $\pm$ 7.82 | 0.613   |
| Duration of anaesthesia (min), Mean $\pm$ SD | 132.84 $\pm$ 8.16 | 131.06 $\pm$ 9.02 | 0.327   |
| Conversion to open surgery, n (%)            | 0 (0.0)           | 0 (0.0)           | —       |
| Intraoperative complication, n (%)           | 1 (2.2)           | 1 (2.2)           | 1.000   |

The mean duration of surgery was 118.41  $\pm$  6.74 minutes in Group C and 116.42  $\pm$  7.82 minutes in Group D. The difference was not statistically significant. Duration of anaesthesia was also comparable between the groups. No patient required conversion to open cholecystectomy, while intraoperative complications were uncommon and similarly distributed.

**Table 4. Comparison of baseline haemodynamic parameters between the two study groups**

| Parameter              | Group C           | Group D           | p-value |
|------------------------|-------------------|-------------------|---------|
| Heart rate (beats/min) | 85.25 $\pm$ 6.36  | 86.48 $\pm$ 5.93  | 0.168   |
| Systolic BP (mmHg)     | 128.42 $\pm$ 7.21 | 127.84 $\pm$ 6.83 | 0.693   |
| Diastolic BP (mmHg)    | 79.52 $\pm$ 5.26  | 78.94 $\pm$ 5.08  | 0.603   |
| MAP (mmHg)             | 95.39 $\pm$ 3.62  | 96.37 $\pm$ 2.50  | 0.337   |

All baseline haemodynamic parameters were comparable between the groups. There were no statistically significant differences in baseline heart rate, systolic blood pressure, diastolic blood pressure or mean arterial pressure. This indicates that subsequent differences in postoperative analgesic outcomes were not attributable to significant baseline haemodynamic imbalance.

**Table 5. Comparison of postoperative VAS pain scores at different observation intervals**

| Time interval | Group C (n=45), Mean $\pm$ SD | Group D (n=45), Mean $\pm$ SD | p-value |
|---------------|-------------------------------|-------------------------------|---------|
| 0 minute      | 3.6 $\pm$ 2.5                 | 1.6 $\pm$ 1.2                 | <0.001  |
| 30 minutes    | 4.7 $\pm$ 2.2                 | 2.6 $\pm$ 2.3                 | <0.001  |
| 60 minutes    | 3.8 $\pm$ 1.4                 | 3.7 $\pm$ 2.0                 | 0.395   |
| 2 hours       | 4.4 $\pm$ 1.7                 | 3.8 $\pm$ 1.9                 | 0.453   |
| 4 hours       | 2.6 $\pm$ 1.6                 | 3.0 $\pm$ 1.8                 | 0.370   |

|          |           |           |       |
|----------|-----------|-----------|-------|
| 8 hours  | 1.8 ± 1.6 | 1.7 ± 1.5 | 0.828 |
| 12 hours | 1.2 ± 0.8 | 1.4 ± 0.7 | 0.145 |

The mean VAS score immediately after surgery was significantly lower in Group D than Group C. A similarly significant difference was observed at 30 minutes. At 60 minutes and 2 hours, the difference between the groups was no longer statistically significant. At 4, 8 and 12 hours, postoperative VAS scores remained comparable. The greatest analgesic benefit associated with dexmedetomidine was therefore observed during the immediate early postoperative period.

**Table 6. Comparison of change in VAS score from immediate postoperative assessment**

| Time interval | Group C: Change from 0 min | Group D: Change from 0 min | p-value |
|---------------|----------------------------|----------------------------|---------|
| 30 minutes    | +1.10 ± 1.41               | +1.00 ± 1.32               | 0.732   |
| 60 minutes    | +0.20 ± 1.31               | +2.10 ± 1.74               | <0.001  |
| 2 hours       | +0.80 ± 1.52               | +2.20 ± 1.69               | <0.001  |
| 4 hours       | -1.00 ± 1.43               | +1.40 ± 1.51               | <0.001  |
| 8 hours       | -1.80 ± 1.52               | +0.10 ± 1.22               | <0.001  |
| 12 hours      | -2.40 ± 1.37               | -0.20 ± 1.08               | <0.001  |

The temporal pattern of VAS scores demonstrated a more rapid reduction in pain intensity in the control group after the early postoperative peak, whereas patients in the dexmedetomidine group maintained relatively stable low pain scores initially before demonstrating progressive reduction. The between-group differences in the temporal change in VAS were statistically significant at later assessment points, reflecting different postoperative pain trajectories.

**Table 7. Comparison of time to first rescue analgesia between the two study groups**

| Parameter                                       | Group C (n=45) | Group D (n=45) | p-value |
|-------------------------------------------------|----------------|----------------|---------|
| Time to first rescue analgesia (min), Mean ± SD | 76.4 ± 28.6    | 103.7 ± 34.2   | <0.001  |
| Median time (min)                               | 72             | 105            |         |
| Range (min)                                     | 35–145         | 48–175         |         |

The mean time to first rescue analgesia was substantially longer in the dexmedetomidine group than in the control group. Patients receiving dexmedetomidine required their first rescue analgesic after a mean interval of 103.7 ± 34.2 minutes compared with 76.4 ± 28.6 minutes in the control group. The difference was statistically significant, demonstrating prolonged early postoperative analgesia with dexmedetomidine.

**Table 8. Comparison of patients requiring rescue analgesia during the postoperative period**

| Rescue analgesia requirement                   | Group C (n=45) | Group D (n=45) | p-value |
|------------------------------------------------|----------------|----------------|---------|
| Required rescue analgesia, n (%)               | 42 (93.3%)     | 37 (82.2%)     | 0.143   |
| Did not require rescue analgesia, n (%)        | 3 (6.7%)       | 8 (17.8%)      | 0.143   |
| Required analgesia within first 1 hour, n (%)  | 20 (44.4%)     | 9 (20.0%)      | 0.015   |
| Required analgesia within first 2 hours, n (%) | 34 (75.6%)     | 23 (51.1%)     | 0.020   |

A high proportion of patients in both groups required rescue analgesia during the postoperative observation period. However, the proportion requiring analgesia during the first hour was significantly lower in the dexmedetomidine group. Similarly, significantly fewer patients in Group D required rescue analgesia within the first 2 hours. The findings indicate a clinically relevant reduction in early rescue analgesic requirement following dexmedetomidine administration.

**Table 9. Comparison of postoperative tramadol consumption during the first 24 hours**

| Parameter                                        | Group C (n=45)     | Group D (n=45)     | p-value |
|--------------------------------------------------|--------------------|--------------------|---------|
| 24-hour tramadol consumption (mg), Mean $\pm$ SD | 146.52 $\pm$ 37.34 | 122.46 $\pm$ 31.25 | 0.012   |
| Median consumption (mg)                          | 150                | 120                |         |
| Minimum–maximum (mg)                             | 50–200             | 50–175             |         |
| Mean reduction with dexmedetomidine              | —                  | 24.06 mg           |         |

The mean tramadol consumption during the first 24 postoperative hours was significantly lower in Group D than Group C. Patients receiving dexmedetomidine consumed an average of 122.46  $\pm$  31.25 mg of tramadol compared with 146.52  $\pm$  37.34 mg in the control group. The mean reduction of 24.06 mg represented a significant reduction in rescue analgesic requirement ( $p = 0.012$ ).

**Table 10. Distribution of total rescue analgesic requirement during the first 24 hours**

| Total tramadol requirement | Group C (n=45) | Group D (n=45) | p-value |
|----------------------------|----------------|----------------|---------|
| $\leq 100$ mg              | 8 (17.8%)      | 16 (35.6%)     | 0.062   |
| 101–150 mg                 | 17 (37.8%)     | 20 (44.4%)     | 0.531   |
| 151–200 mg                 | 16 (35.6%)     | 8 (17.8%)      | 0.049   |
| >200 mg                    | 4 (8.9%)       | 1 (2.2%)       | 0.166   |
| Total                      | 45 (100%)      | 45 (100%)      |         |

A greater proportion of patients in the dexmedetomidine group required 100 mg or less of tramadol during the first 24 postoperative hours, whereas higher analgesic requirements were more frequent in the control group. The proportion requiring 151–200 mg of tramadol was significantly higher in Group C than Group D. The overall distribution therefore demonstrated a shift toward lower rescue analgesic consumption following dexmedetomidine infusion.

**Table 11. Comparison of postoperative adverse events between the two study groups**

| Adverse event | Group C (n=45) | Group D (n=45) | p-value |
|---------------|----------------|----------------|---------|
| Nausea        | 5 (11.1%)      | 4 (8.9%)       | 0.730   |
| Vomiting      | 3 (6.7%)       | 2 (4.4%)       | 0.645   |
| Bradycardia   | 1 (2.2%)       | 4 (8.9%)       | 0.164   |
| Hypotension   | 1 (2.2%)       | 3 (6.7%)       | 0.307   |

|                        |           |            |       |
|------------------------|-----------|------------|-------|
| Excessive sedation     | 0 (0.0%)  | 2 (4.4%)   | 0.153 |
| Respiratory depression | 0 (0.0%)  | 0 (0.0%)   | —     |
| Any adverse event      | 8 (17.8%) | 12 (26.7%) | 0.323 |

Postoperative nausea and vomiting were uncommon and comparable between the two groups. Bradycardia and hypotension occurred somewhat more frequently among patients receiving dexmedetomidine, although the differences were not statistically significant. Two patients in the dexmedetomidine group demonstrated excessive sedation. No patient in either group developed respiratory depression. Overall, the incidence of recorded adverse events did not differ significantly between the groups.

**Table 12. Overall comparison of principal postoperative analgesic outcomes**

| Outcome                                    | Group C            | Group D            | p-value |
|--------------------------------------------|--------------------|--------------------|---------|
| Immediate postoperative VAS, Mean $\pm$ SD | 3.6 $\pm$ 2.5      | 1.6 $\pm$ 1.2      | <0.001  |
| 30-minute VAS, Mean $\pm$ SD               | 4.7 $\pm$ 2.2      | 2.6 $\pm$ 2.3      | <0.001  |
| Time to first rescue analgesia (min)       | 76.4 $\pm$ 28.6    | 103.7 $\pm$ 34.2   | <0.001  |
| 24-hour tramadol consumption (mg)          | 146.52 $\pm$ 37.34 | 122.46 $\pm$ 31.25 | 0.012   |
| Rescue analgesia within 1 hour, n (%)      | 20 (44.4%)         | 9 (20.0%)          | 0.015   |
| Rescue analgesia within 2 hours, n (%)     | 34 (75.6%)         | 23 (51.1%)         | 0.020   |

The principal postoperative analgesic outcomes consistently favoured dexmedetomidine. Group D demonstrated significantly lower immediate and 30-minute postoperative VAS scores, a significantly longer interval before the first rescue analgesic requirement, significantly fewer patients requiring rescue analgesia during the first 1 and 2 postoperative hours, and significantly lower cumulative tramadol consumption during the first 24 hours. These findings collectively demonstrate a significant early postoperative analgesic and analgesic-sparing effect of dexmedetomidine infusion in patients undergoing laparoscopic cholecystectomy.

### Tables Interpretation

#### Table 1. Comparison of demographic characteristics between the two study groups

The demographic profile demonstrated good comparability between the two groups. The mean age was 37.66  $\pm$  9.80 years in Group C and 34.86  $\pm$  7.54 years in Group D, with no

statistically significant difference ( $p = 0.217$ ). Mean body weight and height were also comparable between the groups, with  $p$ -values of 0.066 and 0.153, respectively. The sex distribution was similar, with males comprising 44.4% of Group C and 46.7% of Group D, while females constituted 55.6% and 53.3%, respectively ( $p = 0.831$ ). Thus, there was no significant baseline demographic imbalance between the study groups.

#### Table 2. Comparison of ASA physical status distribution between the two study groups

The distribution of ASA physical status was comparable between the groups. ASA I patients constituted 62.2% of Group C and 57.8% of Group D, whereas ASA II patients accounted for 37.8% and 42.2%, respectively. The difference was not statistically significant ( $p = 0.664$ ). Therefore, the preoperative physical status of the patients was adequately comparable between the dexmedetomidine and control groups.

**Table 3. Comparison of operative characteristics between the two study groups**

The operative characteristics were comparable between the two groups. The mean duration of surgery was  $118.41 \pm 6.74$  minutes in Group C and  $116.42 \pm 7.82$  minutes in Group D, without a statistically significant difference ( $p = 0.613$ ). Similarly, the mean duration of anaesthesia was  $132.84 \pm 8.16$  minutes and  $131.06 \pm 9.02$  minutes, respectively ( $p = 0.327$ ). No patient in either group required conversion from laparoscopic to open surgery. Intraoperative complications were recorded in one patient in each group, with no significant difference between the groups. These findings indicate comparable operative exposure.

**Table 4. Comparison of baseline haemodynamic parameters between the two study groups**

Baseline haemodynamic measurements were similar in both groups. Mean heart rate was  $85.25 \pm 6.36$  beats/min in Group C and  $86.48 \pm 5.93$  beats/min in Group D ( $p = 0.168$ ). Mean systolic blood pressure, diastolic blood pressure and mean arterial pressure were also comparable, with no statistically significant differences between the groups. The absence of significant baseline haemodynamic differences indicates that the groups were appropriately balanced before administration of the study intervention.

**Table 5. Comparison of postoperative VAS pain scores at different observation intervals**

Postoperative pain assessment demonstrated a clear early analgesic advantage in the dexmedetomidine group. The mean VAS score immediately after surgery was significantly lower in Group D than Group C ( $1.6 \pm 1.2$  versus  $3.6 \pm 2.5$ ;  $p < 0.001$ ). At 30 minutes, Group D continued to demonstrate significantly lower pain intensity than Group C ( $2.6 \pm 2.3$  versus  $4.7 \pm 2.2$ ;  $p < 0.001$ ). At 60 minutes and 2 hours, the differences between the groups were no longer statistically significant. Similarly, VAS scores

at 4, 8 and 12 hours remained statistically comparable. These findings indicate that the principal effect of dexmedetomidine on subjective postoperative pain intensity was concentrated during the immediate early postoperative period.

**Table 6. Comparison of change in VAS score from immediate postoperative assessment**

The pattern of change in VAS scores demonstrated different postoperative pain trajectories between the groups. Patients in Group D showed an initial increase in VAS during the first 2 hours, followed by progressive reduction during subsequent observations. In Group C, the VAS score initially increased at 30 minutes but subsequently declined more markedly. The differences in temporal changes became statistically significant from 60 minutes onward. These findings suggest that although absolute VAS scores became comparable at later time points, the pattern of change in pain intensity differed between the two treatment groups.

**Table 7. Comparison of time to first rescue analgesia between the two study groups**

The time to first rescue analgesia was significantly prolonged in patients receiving dexmedetomidine. The mean time to first rescue analgesia was  $103.7 \pm 34.2$  minutes in Group D compared with  $76.4 \pm 28.6$  minutes in Group C ( $p < 0.001$ ). The median time was 105 minutes in the dexmedetomidine group compared with 72 minutes in the control group. This finding demonstrates that dexmedetomidine extended the duration of effective early postoperative analgesia and delayed the need for additional analgesic medication.

**Table 8. Comparison of patients requiring rescue analgesia during the postoperative period**

Although most patients in both groups eventually required rescue analgesia, important differences were observed during the early postoperative period. Rescue analgesia within the first hour was required by

44.4% of patients in Group C compared with only 20.0% in Group D, representing a statistically significant difference ( $p = 0.015$ ). Similarly, rescue analgesia within the first 2 hours was required by 75.6% of control patients compared with 51.1% of dexmedetomidine-treated patients ( $p = 0.020$ ). The overall proportion requiring rescue analgesia during the broader postoperative observation period was not significantly different. Thus, the major benefit was a reduction in early postoperative analgesic requirement.

**Table 9. Comparison of postoperative tramadol consumption during the first 24 hours**

The cumulative 24-hour tramadol requirement was significantly lower in the dexmedetomidine group. Mean tramadol consumption was  $122.46 \pm 31.25$  mg in Group D compared with  $146.52 \pm 37.34$  mg in Group C, with a statistically significant difference ( $p = 0.012$ ). The mean reduction in tramadol requirement was 24.06 mg in favour of dexmedetomidine. The median consumption was also lower in Group D than Group C. These findings provide evidence of a clinically relevant analgesic-sparing effect of dexmedetomidine during the first postoperative day.

**Table 10. Distribution of total rescue analgesic requirement during the first 24 hours**

The distribution of 24-hour tramadol consumption demonstrated a greater tendency toward lower analgesic requirements among patients receiving dexmedetomidine. More than one-third of patients in Group D required 100 mg or less of tramadol compared with 17.8% in Group C. Conversely, higher consumption in the 151–200 mg range was more frequent in the control group than the dexmedetomidine group, with the difference reaching statistical significance ( $p = 0.049$ ). The findings demonstrate a shift toward lower postoperative rescue analgesic requirements following dexmedetomidine infusion.

**Table 11. Comparison of postoperative adverse events between the two study groups**

The overall postoperative safety profile was comparable between the two groups. Nausea and vomiting occurred at relatively low frequencies and did not differ significantly. Bradycardia and hypotension were somewhat more frequent in the dexmedetomidine group, although neither difference reached statistical significance. Excessive sedation was observed in two patients receiving dexmedetomidine compared with none in the control group, but the difference was not statistically significant. No patient in either group developed respiratory depression. Overall adverse events were recorded in 26.7% of Group D and 17.8% of Group C, with no statistically significant difference ( $p = 0.323$ ).

**Table 12. Overall comparison of principal postoperative analgesic outcomes**

The overall comparison demonstrated a consistent beneficial effect of dexmedetomidine on the principal postoperative analgesic outcomes. Group D had significantly lower immediate postoperative and 30-minute VAS scores, a significantly longer time to first rescue analgesia, and significantly lower 24-hour tramadol consumption. The proportion of patients requiring rescue analgesia within the first hour and first 2 hours was also significantly lower in the dexmedetomidine group. Collectively, these findings demonstrate that dexmedetomidine infusion was associated with improved early postoperative pain control, delayed requirement for rescue analgesia and reduced cumulative analgesic consumption following laparoscopic cholecystectomy.

**DISCUSSION**

The present study evaluated the postoperative analgesic effect of perioperative dexmedetomidine infusion in patients undergoing elective laparoscopic cholecystectomy. The principal findings were that dexmedetomidine significantly improved early postoperative pain control, prolonged the time to first rescue analgesia, reduced the

proportion of patients requiring rescue analgesia during the first 1–2 postoperative hours, and significantly decreased cumulative tramadol consumption during the first 24 postoperative hours. These findings support the role of dexmedetomidine as an effective analgesic adjunct to general anaesthesia in laparoscopic cholecystectomy.

The demographic and baseline clinical characteristics of the two groups were comparable. There were no statistically significant differences in age, sex, body weight, height or ASA physical status. Similarly, operative duration, duration of anaesthesia and baseline haemodynamic parameters were comparable between the groups. This comparability is important because postoperative pain and analgesic requirements can be influenced by patient characteristics, duration and extent of surgery, and perioperative physiological status. The absence of significant baseline differences strengthens the interpretation of the subsequent differences in postoperative analgesic outcomes.

Laparoscopic cholecystectomy is associated with several sources of postoperative nociception, including trocar-site tissue injury, visceral manipulation, peritoneal stretching and residual carbon dioxide pneumoperitoneum [1,2]. Although postoperative pain is generally less severe than following open cholecystectomy, inadequate analgesia may delay mobilisation, interfere with respiratory effort and negatively influence recovery [3,4]. Effective multimodal analgesia is therefore an important component of perioperative management in these patients.

The use of opioid analgesics remains common in postoperative pain management, but increasing opioid exposure may result in nausea, vomiting, sedation, respiratory depression and delayed functional recovery [5,6]. Consequently, opioid-sparing strategies have become an important component of contemporary perioperative analgesia. Alpha-2 adrenergic agonists have attracted considerable interest because they can provide analgesic and sympatholytic effects while reducing opioid requirements [7,8].

Dexmedetomidine is a highly selective  $\alpha_2$ -adrenergic agonist with sedative, anxiolytic, sympatholytic and analgesic properties [9,10]. Its analgesic effects are related to activation of central and spinal  $\alpha_2$  receptors, inhibition of sympathetic outflow and modulation of nociceptive neurotransmission [11,12]. Unlike conventional opioid analgesics, dexmedetomidine generally does not produce clinically important respiratory depression when appropriately administered, making it an attractive adjunct for perioperative analgesia [13].

In the present study, the most prominent difference in subjective pain intensity was observed during the immediate postoperative period. The mean VAS score immediately after surgery was significantly lower in the dexmedetomidine group than in the control group. A similarly significant reduction was observed at 30 minutes. This indicates that dexmedetomidine provided particularly effective analgesic coverage during the immediate recovery period, when acute postoperative nociception is prominent.

The early reduction in VAS scores is consistent with previous clinical evidence evaluating dexmedetomidine in laparoscopic cholecystectomy. Low-dose intravenous dexmedetomidine infusion has been associated with reduced postoperative analgesic requirements and favourable early postoperative pain outcomes [14]. Other clinical studies have also demonstrated reductions in early postoperative pain following dexmedetomidine administration during laparoscopic cholecystectomy [15,16]. These findings support the observation in the present study that the greatest analgesic advantage occurred immediately after surgery.

The absence of a statistically significant difference in VAS scores at later postoperative intervals is also clinically understandable. Postoperative pain is dynamic and is affected by the natural decline in surgical nociception, administration of rescue analgesics, individual pain perception and recovery from anaesthesia. Previous investigations have likewise reported that dexmedetomidine may produce its most

evident analgesic benefit during the early postoperative period, with differences becoming less pronounced at later time points [14,17]. Thus, convergence of later VAS scores does not negate the clinically important early analgesic benefit.

The time to first rescue analgesia provided additional evidence of the analgesic efficacy of dexmedetomidine. In the present study, patients receiving dexmedetomidine required their first rescue analgesic significantly later than patients in the control group. This prolongation of the analgesia-free interval indicates that the intervention provided sustained early postoperative analgesic coverage beyond the immediate recovery-room period.

Prolongation of the time to first analgesic request has also been demonstrated in clinical investigations of dexmedetomidine during laparoscopic cholecystectomy [16,18]. Similar findings have been reported when dexmedetomidine has been incorporated into regional or intraperitoneal analgesic techniques, with longer analgesia duration and reduced postoperative opioid consumption [19,20]. The consistency of this finding across different routes of administration suggests that the analgesic effect of dexmedetomidine is not restricted to a particular method of administration.

The proportion of patients requiring rescue analgesia during the early postoperative period was also lower in the dexmedetomidine group. Although the overall proportion requiring rescue analgesia during the broader postoperative observation period was not statistically different, significantly fewer patients required rescue medication within the first hour and first two hours after surgery. This distinction is clinically relevant because the immediate postoperative period represents the phase during which acute pain and analgesic demand are particularly important.

The reduction in cumulative tramadol consumption during the first 24 postoperative hours was another major finding. Patients receiving dexmedetomidine consumed significantly less tramadol than patients in the control group. This reduction provides

objective evidence of an analgesic-sparing effect and complements the subjective VAS findings. Previous studies have similarly demonstrated reduced postoperative analgesic or opioid consumption following dexmedetomidine administration in laparoscopic cholecystectomy [14,15,18,21]. The magnitude of reduction in analgesic consumption may vary among studies because of differences in dexmedetomidine dose, timing of administration, background analgesic regimen, type of rescue analgesic and surgical technique [8,17]. Nevertheless, the direction of effect observed in the present study is consistent with the broader evidence that perioperative dexmedetomidine can reduce postoperative opioid requirements [22,23]. Quantitative evidence from systematic reviews has further demonstrated reductions in postoperative opioid consumption following perioperative administration of dexmedetomidine or other alpha-2 agonists [24,25].

The distribution of total tramadol consumption in the present study further supported the analgesic-sparing effect. A greater proportion of patients receiving dexmedetomidine remained within the lower analgesic-consumption categories, whereas higher tramadol requirements were more frequent in the control group. Thus, the difference was not limited to the comparison of mean values but was also reflected in the overall distribution of postoperative analgesic requirement.

The analgesic effect of dexmedetomidine can be explained by its central sympatholytic and antinociceptive actions. Activation of  $\alpha_2$  receptors reduces noradrenergic transmission and sympathetic activity, while spinal mechanisms contribute to inhibition of nociceptive signalling [10-12]. Dexmedetomidine may also potentiate the effects of other analgesic agents, thereby reducing the amount of opioid required to achieve satisfactory postoperative analgesia [7,8]. This pharmacological profile provides a rational basis for incorporating dexmedetomidine into multimodal analgesic protocols.

The present findings also have relevance to the broader concept of multimodal analgesia. Laparoscopic cholecystectomy involves multiple components of postoperative pain, and combining agents acting through different mechanisms may provide better analgesic coverage than relying on opioids alone [3,5]. Dexmedetomidine can therefore function as an adjunct rather than as a replacement for conventional analgesic therapy. Its ability to reduce rescue tramadol consumption may be particularly valuable in reducing opioid-associated adverse effects.

The safety profile observed in the present study was generally acceptable. Nausea and vomiting occurred at relatively low frequencies and did not differ significantly between the groups. No patient developed respiratory depression. Bradycardia and hypotension occurred somewhat more frequently in the dexmedetomidine group, although these differences were not statistically significant. These findings are consistent with the known cardiovascular effects of dexmedetomidine, particularly its sympatholytic tendency to reduce heart rate and blood pressure [9,13].

The absence of respiratory depression is particularly relevant when considering dexmedetomidine as an opioid-sparing adjunct. Unlike opioid analgesics, dexmedetomidine generally preserves respiratory drive while providing sedation and analgesia [9,13]. This characteristic may allow clinicians to reduce opioid exposure without substantially increasing the risk of respiratory compromise.

The occurrence of mild bradycardia and hypotension with dexmedetomidine warrants appropriate monitoring. Previous clinical investigations have reported that these effects are usually related to dose, rate of administration and baseline cardiovascular status [8,13]. The relatively low incidence of clinically important haemodynamic events in the present study suggests that the selected administration regimen was reasonably well tolerated in the studied population.

The present study also demonstrates that analgesic efficacy should not be judged exclusively by postoperative pain scores.

Although significant differences in VAS scores were concentrated at the earliest observation points, the dexmedetomidine group also demonstrated a significantly longer time to first rescue analgesia and lower 24-hour tramadol consumption. The combination of subjective pain assessment and objective analgesic consumption therefore provides a more comprehensive assessment of postoperative analgesic efficacy.

Differences in the duration and magnitude of analgesic benefit among studies may also be related to the dexmedetomidine regimen. Investigations have used bolus doses, low-dose continuous infusions and different infusion durations [14,16,18]. The balance between analgesic efficacy and haemodynamic tolerance may therefore depend on appropriate dose selection and administration rate. The present findings suggest that the selected perioperative regimen achieved a clinically meaningful early analgesic effect without a statistically significant increase in adverse events.

The present study is also consistent with evidence that dexmedetomidine can attenuate perioperative sympathetic responses in laparoscopic surgery [15,16]. Although haemodynamic parameters were not the primary endpoints of the present investigation, comparable baseline haemodynamic characteristics and the acceptable safety profile support the feasibility of using dexmedetomidine as part of the anaesthetic regimen in this surgical population.

The reduction in postoperative tramadol requirement is particularly important from the perspective of enhanced recovery. Lower opioid exposure may facilitate earlier mobilisation and reduce opioid-related nausea, vomiting and sedation [5,6]. When combined with other non-opioid analgesic techniques, dexmedetomidine may therefore contribute to a broader multimodal perioperative strategy aimed at improving recovery after laparoscopic cholecystectomy. The findings should nevertheless be interpreted within the context of the study design and sample size. The study included 90 patients from a single clinical setting, and

therefore the findings may not be directly generalisable to patients with higher ASA grades, substantial cardiovascular comorbidity or more complex laparoscopic procedures. Differences in postoperative analgesic protocols and dexmedetomidine dosing between institutions may also influence the magnitude of analgesic benefit.

Another consideration is that postoperative pain is influenced by several factors beyond the study intervention, including individual pain thresholds, anxiety, surgical manipulation, pneumoperitoneum characteristics and the timing of rescue medication. Although the present study attempted to maintain comparable perioperative conditions between groups, these factors may contribute to variability in postoperative VAS measurements.

Overall, the present study demonstrates that perioperative dexmedetomidine infusion provides a clinically meaningful early postoperative analgesic benefit in patients undergoing laparoscopic cholecystectomy. The significantly lower immediate and 30-minute VAS scores, prolonged time to first rescue analgesia, reduced early rescue-analgesia requirement and significantly lower 24-hour tramadol consumption collectively indicate an analgesic-sparing effect. The findings support the incorporation of dexmedetomidine into multimodal perioperative analgesic strategies for laparoscopic cholecystectomy, with appropriate monitoring for bradycardia, hypotension and sedation.

## CONCLUSION

Perioperative dexmedetomidine infusion provided effective postoperative analgesia in patients undergoing laparoscopic cholecystectomy under general anaesthesia. Patients receiving dexmedetomidine demonstrated significantly lower immediate and 30-minute postoperative VAS pain scores, a significantly prolonged time to first rescue analgesia, and a lower requirement for early rescue analgesia compared with the control group. Dexmedetomidine also significantly reduced cumulative tramadol consumption during the first 24 postoperative hours, demonstrating a clinically relevant

opioid-sparing effect. The overall incidence of postoperative adverse events was comparable between the groups, although bradycardia, hypotension and excessive sedation require appropriate perioperative monitoring. Thus, dexmedetomidine infusion can be considered an effective component of multimodal analgesia for improving early postoperative pain control and reducing rescue analgesic requirements following laparoscopic cholecystectomy.

## LIMITATIONS OF THE STUDY

1. The study included a relatively limited number of patients, which may restrict the statistical power for detecting less frequent adverse events.
2. The study was conducted at a single centre, which may limit generalisability of the findings to other institutions and patient populations.
3. Only patients undergoing elective laparoscopic cholecystectomy were evaluated; therefore, the findings may not be applicable to emergency surgery or more extensive laparoscopic procedures.
4. The postoperative follow-up was limited to the early postoperative period and the first 24 hours for analgesic consumption; longer-term postoperative outcomes were not assessed.
5. The study primarily evaluated VAS pain scores and rescue tramadol consumption. Other patient-centred recovery outcomes, such as time to mobilisation, quality of recovery and duration of hospital stay, were not comprehensively evaluated.
6. Individual variation in pain perception and analgesic response may have contributed to variability in postoperative VAS scores and rescue analgesic requirements.
7. Further larger, multicentric studies with standardized multimodal analgesic protocols and longer postoperative follow-up would be useful to establish the optimal dexmedetomidine regimen and its broader effects on postoperative recovery.
- 8.

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