RESEARCH PAPER

A Prospective Randomized Controlled Trial to Study the Advantage of Implementation of Enhanced Recovery after Surgery (ERAS) Protocol in Patients Undergoing Elective Coronary Artery Bypass Grafting

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ABSTRACT
Objective: To assess the effectiveness of an ERAS protocol in patients undergoing elective CABG (coronary artery bypass grafting) on CPB (Cardiopulmonary bypass) on patient recovery and length of stay.
Methods: This prospective randomized controlled trial was conducted in a tertiary care hospital from July 2024 to November 2025. Adult patients (18–85 years) undergoing elective CABG on CPB were randomly allocated into two groups: Routine Protocol (RP, n = 26) and ERAS Protocol (EP, n = 26). The ERAS group received structured preoperative counselling, prehabiliteration, preoperative carbohydrate loading, multimodal analgesia and strict normothermia while the control group received routine perioperative care. Primary outcomes were time to extubation and postoperative hospital stay. Secondary outcomes included time to ambulation, time to enteral feeding, opioid consumption and postoperative complications.
Results: Baseline characteristics were comparable between the groups. The ERAS group showed significantly early extubation (4.62 ± 0.64 Vs 6.85 ± 0.61 hours; $p < 0.0001$), shorter postoperative hospital stay (4.04 ± 0.59 Vs 6.08 ± 0.56 days; $p < 0.0001$), earlier ambulation (6.04 ± 0.77 Vs 8.88 ± 0.82 hours; $p < 0.0001$), and early initiation of enteral feeding (7.12 ± 0.77 Vs 10.88 ± 1.07 hours; $p < 0.0001$). Requirement of rescue analgesic doses was significantly less in ERAS group compared to routine group (0.15 ± 0.37 Vs 1.38 ± 0.57: $p < 0.0001$). The incidence of postoperative complications was comparable between groups.
Conclusion: Implementation of an ERAS protocol in patients undergoing CABG on CPB significantly enhances postoperative recovery, reduces hospital stay, and reduces the dose requirement of postoperative opioid use without increasing complications, supporting its safe and effective adoption in cardiac surgical practice.
Keywords: Enhanced Recovery After Surgery, Cardiac surgery, Postoperative recovery
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INTRODUCTION

Cardiac surgery has evolved from a risky intervention in the past into an everyday practice that is considered life-saving. [1] In spite of advances in techniques and equipment used in cardiac surgery, significant neuroendocrine, inflammatory, and metabolic stress reactions remain inherent to cardiac surgery. [2] Such reactions are associated with delayed functional recovery, longer intensive care unit and hospital stays, and postoperative complications that negatively impact quality of life. [3]

The stress response associated with surgery is more significant in cardiac surgery due to sternotomy, cardiopulmonary bypass, ischemia-reperfusion syndrome, and fluid shifts. [4] Such stress response is associated with postoperative pain, respiratory problems, ileus, confusion, infections, and delayed mobilization. [4] Conventional perioperative care strategies such as preoperative fasting,

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liberal opioid administration, delayed oral feeding, and strict bed rest have been considered protective in the past but are now considered to be associated with postoperative complications and delayed recovery. [5]

Enhanced Recovery After Surgery (ERAS) is considered a multimodal and evidence-based strategy for reducing stress and enhancing postoperative recovery. [6] ERAS protocols have been shown to reduce postoperative complications and hospital stay without compromising safety in colorectal surgery. [7] The ERAS concept focuses on optimizing care strategies from preoperative, intraoperative, and postoperative phases. [8] The major components of ERAS include counselling, reduced preoperative fasting and carbohydrate loading, opioid-sparing analgesia, normothermia, goal-directed fluid therapy, early extubation, early oral feeding, and early mobilization. [9]

However, the application of ERAS principles in cardiac surgery has its challenges, especially in elderly patients with multiple co-morbidities, and the use of cardiopulmonary bypass causes systemic inflammation and coagulopathy. [10] Therefore, Enhanced Recovery After Cardiac Surgery (ERACS) has evolved by adopting ERAS principles and other interventions such as standardized anesthesia, analgesia, extubation, enteral nutrition, and mobilization. [8,11] Observational studies suggest that implementation of ERACS reduces ventilation time and ICU and hospital stay without affecting mortality. [12-14] However, there is limited evidence, especially from low and middle-income countries.

In India, cardiovascular diseases are increasingly affecting the population, resulting in an increase in cardiac surgeries. [15] Prolonged hospitalization increases healthcare costs and patient morbidity, highlighting the need for efficient, evidence-based perioperative strategies. Thus, the study aims to assess the effectiveness of an ERAS protocol in patients undergoing cardiac surgery with regard to recovery and length of stay.

METHODS

This randomized controlled trial was conducted in a tertiary care hospital over a period of 1.5 years (July 2024 to November 2025). Patients aged between 18 and 85 years undergoing elective coronary artery bypass grafting (CABG) on pump under general anaesthesia were considered in the study. Patients with overt congestive heart failure, morbid obesity (BMI > 35 kg/m²), previous history of stroke or endocarditis, preoperative ejection fraction less than 35%, abnormal liver function tests (albumin levels less than 30 g/L and/or AST and/or ALT > 100 IU/L), and those who declined consent were excluded from the study.

Sample size was determined based on a previous study by Hendy A et al., [16] where the mean postoperative hospital stay was 8.88 ± 3.50 days in the control group and 5.13 ± 1.34 days in the ERAS group. The sample size was determined using the G*Power 3.1.9.4 program for comparison of two independent means with a medium effect size and 90% power with a significance level of 0.05. The sample size required was 52 patients (26 in each group).

Randomization and Group Allocation

The participants were randomly allocated into two equal groups preoperatively: Control Group (Routine Protocol) and ERAS Group (Enhanced Recovery Protocol), with a 1:1 allocation ratio. The random allocation sequence was generated using a computer-generated table of random numbers.

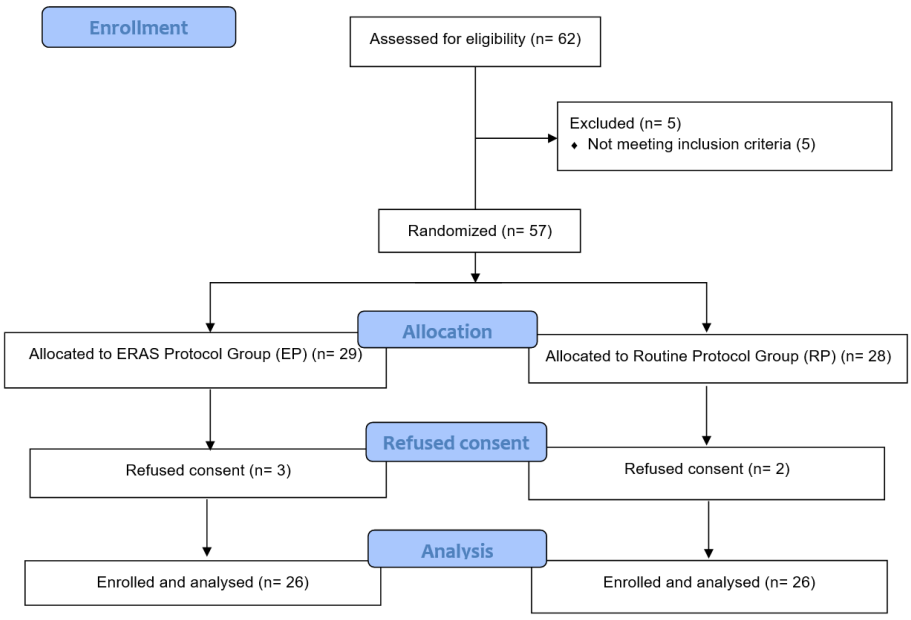

Figure 1: Randomization flow diagram

Perioperative Management

All the participants were subjected to routine preanesthetic evaluation and were assessed with a preoperative medical history and physical and systemic examination. Airway assessment included Mallampati score.

In the control group, routine perioperative care was followed. Pre-emptive analgesia consisted of oral paracetamol 1 g and gabapentin 300 mg on the morning of surgery. Anaesthesia was induced with propofol or etomidate, injection Fentanyl 2 µg/kg, injection Vecuronium 0.1 mg/kg for intubation and maintained using fentanyl (5–10 µg/kg) and morphine (0.1–0.2 mg/kg) with Isoflurane 0.6-1% to achieve a minimum alveolar concentration (MAC) of 1, oxygen, medical air, and injection Vecuronium 2 mg boluses iv. On cardiopulmonary bypass patient received intermittent boluses of Fentanyl (50 µg), Propofol (30-40 mg) and Vecuronium 2mg iv. Postoperatively, analgesia was intravenous paracetamol 1gm 8th hourly and rescue analgesia was injection Fentanyl 50mcg iv boluses when VAS score was ≥ 4 to a maximum dose of 200 µg of injection Fentanyl over 6 hours. Extubation was performed after stable haemodynamics and when extubation criteria were met.

In the ERAS group, patients received structured preoperative counselling regarding pain management, early feeding, mobilization, and discharge criteria. Patient received 25 gm of Dextrose dissolved in 100 ml of water 3 hours before induction of anaesthesia. Pre-emptive analgesia included oral paracetamol 1 g and gabapentin 300 mg on the morning of surgery. Anaesthesia was induced with propofol or etomidate, fentanyl 2 µg/kg and vecuronium 0.1mg/kg, maintenance was with fentanyl infusion 1–2 µg/kg/hr and morphine 0.1 mg/kg, Isoflurane 0.6-1% to achieve a minimum alveolar concentration (MAC) of 1, oxygen, medical air, and injection Vecuronium 2 mg boluses iv. On cardiopulmonary bypass patient received Fentanyl infusion (1-2 µg/kg/hr) and propofol infusion (80-100 µg/kg/min). Fentanyl and Propofol infusions were stopped after discontinuing the cardiopulmonary bypass. After stopping infusions Injection morphine boluses (upto total dose of 0.1mg/kg) and injection Vecuronium 2 mg boluses were given if required. Temperature is measured by using nasopharyngeal temperature probe. Strict normothermia (36.5–37.2°C) was maintained by underbody contact warmer or forced air warmer. Postoperative analgesia was paracetamol 1 gm 8th hourly and ketorolac 30 mg 12th hourly iv. Rescue analgesic was Tramadol 75 mg which is a synthetic opoid was given iv over 5-10 minutes when VAS score was ≥4 upto 48 hours.

Both groups received invasive lines under local anaesthesia before the induction of anaesthesia, received antibiotic prophylaxis with piperacillin–tazobactam 4.5 gm 30–60 minutes before incision, injection Tranexamic acid 500 mg iv and ondansetron 4 mg iv for prevention of postoperative nausea and vomiting. Weaning from the cardiopulmonary bypass (CBP) was done when there was sinus rhythm with stable heart rate, contractility and hemodynamics and blood gases on CPB. Inotropes were used as required Dobutamine (5-10 µg/kg/min), Noradrenaline (0.05-0.1 µg/kg/min). In the post operative period, patients were monitored with arterial blood pressure, central venous pressure, heart rate, SpO2, urine output, chest tube drainage. Fluid management as per goal directed therapy to achieve urine output of >0.5ml/kg/hr, lactate <2mmol/l and haemoglobin > 8 gm%. If haemoglobin < 8 gm% packed red blood cells (PRBC) was given. If urine output and lactate levels were beyond acceptable limits, hydroxyethyl starch boluses of 200 ml were given. Patient requiring cardiac pacing were excluded from the study.

Extubation criteria for both groups was stable hemodynamics, tidal volume > 6ml/kg, RR< 25 per min and PaO2/FiO2 > 200 on PSV mode of ventilation with settings of PEEP 5 cm H_2O, pressure support 10 cm H_2O, FiO2 – 40% and minimal chest tube drainage. (<100ml in any 2 hours). Patient pain was assessed by VAS score and rescue analgesia was given when VAS score was ≥ 4. Patient mobilisation and enteral feeding were initiated when the patient was fully awake, haemodynamically stable with minimal inotrope support (injection Noradrenaline < 0.05 µg/kg/min and injection Dobutamine <5 µg/kg/min) and minimal chest tube drainage < 100 ml in 4 hours.

Patients in both groups were mobilized according to hemodynamic stability. On postoperative day 0, patients were made to sit at the edge of the bed after extubation. On postoperative day 1, patients would be sitting in the chair and mobilised with inotropic support (injection Noradrenaline < 0.05 µg/kg/min and injection Dobutamine <5 µg/kg/min).

Most patients were weaned off inotropes within 24 hours. Three patients in routine protocol and two patients in ERAS protocol had inotropes beyond 24 hours but for not more than 48 hours.

Similarly, ITU discharge criteria were predefined and uniformly applied.

Criteria for transferring patients from the ITU to step down ICU:

1. Haemodynamic stability with systolic BP > 100 mm Hg or MBP > 65 mm Hg
2. Ambulating and eating
3. Obeying commands
4. No active bleeding
5. Off ventilator and NIV support
6. No active pain or VAS score < 4

Outcome Measures

Primary outcome was time to extubation and length of hospital stay. Secondary outcomes included time to ambulation, time to enteral feeding, opioid consumption and occurrence of postoperative complications such as atrial fibrillation, pneumonia, urinary tract infection, stroke, and acute kidney injury. Patients were followed until discharge, which was decided by the treating cardiac surgeon based on institutional guidelines.

Statistical Analysis

Data were analyzed using SPSS version 26. Continuous variables were expressed as mean ± standard deviation and analysed using independent sample t-test. Categorical variables were expressed as frequencies and percentages and analysed using Chi-square. All tests were two-tailed, and a P value <0.05 was considered statistically significant.

Ethics

The study was approved by the Institutional Ethics Committee. All procedures were conducted in accordance with the Helsinki Declaration and ICMR guidelines. Confidentiality of patient data was maintained throughout the study.

RESULTS

The baseline demographic and clinical characteristics were comparable between the two groups. The majority of patients in both groups belonged to the 51–70 year age range, with identical mean age observed in Group RP (58.58 ± 8.54 years) and Group EP (58.58 ± 11.47 years). Male predominance was noted in both groups (80.77% in RP vs. 69.23% in EP), with no statistically significant difference (p = 0.337). Similarly, the distribution of ASA physical status grades II, III, and IV was comparable between the groups (p = 0.815). Overall, there were no statistically significant differences in baseline variables, indicating that both groups were well matched for comparison (Table 1).

Table 1: Baseline Demographic Characteristics

Variable		Group RP (n = 26)	Group EP (n = 26)	Chi-square (χ^2)	p-value
Age	30-40 years	0 (0%)	2 (7.69%)	3.65	0.455
	41-50 years	6 (23.08%)	4 (15.38%)		
	51-60 years	9 (34.62%)	7 (26.92%)		
	61-70 years	10 (38.46%)	10 (38.46%)		
	71-80 years	1 (3.85%)	3 (11.54%)		
	(Mean ± SD)	58.58 ± 8.54	58.58 ± 11.47		
Gender	Male	21 (80.77%)	18 (69.23%)	0.923	0.337
	Female	5 (19.23%)	8 (30.77%)		
ASA physical status	II	8 (30.77%)	7 (26.92%)	0.412	0.815
	III	12 (46.15%)	13 (50.00%)		
	IV	6 (23.08%)	6 (23.08%)		

Postoperative recovery parameters demonstrated significantly improved outcomes in the ERAS group compared to the routine protocol group. The mean duration of hospital stay was significantly shorter in Group EP (4.04 ± 0.59 days) compared to Group RP (6.08 ± 0.56 days) (p < 0.0001). Additionally, time to extubation, ambulation, and initiation of enteral feeding were all significantly reduced in the ERAS group, with highly significant p-values (<0.0001 for all parameters). These findings indicate faster postoperative recovery and earlier return to physiological function in patients managed under the ERAS protocol (Table 2).

Table 2: Postoperative Recovery Parameters

Parameter	Group RP (Mean ± SD)	Group EP (Mean ± SD)	t-value	p-value
Postoperative hospital stay (days)	6.08 ± 0.56	4.04 ± 0.59	−12.67	<0.0001
Time to extubation (hours)	6.85 ± 0.61	4.62 ± 0.64	−16.68	<0.0001
Time to ambulation (hours)	8.88 ± 0.82	6.04 ± 0.77	−20.81	<0.0001
Time to enteral feeding (hours)	10.88 ± 1.07	7.12 ± 0.77	−20.97	<0.0001

Analysis of postoperative pain scores revealed that patients in the ERAS group experienced significantly lower pain scores during the early postoperative period. At 4, 8, and 12 hours post-surgery, pain scores were significantly lower in Group EP compared to Group RP (p < 0.01 for all). Although differences at 18 and 30 hours were not statistically significant, significant reductions in pain were again observed at 24, 36, and 48 hours in the ERAS group. Overall, the ERAS protocol was associated with better pain control, particularly in the early postoperative phase (Table 3).

Table 3: Postoperative Pain Scores (VAS)

Time (hours) since surgery	Group RP (Mean ± SD)	Group EP (Mean ± SD)	t-value	p-value
4 hrs	4.6 ± 0.6	4.1 ± 0.6	3.06	0.003
8 hrs	5.5 ± 0.7	4.9 ± 0.7	3.16	0.002

12 hrs	3.5 ± 0.6	3.0 ± 0.6	3.06	0.003
18 hrs	3.4 ± 0.5	3.2 ± 0.5	1.41	0.16
24 hrs	2.6 ± 0.5	2.2 ± 0.5	2.94	0.005
30 hrs	2.4 ± 0.5	2.3 ± 0.5	0.80	0.42
36 hrs	2.3 ± 0.5	2.0 ± 0.5	2.40	0.02
42 hrs	2.2 ± 0.4	2.1 ± 0.4	0.88	0.38
48 hrs	2.0 ± 0.4	1.7 ± 0.4	2.65	0.01

The requirement for rescue analgesia was markedly reduced in the ERAS group. All patients in Group RP (100%) required rescue analgesia, whereas only 7.69% of patients in Group EP required additional analgesia ($p < 0.0001$). The total number of rescue analgesic doses was substantially higher in Group RP (36 doses) compared to Group EP (4 doses), with a significantly higher mean number of doses per patient in the RP group (1.38 ± 0.57 vs. 0.15 ± 0.37; $p < 0.0001$). These findings highlight the superior analgesic efficacy of the ERAS protocol (Table 4).

Table 4: Analgesic Requirement and Opioid Use

Variable	Group RP (n=26)	Group EP (n=26)	χ^2 / t-value	p-value
Patients requiring rescue analgesia, n (%)	26 (100%)	2 (7.69%)	χ^2 = 44.17	<0.0001
Total number of rescue analgesic doses	36	4	-	-
Mean number of doses per patient (Mean ± SD)	1.38 ± 0.57	0.15 ± 0.37	t = 9.52	<0.0001

Intraoperative fentanyl consumption was significantly lower in the ERAS group, with a mean dose of 350 ± 80 µg compared to 525 ± 175 µg in the routine care group ($p < 0.0001$). Furthermore, postoperative fentanyl requirement was observed in all patients in Group RP (100%) but was completely absent in Group EP (0%), with a highly significant difference ($p < 0.0001$). The mean postoperative fentanyl dose in Group RP was 55.8 ± 16.6 µg. These findings indicate reduced opioid requirement with ERAS implementation (Table 5).

Table 5: Fentanyl Consumption

Parameter	Group RP (n=26)	Group EP (n=26)	χ^2 / t-value	p-value
Intraoperative fentanyl	2 µg/kg at intubation + total 5–10 µg/kg (≈350–700 µg)	2 µg/kg at intubation + infusion 1–2 µg/kg/hr (≈140 µg bolus + 70–140 µg/hr infusion)	-	-
Mean total intraoperative fentanyl (µg)	525 ± 175	350 ± 80	t = 4.86	<0.0001
Postoperative fentanyl use, n (%)	26 (100%)	0 (0%)	χ^2 = 52.00	<0.0001
50 µg once, n (%)	23 (88.46%)	0	-	-
50 µg twice (100 µg), n (%)	3 (11.54%)	0	-	-
Mean postoperative fentanyl dose (µg)	55.8 ± 16.6	0	t = 17.10	<0.0001

Similarly, morphine usage was significantly lower in the ERAS group. Although both groups received comparable dosing protocols, the mean total morphine consumption was significantly reduced in Group EP (7.8 ± 1.3 mg) compared to Group RP (10.5 ± 3.5 mg) ($p < 0.0001$). This further supports the opioid-sparing effect of the ERAS protocol (Table 6).

Table 6: Morphine Usage

Parameter	Group RP (n=26)	Group EP (n=26)	t-value	p-value
Dose (mg/kg)	0.1–0.2 mg/kg	0.1 mg/kg	-	-
Approx. total dose (mg)	7–14 mg	7 mg	-	-
Mean total dose (mg)	10.5 ± 3.5	7.8 ± 1.3	5.10	<0.0001

Postoperative complications were minimal and comparable between the two groups. Atrial fibrillation was the only complication observed, occurring in 11.54% of patients in Group RP and 7.69% in Group EP, with no statistically significant difference ($p = 0.39$). It was treated with Injection Amiodarone 150mg given over 20 minutes in both the groups. It was followed by oral Amiodarone 200 mg 12th hourly. No cases of urinary tract infection, pneumonia, wound infection, stroke, acute kidney injury requiring dialysis, or in-hospital mortality were reported in

either group. This indicates that the ERAS protocol is safe and does not increase postoperative complications (Table 7).

Table 7: Postoperative Complications

Complication	Group RP (n=26)	Group EP (n=26)	Chi-square (χ^2)	p-value
Atrial fibrillation	3 (11.54%)	2 (7.69%)	0.75	0.39
Urinary tract infection	0 (0%)	0 (0%)	-	-
Pneumonia	0 (0%)	0 (0%)	-	-
Wound infection	0 (0%)	0 (0%)	-	-
Stroke	0 (0%)	0 (0%)	-	-
Acute kidney injury requiring dialysis	0 (0%)	0 (0%)	-	-
In-hospital mortality	0 (0%)	0 (0%)	-	-

DISCUSSION

The present study findings show that the use of an ERAS-based perioperative care pathway can lead to faster postoperative recovery, as indicated by reduced hospital stays and the achievement of postoperative recovery milestones, including the time to extubation, ambulation, and the initiation of enteral nutrition. These findings are consistent with other studies like Hendy et al. who noted that the ERAS protocol can lead to reduced hospital stays following cardiac surgery, with the length of stay being 8.88 ± 3.50 days in the non-ERAS group compared to 5.13 ± 1.34 days in the ERAS group. [16] Borys et al. also noted that the ERAS protocol can lead to reduced hospital stays following cardiac surgery, with the median hospital stays being 10 days in the non-ERAS group compared to 7 days in the ERAS group. [12] Hosseini et al. noted that the ERAS protocol can lead to reduced hospital stays as compared to the non-ERAS group. [17] In addition, a meta-analysis by Hoogma DF et al. has noted that the ERAS protocol can lead to reduced hospital stays following cardiac surgery. [18]

Patient education, prehabilitation, preoperative carbohydrate loading, early extubation and mobilization are key components of ERAS and play a crucial role in preventing respiratory complications and dependency in ICUs. In the present study, ERAS patients showed earlier extubation and mobilization compared with routine patients. Similar findings were reported by Hendy et al., who reported a decrease in ventilation time from 10.54 ± 7.83 hours to 6.69 ± 1.63 hours using ERAS. [16] Similarly, Hosseini et al. reported a decrease in ventilation time and earlier mobilization in ERAS patients. [17] Borys et al. reported even more impressive results, with ERAS patients showing extubation at 1–3 hours post-surgery and routine patients at 8–13 hours. [12] Early mobilization has been associated with a lower risk of atelectasis, venous thromboembolism, and muscle deconditioning, thereby facilitating faster recovery and discharge.

From the perspective of pain management, the present study has demonstrated that ERAS patients achieved adequate pain relief without a corresponding increase in rescue analgesia use, while reducing requirement of post operative opioids. Similarly, Hendy et al. reported a reduction in morphine use by nearly 75% using ERAS. [12] Similarly, Borys et al. reported a marked decrease in patient-controlled analgesia bolus use in ERAS patients. [12] Another study by Hosseini et al. reported lower pain scores and analgesia use in ERAS patients. [17] Furthermore, a meta-analysis by Hoogma et al. has established that ERAS patients show a marked reduction in opioid use without affecting analgesia efficacy. [18] Opioid use should be minimized in elderly cardiac surgical patients because these patients are at a high risk for respiratory depression, postoperative ileus, nausea and vomiting, delirium, and increased sedation, all of which can prolong hospitalization and recovery.

Notably, the enhanced recovery observed with the implementation of ERAS did not lead to an increased rate of postoperative complications and mortality. In the present study the incidence of atrial fibrillation did not show any statistically significant difference between the two groups. Similar results have also been observed by Hendy et al. and Hosseini et al., who have demonstrated that there is no increase in postoperative complications and readmission with the implementation of ERAS, including earlier extubation and feeding. [16,17] Moreover, a meta-analysis has also demonstrated that the implementation of ERAS is associated with a reduction in opioid use without any increase in postoperative complications and mortality. [18]

Our limitations of study were, follow-up was only done up to the time of discharge and cost effectiveness was not studied. Intraoperative awareness was not assessed in this study. In addition, variability in perioperative decision-making could have also acted as confounding factor. Since we are comparing different protocols, the intraoperative analgesia, hypnosis, sedation is likely to be different between the groups. This might bring about bias in the patient outcome and we are aware of it since blinding is not possible and it is a limitation of the study. However we eliminated the bias by strictly following the criteria for extubation and discharge from ITU.

CONCLUSION

Implementation of an ERAS protocol in patients undergoing elective CABG on CPB (cardiopulmonary bypass) resulted in significantly faster postoperative recovery, as evidenced by reduced hospital stay and earlier achievement of key recovery milestones such as

extubation, ambulation, and initiation of enteral feeding. The ERAS pathway also enabled reduced usage of postoperative opioid without increasing the number of rescue analgesics required, highlighting the effectiveness of multimodal, peri operative care strategies. Importantly, these improvements were achieved without an associated increase in postoperative complications or mortality, demonstrating that ERAS can be safely applied in cardiac surgical patients. These findings support the incorporation of structured ERAS pathways into routine perioperative care for cardiac surgery to improve patient-centered outcomes, enhance recovery, and optimize utilization of healthcare resources.

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