RESEARCH

ENHANCED RECOVERY AFTER CARDIAC SURGERY USING REGIONAL ANAESTHESIA AND OPIOID-SPARING TECHNIQUES: A PROSPECTIVE RANDOMIZED CONTROLLED TRIAL

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ABSTRACT

Background: Enhanced Recovery After Cardiac Surgery (ERACS) is a multidisciplinary perioperative care pathway that integrates regional anaesthesia and opioid-sparing multimodal analgesia to improve postoperative recovery. However, evidence regarding its effectiveness in adult cardiac surgery remains limited, particularly in low- and middle-income healthcare settings. The objective is to evaluate the effectiveness of an ERACS protocol incorporating ultrasound-guided regional anaesthesia and opioid-sparing techniques on postoperative recovery in adult patients undergoing elective cardiac surgery. **Materials and Methods:** This prospective, single-center, randomized controlled trial was conducted in the Department of Cardiac Anaesthesia and Cardiothoracic Surgery, Rajendra Institute of Medical Sciences (RIMS), Ranchi, from. April 2020 to March 2022 A total of 120 adult patients aged 18–75 years undergoing elective cardiac surgery through median sternotomy were randomly assigned to Group A (ERACS; n=60), receiving bilateral ultrasound-guided erector spinae plane block with opioid-sparing multimodal analgesia, or Group B (Conventional; n=60), receiving standard opioid-based general anaesthesia. The primary outcome was total opioid consumption during the first 24 postoperative hours. Secondary outcomes included postoperative pain scores, time to extubation, intensive care unit (ICU) stay, hospital stay, rescue analgesic requirement, postoperative nausea and vomiting, postoperative complications, and patient satisfaction. **Result:** Baseline demographic and operative characteristics were comparable between the groups. Group A demonstrated significantly lower 24-hour opioid consumption (18.4 ± 5.7 vs. 34.9 ± 8.6 mg morphine equivalent; P<0.001), lower postoperative pain scores, longer time to first rescue analgesia, earlier extubation (5.2 ± 1.4 vs. 8.6 ± 2.3 hours; P<0.001), shorter ICU stay (2.1 ± 0.7 vs. 3.4 ± 1.1 days; P<0.001), and reduced hospital stay (6.8 ± 1.5 vs. 8.7 ± 2.0 days; P<0.001). The incidence of postoperative nausea and vomiting was significantly lower, while patient satisfaction scores were significantly higher in Group A. The incidence of major postoperative complications, including atrial fibrillation, respiratory complications, acute kidney injury, and 30-day mortality, was comparable between the groups. **Conclusion:** An ERACS protocol incorporating regional anaesthesia and opioid-sparing multimodal analgesia significantly improves postoperative recovery following adult cardiac surgery by reducing opioid requirements, improving pain control, facilitating early extubation, and shortening ICU and hospital stay without increasing perioperative complications.

INTRODUCTION

Cardiac surgery is associated with significant physiological stress, substantial postoperative pain, and a high risk of perioperative complications despite remarkable advances in surgical techniques, cardiopulmonary bypass technology, myocardial protection, and perioperative critical care. Patients undergoing median sternotomy often experience delayed extubation, impaired pulmonary function, prolonged intensive care unit (ICU) stay, delayed mobilization, and increased healthcare costs. Consequently, modern perioperative management has evolved beyond achieving successful surgical outcomes to emphasizing strategies that promote rapid recovery, minimize complications, and improve patient-centered outcomes.[1–3]

Traditionally, opioid-based anaesthesia has been the cornerstone of perioperative pain management in cardiac surgery because of its ability to provide profound analgesia and maintain haemodynamic stability. However, high-dose opioid administration is associated with several adverse effects, including respiratory depression, prolonged mechanical ventilation, postoperative nausea and vomiting (PONV), ileus, urinary retention, opioid-induced hyperalgesia, delirium, delayed mobilization, and prolonged hospitalization. Increasing awareness of these opioid-related complications has led to the adoption of opioid-sparing perioperative strategies aimed at improving recovery while maintaining adequate analgesia.[4–6]

Enhanced Recovery After Surgery (ERAS) is a multidisciplinary, evidence-based perioperative care pathway designed to reduce the physiological stress response to surgery, preserve organ function, and accelerate postoperative recovery. Initially developed for colorectal surgery, ERAS programmes have demonstrated significant reductions in postoperative complications, hospital length of stay, and healthcare costs across various surgical specialties. Building on these principles, the Enhanced Recovery After Cardiac Surgery (ERACS) programme was developed to address the unique perioperative challenges of cardiac surgery. ERACS integrates evidence-based interventions including preoperative counselling, optimization of comorbidities, standardized anaesthetic management, multimodal opioid-sparing analgesia, goal-directed fluid therapy, early extubation, early enteral nutrition, and early mobilization to enhance postoperative recovery and improve clinical outcomes.[1,2,7–10]

Effective postoperative analgesia is a fundamental component of ERACS because pain following median sternotomy can impair deep breathing, coughing, incentive spirometry, and physiotherapy, thereby increasing the risk of atelectasis, pneumonia, and delayed functional recovery. Multimodal analgesia combines different analgesic agents and techniques to provide superior pain control while reducing opioid requirements and opioid-related adverse events. Non-opioid analgesics, including paracetamol, ketamine, dexmedetomidine, and regional anaesthesia techniques, have demonstrated improved analgesic efficacy and facilitated earlier recovery after major cardiac surgery.[11–16]

Among regional anaesthetic techniques, the ultrasound-guided erector spinae plane (ESP) block has emerged as a safe and effective modality for perioperative analgesia in cardiac surgery. The ESP block provides extensive thoracic analgesia through the spread of local anaesthetic to the dorsal and ventral rami of the thoracic spinal nerves while avoiding many of the risks associated with neuraxial techniques in anticoagulated patients. Recent randomized controlled trials have demonstrated that bilateral ESP block significantly reduces perioperative opioid consumption, improves postoperative pain scores, facilitates early extubation, shortens ICU stay, and enhances patient satisfaction following cardiac surgery.[17–19]

Although ERACS has gained increasing acceptance worldwide, evidence regarding the combined use of regional anaesthesia and opioid-sparing multimodal analgesia in adult cardiac surgery remains limited, particularly in resource-constrained healthcare settings. Additional randomized controlled trials are required to establish the effectiveness and feasibility of these strategies across diverse patient populations. Therefore, the present prospective, single-center, randomized controlled trial was conducted in the Department of Cardiac Anaesthesia and Cardiothoracic Surgery at Rajendra Institute of Medical Sciences (RIMS), Ranchi, between. April 2020 to March 2022 to evaluate the effectiveness of an ERACS protocol incorporating ultrasound-guided bilateral erector spinae plane block and opioid-sparing multimodal analgesia in adult patients undergoing elective cardiac surgery. We hypothesized that the ERACS protocol would reduce postoperative opioid consumption, improve pain control, facilitate earlier extubation, shorten ICU and hospital stay, and enhance postoperative recovery without increasing perioperative complications compared with conventional opioid-based anaesthesia.[20]

MATERIALS AND METHODS

Study Design: This prospective, single-center, randomized controlled trial was conducted to evaluate the effectiveness of an Enhanced Recovery After Cardiac Surgery (ERACS) protocol incorporating regional anaesthesia and opioid-sparing multimodal analgesia in adult patients undergoing elective cardiac surgery.

Study Setting: The study was conducted in the Department of Cardiac Anaesthesia and Cardiothoracic Surgery, Rajendra Institute of Medical Sciences (RIMS), Ranchi, Jharkhand, India, from April 2020 to March 2022.

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Study Population: Adult patients scheduled for elective cardiac surgery through median sternotomy were prospectively screened for eligibility. A total of 120 patients were enrolled and randomly allocated into two equal groups.

Inclusion Criteria

1. Adult patients aged 18–75 years.
2. Patients scheduled for elective cardiac surgery through median sternotomy.
3. Patients undergoing coronary artery bypass grafting (CABG), valve replacement/repair, or combined CABG with valve surgery using cardiopulmonary bypass.
4. American Society of Anesthesiologists (ASA) physical status II–IV.
5. Patients willing to provide written informed consent.

Exclusion Criteria

1. Emergency or redo cardiac surgery.
2. Off-pump cardiac surgery.
3. Known allergy or contraindication to local anaesthetic drugs or regional anaesthesia.
4. Chronic opioid therapy or neurological disorders affecting pain assessment.
5. Patients refusing participation or unable to provide informed consent.

Sample Size: Based on previous studies evaluating opioid-sparing analgesia in cardiac surgery, a sample size of 120 patients (60 per group) was considered sufficient to detect a clinically significant difference in 24-hour postoperative opioid consumption with 80% power and a 5% level of significance, allowing for a 10% dropout rate.

Randomization and Blinding: Eligible patients were randomly assigned in a 1:1 ratio to either Group A (ERACS) or Group B (Conventional) using a computer-generated randomization sequence. Allocation concealment was ensured using sequentially numbered, opaque, sealed envelopes that were opened immediately before anaesthetic induction. Owing to the nature of the intervention, the attending anaesthesiologist was aware of the group allocation. However, the surgeons, postoperative ICU staff, outcome assessors, and statistician remained blinded to the treatment allocation throughout the study to minimize assessment bias.

Study Groups: Following randomization, the 120 eligible patients were equally allocated into two groups of 60 patients each.

Group A (Enhanced Recovery After Cardiac Surgery [ERACS] Group; n = 60): Patients received a standardized ERACS protocol in addition to conventional general anaesthesia. The protocol included an ultrasound-guided bilateral erector spinae plane (ESP) block performed before induction of anaesthesia, opioid-sparing multimodal analgesia with intravenous paracetamol, dexmedetomidine, and low-dose ketamine, goal-directed fluid therapy, early tracheal extubation, early enteral nutrition, respiratory physiotherapy, and early postoperative mobilization. These interventions were implemented according to the institutional ERACS pathway to optimize perioperative recovery and reduce opioid-related adverse effects.

Group B (Conventional Care Group; n = 60): Patients received standard opioid-based general anaesthesia without the use of regional anaesthesia. Perioperative management included routine intraoperative fluid therapy, conventional postoperative analgesia based primarily on intravenous opioids with supplemental non-opioid analgesics as required, and standard postoperative intensive care. Extubation, mobilization, and hospital discharge were performed according to conventional institutional practices without implementation of an enhanced recovery protocol.

Anaesthetic Technique: All patients underwent a standardized general anaesthesia protocol administered by experienced cardiac anaesthesiologists. Standard monitoring included continuous electrocardiography, pulse oximetry, invasive arterial blood pressure, central venous pressure, capnography, temperature, urine output, and bispectral index (BIS) monitoring. Following preoxygenation, anaesthesia was induced with intravenous midazolam (0.03–0.05 mg/kg), fentanyl (2–4 μg/kg), propofol (1–2 mg/kg), and rocuronium (0.6–1.0 mg/kg) to facilitate endotracheal intubation. Anaesthesia was maintained with sevoflurane in an oxygen–air mixture, supplemented with intermittent doses of rocuronium to maintain adequate neuromuscular blockade. Mechanical ventilation was adjusted to maintain normocapnia (end-tidal carbon dioxide 35–40 mmHg). Intraoperative haemodynamic management was guided by invasive monitoring, with vasopressors or inotropes administered as clinically indicated to maintain a mean arterial pressure of 65–80 mmHg. Cardiopulmonary bypass was conducted using standardized institutional protocols with systemic heparinization, mild hypothermia (32–34°C), and myocardial protection achieved using cold blood cardioplegia. At the completion of surgery, residual neuromuscular blockade was reversed, and patients were transferred to the cardiac surgical intensive care unit for postoperative management. The anaesthetic technique was standardized for both groups, with the primary difference being the addition of the ERACS interventions, including the ultrasound-guided bilateral erector spinae plane block and opioid-sparing multimodal analgesia in Group A.

Surgical Procedure: All surgical procedures were performed by experienced consultant cardiothoracic surgeons through a standard median sternotomy under cardiopulmonary bypass (CPB). After systemic heparinization (300–400 IU/kg) and achievement of an activated clotting time (ACT) greater than 480 seconds, CPB was established using standard aortic and right atrial cannulation. Myocardial protection was achieved with intermittent cold blood cardioplegia following aortic cross-clamping, and mild systemic hypothermia (32–34°C) was maintained during CPB. The surgical procedures included isolated coronary artery bypass

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grafting (CABG), valve replacement or repair, and combined CABG with valve surgery, performed according to the patient's underlying cardiac pathology and standard institutional protocols. At the completion of the procedure, patients were weaned from CPB after restoration of satisfactory cardiac function, anticoagulation was reversed with protamine sulfate, meticulous haemostasis was achieved, mediastinal and pleural drains were placed as indicated, and the sternum was closed using stainless-steel wires followed by layered closure of the soft tissues and skin. All patients were subsequently transferred to the cardiac surgical intensive care unit for standardized postoperative monitoring and management.

Surgical Procedure: All patients underwent elective cardiac surgery through a standard median sternotomy performed by experienced cardiothoracic surgeons. Following induction of general anaesthesia and systemic heparinization, cardiopulmonary bypass (CPB) was established using standard aortic and right atrial cannulation. Myocardial protection was achieved with intermittent cold blood cardioplegia, and mild systemic hypothermia (32–34°C) was maintained during CPB. Surgical procedures included isolated coronary artery bypass grafting (CABG), valve replacement or repair, and combined CABG with valve surgery, depending on the patient's underlying cardiac pathology. After completion of the surgical procedure, patients were weaned from CPB following satisfactory restoration of cardiac function, and anticoagulation was reversed with protamine sulfate. Meticulous haemostasis was achieved before placement of mediastinal and pleural drains, and the sternum was closed using stainless-steel wires followed by routine soft tissue and skin closure. The operative technique and cardiopulmonary bypass management were standardized for all patients to minimize procedural variability between the two study groups.

Postoperative Management: Following completion of surgery, all patients were transferred to the cardiac surgical intensive care unit (ICU) for standardized postoperative care. Mechanical ventilation was continued until patients fulfilled predefined extubation criteria, including haemodynamic stability, adequate oxygenation, normothermia, satisfactory neurological status, and acceptable arterial blood gas parameters. Patients in the ERACS group underwent protocol-directed early extubation, whereas those in the conventional care group were extubated according to routine institutional practice. Postoperative analgesia in the ERACS group consisted of opioid-sparing multimodal analgesia with scheduled intravenous paracetamol and adjunctive non-opioid analgesics, with intravenous morphine administered only as rescue medication for a Visual Analogue Scale (VAS) pain score ≥4. In the conventional care group, postoperative pain was managed primarily with intravenous opioids supplemented by non-opioid analgesics as required. All patients received standardized postoperative monitoring, respiratory physiotherapy, incentive spirometry, early enteral nutrition as tolerated, thromboprophylaxis, glycaemic control, and early mobilization according to institutional protocols. Postoperative recovery parameters, analgesic requirements, complications, duration of ICU stay, and length of hospital stay were prospectively recorded for all patients.

Outcome Measures: The primary outcome of the study was total opioid consumption during the first 24 hours after surgery, expressed as intravenous morphine-equivalent dose, to evaluate the opioid-sparing effect of the ERACS protocol.

The secondary outcomes included postoperative pain intensity assessed using the Visual Analogue Scale (VAS) at 6, 12, 24, and 48 hours after surgery; time to first rescue analgesia; time to tracheal extubation; duration of mechanical ventilation; length of intensive care unit (ICU) stay; total postoperative hospital stay; incidence of postoperative nausea and vomiting (PONV); occurrence of postoperative complications including atrial fibrillation, respiratory complications, acute kidney injury, surgical site infection, and 30-day mortality; total postoperative opioid requirement; and patient satisfaction with postoperative pain management, assessed using a 5-point Likert scale before hospital discharge.

Data Collection: Baseline demographic and clinical characteristics, including age, sex, body mass index (BMI), American Society of Anesthesiologists (ASA) physical status, comorbidities, and type of cardiac surgery, were recorded preoperatively using standardized case record forms. Intraoperative data collected included duration of surgery, cardiopulmonary bypass (CPB) time, aortic cross-clamp time, haemodynamic parameters, anaesthetic drug consumption, fluid administration, blood loss, and transfusion requirements. Postoperative data included opioid consumption during the first 24 hours, Visual Analogue Scale (VAS) pain scores at predefined time points, time to first rescue analgesia, time to tracheal extubation, duration of mechanical ventilation, length of intensive care unit (ICU) stay, length of hospital stay, postoperative nausea and vomiting, postoperative complications, and patient satisfaction scores. All data were prospectively collected by trained investigators using standardized data collection forms, and postoperative outcome assessments were performed by personnel blinded to the patients' group allocation to minimize observer bias.

Ethical Considerations: The study was approved by the Institutional Ethics Committee (IEC) of Rajendra Institute of Medical Sciences (RIMS), Ranchi. Written informed consent was obtained from all participants before enrolment. The study was conducted in accordance with the Declaration of Helsinki (2013 revision), and patient confidentiality was maintained throughout the study.

Statistical Analysis: Statistical analysis was performed using IBM SPSS Statistics for Windows, Version 25.0 (IBM Corp., Armonk, NY, USA).

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Continuous variables were expressed as mean ± standard deviation (SD) and compared using the independent Student's t-test or Mann–Whitney U test, as appropriate. Categorical variables were presented as frequency and percentage and compared using the Chi-square test or Fisher's exact test. Repeated postoperative pain scores were analyzed using repeated-measures analysis of variance (ANOVA). A two-tailed P value of <0.05 was considered statistically significant.

RESULTS

During the study period, 120 adult patients scheduled for elective cardiac surgery fulfilled the eligibility criteria and were enrolled in the study. Patients were randomized equally into Group A (EEG-guided anaesthesia, n = 60) and Group B (standard anaesthesia, n = 60). All randomized patients completed the study protocol and were included in the final statistical analysis. No patient was excluded after randomization, and complete perioperative and postoperative outcome data were available for all participants.

Baseline Demographic and Clinical Characteristics: The baseline demographic and clinical characteristics of the study participants are presented in [Table 1]. The mean age of the study population was comparable between the two groups, with no significant differences in sex distribution, body mass index (BMI), American Society of Anesthesiologists (ASA) physical status, prevalence of hypertension, diabetes mellitus, baseline Mini-Mental State Examination (MMSE) score, or type of cardiac surgery (all P > 0.05). These findings indicate that the study groups were well matched at baseline before the intervention.

Table 1: Baseline Demographic and Perioperative Characteristics of the Study Population

Variable	Group A (ERACS) (n=60)	Group B (Conventional) (n=60)	P value
Age (years)	56.8 ± 10.2	57.4 ± 9.8	0.741
Male, n (%)	42 (70.0)	40 (66.7)	0.697
BMI (kg/m²)	25.4 ± 3.2	25.8 ± 3.5	0.512
ASA II, n (%)	24 (40.0)	22 (36.7)	0.706
ASA III, n (%)	36 (60.0)	38 (63.3)	-
CABG, n (%)	36 (60.0)	34 (56.7)	0.714
Valve surgery, n (%)	18 (30.0)	20 (33.3)	-
Combined CABG + Valve, n (%)	6 (10.0)	6 (10.0)	-
CPB time (minutes)	102.8 ± 18.6	104.5 ± 19.4	0.623
Aortic cross-clamp time (minutes)	71.5 ± 13.7	72.8 ± 14.1	0.604

Table Note: Data are presented as mean ± standard deviation (SD) or number (%). Continuous variables were compared using the independent Student's t-test, and categorical variables were compared using the Chi-square test. P<0.05 was considered statistically significant.

Abbreviations: BMI, body mass index; ASA, American Society of Anesthesiologists; CABG, coronary artery bypass grafting; CPB, cardiopulmonary bypass.

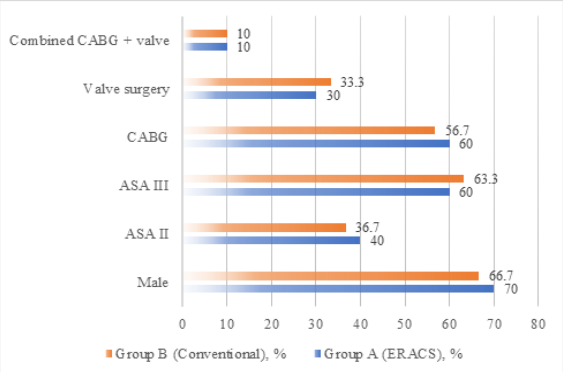

Figure 1: Comparison of Baseline Demographic and Surgical Characteristics Between the Study Groups

Note: Values are presented as percentages. Group A received the Enhanced Recovery After Cardiac Surgery protocol, whereas Group B received conventional perioperative care. The distributions of sex, ASA physical status, and type of cardiac surgery were comparable between the groups, with no statistically significant baseline differences. ASA, American Society of Anesthesiologists; CABG, coronary artery bypass grafting; ERACS, Enhanced Recovery After Cardiac Surgery.

Postoperative Recovery Outcomes: The postoperative analgesic and recovery outcomes are summarized in [Table 2]. Compared with the conventional care group, patients managed with the ERACS protocol had significantly lower opioid consumption during the first 24 postoperative hours, longer time to first rescue analgesia, earlier tracheal extubation, shorter ICU stay, and reduced postoperative hospital stay (all P<0.001).

Table 2: Comparison of Postoperative Analgesic and Recovery Outcomes Between the Study Groups

Outcome	Group A (n=60)	Group B (n=60)	P value
Total opioid consumption during first 24 h (mg morphine equivalent)	18.4 ± 5.7	34.9 ± 8.6	<0.001
Time to first rescue analgesia (hours)	10.8 ± 2.4	5.7 ± 1.8	<0.001
Time to extubation (hours)	5.2 ± 1.4	8.6 ± 2.3	<0.001
ICU stay (days)	2.1 ± 0.7	3.4 ± 1.1	<0.001
Hospital stay (days)	6.8 ± 1.5	8.7 ± 2.0	<0.001

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Table Note: Data are presented as mean ± SD. Comparisons were performed using the independent Student's t-test. Lower values indicate improved postoperative recovery except for time to first rescue analgesia, where a higher value indicates prolonged analgesic efficacy.
Abbreviations: ICU, intensive care unit.

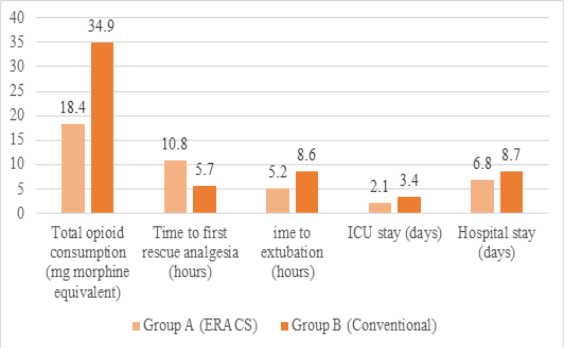

Figure 2: Comparison of Postoperative Analgesic and Recovery Outcomes Between the Study Groups

Note: Data are presented as mean values. Group A received the Enhanced Recovery After Cardiac Surgery protocol, whereas Group B received conventional perioperative care. Group A demonstrated significantly lower 24-hour opioid consumption, longer time to first rescue analgesia, earlier tracheal extubation, and shorter ICU and hospital stays than Group B (all P < 0.001). Error bars, where included, represent standard deviations. ICU, intensive care unit; ERACS, Enhanced Recovery After Cardiac Surgery.

Postoperative Pain Assessment: Postoperative pain intensity assessed using the Visual Analogue Scale (VAS) is presented in [Table 3]. Pain scores were significantly lower in the ERACS group at all postoperative assessment time points, demonstrating superior analgesic efficacy throughout the first 48 hours after surgery (all P<0.001).

Table 3: Comparison of Postoperative Visual Analogue Scale (VAS) Pain Scores

Time after surgery	Group A (n=60)	Group B (n=60)	P value
6 hours	2.6 ± 0.8	4.8 ± 1.0	<0.001
12 hours	2.1 ± 0.7	4.1 ± 0.9	<0.001
24 hours	1.7 ± 0.6	3.3 ± 0.8	<0.001
48 hours	1.2 ± 0.5	2.4 ± 0.7	<0.001

Table Note: Data are presented as mean ± SD. Pain intensity was measured using a 10-point Visual Analogue Scale (0 = no pain; 10 = worst imaginable pain). Repeated measurements were analyzed using repeated-measures ANOVA.

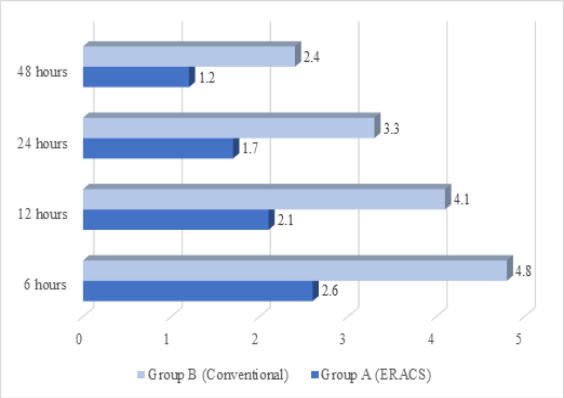

Figure 3: Comparison of Postoperative Pain Scores (Visual Analog Scale) Between the Study Groups Over the First 48 Hours After Surgery

Note: Values are presented as mean Visual Analog Scale (VAS) pain scores assessed at 6, 12, 24, and 48 hours after surgery. Patients managed with the Enhanced Recovery After Cardiac Surgery (ERACS) protocol consistently demonstrated significantly lower postoperative pain scores than those receiving conventional perioperative care at all assessment time points (all P < 0.001). Error bars, where displayed, represent standard deviations. VAS, Visual Analog Scale; ERACS, Enhanced Recovery After Cardiac Surgery.

Postoperative Complications: The incidence of postoperative complications is shown in [Table 4]. Postoperative nausea and vomiting occurred significantly less frequently in the ERACS group than in the conventional care group (P=0.024). The incidence of atrial fibrillation, respiratory complications, acute kidney injury, surgical site infection, re-exploration for bleeding, and 30-day mortality was comparable between the two groups.

Table 4: Comparison of Postoperative Complications Between the Study Groups

Complication	Group A (n=60)	Group B (n=60)	P value
Postoperative nausea and vomiting	5 (8.3%)	14 (23.3%)	0.024
Atrial fibrillation	4 (6.7%)	7 (11.7%)	0.337
Respiratory complications	3 (5.0%)	6 (10.0%)	0.298
Acute kidney injury	2 (3.3%)	4 (6.7%)	0.399
Surgical site infection	2 (3.3%)	3 (5.0%)	0.648
Re-exploration for bleeding	1 (1.7%)	2 (3.3%)	0.558
Thirty-day mortality	1 (1.7%)	2 (3.3%)	0.558

Table Note: Data are presented as number (%). Categorical variables were compared using the Chi-square test or Fisher's exact test where appropriate.

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Patient Satisfaction: Patient satisfaction with postoperative pain management is presented in [Table 5]. Patients in the ERACS group reported significantly greater satisfaction than those receiving conventional care (P<0.001).

Table 5: Comparison of Patient Satisfaction Scores Between the Study Groups

Satisfaction level	Group A (n=60)	Group B (n=60)	P value
Excellent	35 (58.3%)	15 (25.0%)	<0.001
Very Good	18 (30.0%)	22 (36.7%)	-
Good	6 (10.0%)	16 (26.7%)	-
Fair	1 (1.7%)	7 (11.7%)	-

Table Note: Data are presented as number (%). Patient satisfaction was assessed at hospital discharge using a standardized 5-point Likert scale, with higher scores indicating greater satisfaction with postoperative pain management and overall recovery.

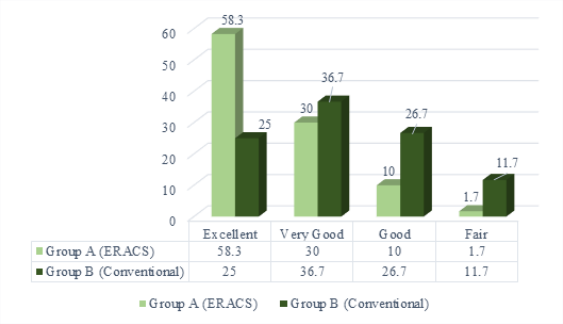

Figure 4: Comparison of Patient Satisfaction Levels Between the ERACS and Conventional Care Groups

Note: Patient satisfaction was assessed before hospital discharge and categorized as Excellent, Very Good, Good, or Fair. Patients managed with the Enhanced Recovery After Cardiac Surgery (ERACS) protocol reported higher overall satisfaction, with a greater proportion rating their perioperative experience as Excellent and fewer reporting Fair satisfaction compared with patients receiving conventional perioperative care. Values are expressed as percentages of patients within each study group. ERACS, Enhanced Recovery After Cardiac Surgery.

DISCUSSION

The present prospective randomized controlled trial demonstrated that an Enhanced Recovery After Cardiac Surgery (ERACS) protocol incorporating bilateral ultrasound-guided erector spinae plane (ESP) block and opioid-sparing multimodal analgesia significantly improved postoperative recovery after adult cardiac surgery. Patients in the ERACS group experienced lower opioid consumption, better pain control, earlier extubation, shorter ICU and hospital stay, fewer episodes of postoperative nausea and vomiting, and greater patient satisfaction. These findings support the principles of fast-track surgery proposed by Kehlet and Wilmore, which emphasize reducing surgical stress and accelerating recovery through evidence-based perioperative care.[1]

Enhanced Recovery After Surgery (ERAS) programmes combine standardized perioperative management, multimodal analgesia, early mobilization, and optimized recovery pathways to improve clinical outcomes.[2] Cardiac-specific ERAS recommendations further advocate multidisciplinary care, opioid-sparing analgesia, early extubation, and protocol-based perioperative management.[3] Similar recommendations have also been successfully applied in thoracic surgery.[4] Optimized cardiopulmonary bypass management is another important component of perioperative cardiac care.[5] Effective pain management is fundamental after median sternotomy because inadequate analgesia delays mobilization and respiratory recovery. The ESP block has emerged as a safe and effective regional analgesic technique for cardiac surgery.[6] Randomized trials have demonstrated significant reductions in postoperative pain and opioid requirements following bilateral ESP block.[7,8] The anatomical basis of the block, described by Forero et al., supports extensive thoracic analgesia through fascial plane spread of local anaesthetic.[9] The reduced pain scores and opioid consumption observed in our study are therefore consistent with previous clinical evidence.

Reduced opioid exposure also contributes to fewer opioid-related adverse effects and facilitates enhanced recovery. Appropriate perioperative fluid therapy is equally important because both restrictive and excessive fluid administration may adversely affect postoperative outcomes.[10] ERAS consensus recommendations advocate balanced perioperative care that combines optimized analgesia with individualized fluid management.[11] Adjunctive analgesics such as low-dose ketamine reduce postoperative opioid requirements,[12] while perioperative α2-agonists improve analgesia and decrease morphine consumption.[13] Dexmedetomidine has also been associated with improved postoperative neurological recovery in cardiac surgical patients.[14]

Thoracic epidural analgesia remains an effective technique but is less frequently used in cardiac surgery because of concerns related to anticoagulation and neuraxial complications.[15] Likewise, anaesthetic maintenance strategies may influence postoperative recovery, although current evidence suggests that overall perioperative management is more important than any single intervention.[16]

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Earlier extubation and shorter ICU stay observed in the present study likely resulted from the combined effects of effective analgesia, reduced opioid use, standardized anaesthetic management, and optimized haemodynamic care. Goal-directed fluid therapy supports these outcomes by maintaining adequate organ perfusion while avoiding unnecessary fluid overload.[17] Appropriate preoperative assessment and patient optimization also remain essential components of successful enhanced recovery pathways.[18] Furthermore, coordinated perioperative care and early rehabilitation have consistently been associated with shorter hospitalization and improved recovery.[19] Individualized perioperative fluid management should therefore remain an integral part of ERACS protocols.[20]

The strengths of this study include its prospective randomized design and standardized perioperative protocol. However, this was a single-centre study with a relatively small sample size, and long-term outcomes such as chronic pain, quality of life, and cost-effectiveness were not evaluated. Larger multicentre randomized studies are required to validate these findings.

Overall, implementation of an ERACS protocol incorporating bilateral ESP block and opioid-sparing multimodal analgesia significantly enhanced postoperative recovery after adult cardiac surgery by improving analgesia, reducing opioid requirements, facilitating earlier extubation, shortening ICU and hospital stay, and improving patient satisfaction without increasing perioperative complications.

Limitations: This study has several limitations. First, it was conducted at a single tertiary-care centre with a relatively small sample size, which may limit the generalizability of the findings. Second, blinding of the attending anaesthesiologists was not feasible because of the nature of the regional anaesthesia intervention, introducing the potential for performance bias. Third, the study evaluated a bundled ERACS protocol; therefore, the individual contributions of the erector spinae plane block, opioid-sparing analgesia, and other enhanced recovery components could not be assessed separately. Fourth, only short-term postoperative outcomes were evaluated, while long-term outcomes such as chronic pain, quality of life, functional recovery, readmission rates, and cost-effectiveness were not investigated. Finally, although the study demonstrated significant improvements in recovery-related outcomes, it was not powered to detect differences in infrequent major postoperative complications or mortality. Multicentre studies with larger sample sizes and longer follow-up are warranted to confirm these findings and evaluate long-term clinical benefits.

CONCLUSION

The findings of this prospective randomized controlled trial demonstrate that implementation of an Enhanced Recovery After Cardiac Surgery (ERACS) protocol incorporating bilateral ultrasound-guided erector spinae plane block and opioid-sparing multimodal analgesia significantly enhances early postoperative recovery following adult cardiac surgery. Compared with conventional perioperative care, the ERACS protocol provided superior pain control, reduced opioid requirements, facilitated earlier tracheal extubation, shortened ICU and hospital stay, decreased postoperative nausea and vomiting, and improved patient satisfaction without increasing perioperative complications. These results support the routine incorporation of evidence-based ERACS principles into contemporary cardiac anaesthesia practice. Further multicentre studies with larger sample sizes and longer follow-up are warranted to confirm these findings and evaluate their long-term clinical and economic benefits.

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