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Implementing Enhanced Recovery After Surgery in Adult Cardiac Surgery: A Before-and-After Cohort Study of Perioperative Practices and Clinical Outcomes

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Abstract

Background

Enhanced recovery after surgery (ERAS) programs have been increasingly adopted in cardiac surgery to optimize perioperative care and improve postoperative recovery. However, evidence from lower-middle-income countries remains limited. This study aimed to evaluate the feasibility and clinical impact of ERAS implementation on postoperative outcomes in patients undergoing adult cardiac surgery at a tertiary referral center in a lower-middle-income country.

Methods

We conducted a retrospective before-and-after cohort study at the Department of Anesthesiology and Intensive Care at Mohammed VI University Hospital, a tertiary referral cardiac surgery center in Oujda, Morocco. A total of 124 adult patients undergoing cardiac surgery during two consecutive periods before and after ERAS implementation were included. Fifty-two patients received conventional perioperative care, whereas 72 patients were managed according to an institutional ERAS pathway. Postoperative outcomes before and after ERAS implementation were compared.

Results

Demographic characteristics, perioperative variables, postoperative complications, duration of mechanical ventilation, intensive care unit (ICU) length of stay (LOS), hospital LOS, and in-hospital mortality were compared between groups. Patients managed under the ERAS pathway were older and presented a higher perioperative risk profile, including higher rates of hypertension, ischemic heart disease, advanced American Society of Anesthesiologists (ASA) class, and lower left ventricular ejection fraction. Despite this increased baseline risk, ERAS implementation was associated with significant reductions in cardiopulmonary bypass duration (113 vs. 130 min, p = 0.001), aortic cross-clamp time (84 vs. 94 min, p = 0.004), extubation time (1.85 vs. 2.40 h, p = 0.022), use of high-flow nasal oxygen (2.8% vs. 15.4%, p = 0.033), reintubation rate (4.2% vs. 11.5%, p = 0.020), postoperative infections (12.5% vs. 25.0%, p = 0.014), and respiratory complications. ICU LOS decreased from four to three days (p = 0.009). In-hospital mortality decreased from 15.4% to 8.3%; however, this difference did not reach statistical significance (p = 0.25).

Conclusions

Implementation of an ERAS pathway in adult cardiac surgery was associated with improved postoperative recovery, fewer complications, and shorter ICU stays despite a higher baseline risk profile in the ERAS cohort. These findings support the feasibility of implementing ERAS principles in resource-limited cardiac surgery programs and suggest that clinically meaningful improvements can be achieved in lower-middle-income countries despite limited resources and increasing patient complexity.

Categories: Physical Medicine & Rehabilitation, Quality Improvement, Cardiac/Thoracic/Vascular Surgery
Keywords: cardiac surgical procedures, developing countries, enhanced recovery after surgery (eras), length of stay, perioperative care, postoperative complications

Introduction

Cardiac surgery remains one of the most complex surgical specialties, requiring highly coordinated

perioperative management to minimize postoperative morbidity and optimize recovery. Despite substantial advances in surgical techniques, anesthesia, cardiopulmonary bypass technology, and intensive care management, postoperative complications remain common and contribute significantly to prolonged intensive care unit (ICU) and hospital stays, increased healthcare costs, and impaired patient outcomes. Respiratory complications, infections, transfusion requirements, and delayed mobilization continue to represent major challenges in the postoperative period following cardiac surgery [1,2].

Enhanced recovery after surgery (ERAS) programs were initially developed by Kehlet and colleagues to reduce the physiological stress response to surgery and improve postoperative recovery through a multimodal and multidisciplinary approach [3]. Initially applied in colorectal surgery, ERAS pathways have progressively expanded to various surgical specialties and have consistently demonstrated reductions in postoperative complications, length of hospital stay, and healthcare expenditures [4-6].

ERAS protocols are based on a series of evidence-based perioperative interventions, including preoperative patient optimization, minimization of fasting, multimodal opioid-sparing analgesia, goal-directed fluid therapy, early extubation, early mobilization, and standardized postoperative care pathways [6]. By attenuating the surgical stress response and preserving physiological function, these measures contribute to enhanced recovery and improved clinical outcomes.

Over the last decade, ERAS principles have increasingly been adapted to cardiac surgery. In 2019, the ERAS Society published specific recommendations for perioperative care in cardiac surgery, establishing a comprehensive framework aimed at improving patient recovery while maintaining safety [1]. Several studies have subsequently reported favorable outcomes associated with ERAS implementation, including shorter durations of mechanical ventilation, reduced ICU and hospital length of stay (LOS), lower transfusion requirements, and decreased postoperative morbidity [2].

Although ERAS pathways have demonstrated substantial benefits in high-income countries, their implementation in lower-middle-income countries remains insufficiently investigated. Differences in healthcare infrastructure, ICU bed availability, perioperative organization, and access to advanced technologies may substantially influence both the feasibility and effectiveness of ERAS pathways. Consequently, evidence generated in these settings remains limited, and findings from high-income healthcare systems cannot always be directly extrapolated.

In Morocco and other North African countries, experience with ERAS protocols in cardiac surgery remains limited, and few studies have assessed their impact on postoperative outcomes. Therefore, the present study aimed to evaluate the feasibility and clinical impact of implementing an ERAS pathway in adult patients undergoing cardiac surgery at a tertiary university hospital in Morocco, a resource-constrained healthcare setting. We hypothesized that ERAS implementation would be associated with improved postoperative recovery, reduced postoperative complications, shorter ICU LOS, and lower healthcare resource utilization compared with conventional perioperative care.

Materials And Methods

Study design and setting

This retrospective before-and-after cohort study was conducted in the Department of Anesthesiology and Critical Care of Mohammed VI University Hospital, a tertiary university hospital in Morocco, a lower-middle-income country. This healthcare setting is characterized by limited ICU capacity and constrained perioperative resources compared with high-income healthcare systems. The study included adult patients undergoing cardiac surgery between January 2021 and November 2024 and aimed to evaluate the impact of implementing an ERAS protocol on postoperative outcomes.

Patients were divided into two groups according to the perioperative management strategy received. The control group consisted of patients managed before ERAS implementation using conventional perioperative care, whereas the ERAS group included patients managed after implementation of the institutional ERAS protocol in January 2024.

Study population

All consecutive adult patients admitted to the ICU following elective cardiac surgery were eligible for inclusion. The study population mainly comprised patients undergoing coronary artery bypass grafting and valvular surgery. Patients who died intraoperatively, those with congenital heart diseases, and those undergoing emergency cardiac surgery were excluded from the study.

ERAS protocol

The institutional ERAS protocol was developed according to contemporary evidence-based recommendations for enhanced recovery in cardiac surgery and adapted to local practice. The protocol included preoperative patient optimization, minimization of preoperative fasting, multimodal opioid-

sparing analgesia, blood conservation strategies, goal-directed fluid management, early extubation, early enteral nutrition, early mobilization, and standardized postoperative care. Patients managed before January 2024 received conventional perioperative care according to routine institutional practice.

Perioperative multimodal analgesia

As part of the ERAS pathway, a structured multimodal analgesic strategy was implemented throughout the perioperative period. Intraoperatively, intravenous paracetamol was routinely administered in the absence of contraindications, while ketamine was administered as an initial bolus followed by continuous infusion as an opioid-sparing adjunct. At the end of surgery, analgesia consisted of paracetamol, nefopam (20 mg), and ketoprofen (50-100 mg), when clinically appropriate and in the absence of contraindications, particularly renal dysfunction or increased bleeding risk.

Postoperatively, intravenous paracetamol and nefopam were continued, with ketoprofen administered selectively according to individual clinical conditions. Sedation was primarily maintained with propofol without routine fentanyl infusion. Pain was assessed using the Behavioral Pain Scale (BPS) in patients unable to self-report, and intravenous morphine was administered as rescue analgesia when required. From postoperative day one, oral analgesics were introduced when swallowing function permitted, with tramadol available as an additional analgesic when appropriate. Procedural pain associated with drain removal, dressing changes, and early mobilization was also addressed, with low-dose intravenous ketamine (0.15-0.2 mg/kg) considered for severe pain.

Data collection

Data were retrospectively extracted from patient medical records, anesthesia charts, operative reports, and ICU databases using a standardized data collection form. Collected variables included demographic characteristics, cardiovascular risk factors, medical history, chronic medications, preoperative clinical and echocardiographic findings, operative characteristics, cardiopulmonary bypass duration, aortic cross-clamp duration, postoperative mechanical ventilation duration, postoperative complications, ICU LOS, and in-hospital mortality.

Outcomes

The primary outcome was the occurrence of postoperative complications following cardiac surgery. Secondary outcomes included duration of mechanical ventilation, reintubation rate, ICU LOS, and in-hospital mortality.

Statistical analysis

Statistical analyses were performed using IBM SPSS Statistics version 26.0 (IBM Corp., Armonk, NY, USA).

Continuous variables were expressed as mean ± standard deviation or median with interquartile range according to their distribution. Categorical variables were expressed as frequencies and percentages.

Comparisons between groups were performed using Student’s t-test or Mann-Whitney U test for continuous variables and Chi-square test or Fisher’s exact test for categorical variables, as appropriate.

All tests were two-sided, and a p-value < 0.05 was considered statistically significant.

Because of the retrospective before-and-after design of the study, the observed associations should be interpreted with caution and do not establish a direct causal relationship between ERAS implementation and clinical outcomes.

An exploratory multivariable analysis was performed to assess whether ERAS implementation remained associated with postoperative outcomes after adjustment for baseline differences between groups. Logistic regression models were used for binary outcomes, and log-transformed linear regression models were used for extubation time and ICU LOS. Models were adjusted for age, American Society of Anesthesiologists (ASA) III-IV status, ischemic heart disease, and left ventricular ejection fraction. Because of the limited number of events, adjusted analyses were not performed for mortality.

Ethics approval

According to institutional policy, formal ethical approval was not required for this retrospective observational study based exclusively on anonymized data collected during routine clinical practice. No intervention beyond standard patient management was performed. Patient confidentiality was strictly maintained throughout the study. The study was conducted in accordance with the ethical principles of the Declaration of Helsinki, originally adopted by the World Medical Association in 1964 [7].

Results

Patient characteristics

Patient selection is illustrated in Figure 1. A total of 179 patients underwent cardiac surgery during the study period. After exclusion of patients with congenital heart disease, emergency procedures, and incomplete records, 124 patients were included in the final analysis, comprising 52 patients managed before implementation of the ERAS protocol and 72 patients managed after ERAS implementation.

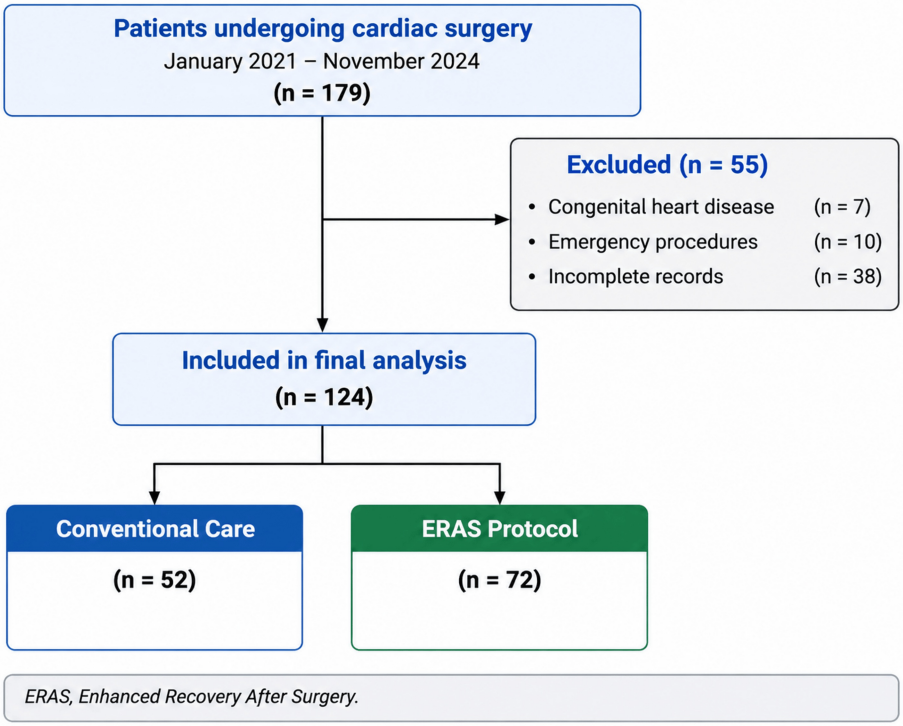


FIGURE 1: Flow diagram of patient selection and study inclusion.

Patients in the ERAS group were significantly older than those in the conventional care group (61.36 ± 10.0 vs. 56.85 ± 12.0 years, p = 0.039). Sex distribution was comparable between groups (p = 0.780).

Regarding cardiovascular risk factors, hypertension and ischemic heart disease were significantly more prevalent in the ERAS group (34 (47.2%) vs. 15 (28.8%), p = 0.039 and 47 (65.3%) vs. 22 (42.3%), p = 0.011, respectively). Antiplatelet therapy was also more frequently prescribed after ERAS implementation (51 (70.8%) vs. 21 (40.4%), p = 0.020).

Preoperative risk assessment revealed a significantly higher proportion of ASA III-IV patients in the ERAS group (56 (77.8%) vs. 19 (36.5%), p = 0.001). Similarly, the left ventricular ejection fraction was significantly lower (53.38 ± 9.8% vs. 58.76 ± 7.2%, p = 0.001), and segmental akinesia was more frequent (27 (37.5%) vs. 8 (15.4%), p = 0.016). The baseline demographic and clinical characteristics of the study population are summarized in Table 1.

Variable	Conventional care (n = 52)	ERAS (n = 72)	p-value
Age, years	56.85 ± 12.0	61.36 ± 10.0	0.039
Male sex, n (%)	24 (46.2)	35 (48.6)	0.780
Hypertension, n (%)	15 (28.8)	34 (47.2)	0.039
Ischemic heart disease, n (%)	22 (42.3)	47 (65.3)	0.011
Antiplatelet therapy, n (%)	21 (40.4)	51 (70.8)	0.020
ASA III–IV, n (%)	19 (36.5)	56 (77.8)	0.001
Left ventricular ejection fraction (%)	58.76 ± 7.2	53.38 ± 9.8	0.001
Segmental akinesia, n (%)	8 (15.4)	27 (37.5)	0.016

TABLE 1: Baseline demographic and clinical characteristics of the study population

Data are presented as mean ± standard deviation or number (%), as appropriate. Between-group comparisons were performed using Student's t-test or the Mann–Whitney U test for continuous variables and the chi-square test or Fisher's exact test for categorical variables, as appropriate.

ERAS, Enhanced Recovery After Surgery; ASA, American Society of Anesthesiologists

Operative characteristics

The distribution of surgical procedures was comparable between groups (p = 0.053), although a higher proportion of coronary artery bypass grafting procedures was observed in the ERAS group.

Implementation of the ERAS protocol was associated with a significant reduction in cardiopulmonary bypass duration, from a median of 130 minutes (IQR, 114-160) in the conventional care group to 113 minutes (IQR, 89-130) in the ERAS group (p = 0.001). Aortic cross-clamp time similarly decreased from 94 minutes (IQR, 77-120) to 84 minutes (IQR, 65-94; p = 0.004).

Exclusive norepinephrine administration decreased significantly after ERAS implementation (8 (15.4%) vs. 4 (5.6%), p = 0.045), whereas operative duration remained unchanged between groups (p = 0.707). Postoperative outcomes and complications in the conventional care and ERAS groups are presented in Table *2*.

Variable	Conventional care (n = 52)	ERAS (n = 72)	p-value
Coronary artery bypass grafting (CABG), n (%)	20 (38.5)	44 (61.1)	0.053*
Valvular surgery, n (%)	28 (53.8)	26 (36.1)	
Combined procedures, n (%)	3 (5.8)	2 (2.8)	
Operative duration, h	4.5 (4.0–5.0)	4.5 (4.0–5.0)	0.707
Cardiopulmonary bypass duration, min	130 (114–160)	113 (89–130)	0.001
Aortic cross-clamp duration, min	94 (77–120)	84 (65–94)	0.004
Exclusive norepinephrine administration, n (%)	8 (15.4)	4 (5.6)	0.045

TABLE 2: Operative characteristics

Data are presented as median (interquartile range) or number (%), as appropriate. Between-group comparisons were performed using Student's t-test or the Mann–Whitney U test for continuous variables and the chi-square test or Fisher's exact test for categorical variables, as appropriate.

*The p-value refers to the overall comparison of surgical procedure distribution between groups.

ERAS, Enhanced Recovery After Surgery

Postoperative outcomes

Patients managed according to the ERAS pathway experienced significantly earlier extubation, with mean extubation time decreasing from 2.40 ± 1.41 hours in the conventional care group to 1.85 ± 1.14 hours in the ERAS group (p = 0.022).

The use of high-flow nasal oxygen therapy was significantly reduced following ERAS implementation (8 (15.4%) vs. 2 (2.8%), p = 0.033), whereas non-invasive ventilation requirements remained similar between groups (3 (5.8%) vs. 3 (4.2%), p = 0.680).

The incidence of acute respiratory distress decreased from seven (13.5%) to seven (9.7%) (p = 0.040), while reintubation rates fell from six (11.5%) to three (4.2%) (p = 0.020). Overall postoperative infections decreased from 13 (25.0%) before ERAS implementation to nine (12.5%) afterward (p = 0.014).

The median ICU LOS decreased significantly from four days (IQR, 3-6) in the conventional care group to three days (IQR, 3-4) in the ERAS group (p = 0.009).

The total hospital LOS showed a numerical reduction from 15 days (IQR, 14-19.3) in the conventional care group to 14 days (IQR, 12-19.3) in the ERAS group, although this difference did not reach statistical significance (p = 0.091).

Overall in-hospital mortality was 14 (11.3%). Mortality decreased from eight (15.4%) in the conventional care group to six (8.3%) in the ERAS group; however, this difference did not reach statistical significance (p = 0.250).

The results of the multivariable logistic regression analysis are presented in Table *3*.

Outcome	Conventional care (n = 52)	ERAS (n = 72)	p-value
Extubation time, h	2.40 ± 1.41	1.85 ± 1.14	0.022
High-flow nasal oxygen therapy, n (%)	8 (15.4)	2 (2.8)	0.033
Non-invasive ventilation, n (%)	3 (5.8)	3 (4.2)	0.680
Acute respiratory distress, n (%)	7 (13.5)	7 (9.7)	0.040
Reintubation, n (%)	6 (11.5)	3 (4.2)	0.020
Postoperative infection, n (%)	13 (25.0)	9 (12.5)	0.014
ICU length of stay, days	4 (3–6)	3 (3–4)	0.009
Total hospital length of stay, days	15 (14–19.3)	14 (12–19.3)	0.091
In-hospital mortality, n (%)	8 (15.4)	6 (8.3)	0.250

TABLE 3: Postoperative outcomes and complications

Data are presented as mean ± standard deviation, median (interquartile range), or number (%), as appropriate. Between-group comparisons were performed using Student's t-test or the Mann–Whitney U test for continuous variables and the chi-square test or Fisher's exact test for categorical variables, as appropriate.

ICU, intensive care unit

Multivariable analysis

After adjustment for age, ASA III-IV status, ischemic heart disease, and left ventricular ejection fraction, ERAS implementation remained independently associated with a lower risk of overall postoperative complications (adjusted OR 0.28, 95% CI 0.11-0.72; p = 0.008), postoperative infections (adjusted OR 0.22, 95% CI 0.07-0.72; p = 0.012), and respiratory complications (adjusted OR 0.27, 95% CI 0.07-0.94; p = 0.040).

ERAS implementation was also associated with shorter extubation time (adjusted ratio 0.73, 95% CI 0.58-0.91; p = 0.005) and shorter ICU LOS (adjusted ratio 0.81, 95% CI 0.68-0.97; p = 0.025). The results of the multivariable analyses are summarized in Table *4*.

Outcome	Adjusted effect (95% CI)	p-value
Overall postoperative complications	OR 0.28 (0.11–0.72)	0.008
Postoperative infections	OR 0.22 (0.07–0.72)	0.012
Respiratory complications	OR 0.27 (0.07–0.94)	0.040
Extubation time	Ratio 0.73 (0.58–0.91)	0.005
ICU length of stay	Ratio 0.81 (0.68–0.97)	0.025

TABLE 4: Multivariable analysis of postoperative outcomes associated with ERAS implementation

Adjusted for age, ASA III–IV status, ischemic heart disease, and left ventricular ejection fraction. Between-group comparisons were performed using Student's t-test or the Mann–Whitney U test for continuous variables and the chi-square test or Fisher's exact test for categorical variables, as appropriate.

OR, odds ratio; CI, confidence interval

Discussion

The present study evaluated the implementation of an ERAS pathway in adult cardiac surgery at a tertiary university hospital in Morocco. ERAS implementation was associated with earlier extubation, fewer respiratory and infectious complications, and shorter ICU stays, despite a higher baseline risk profile among patients managed after implementation.

The principal contribution of this study is to provide real-world evidence regarding the feasibility and clinical outcomes associated with implementing a comprehensive ERAS pathway in a resource-constrained healthcare system characterized by limited perioperative resources and ICU capacity. Although enhanced recovery strategies have been extensively investigated in high-income countries, evidence from North African cardiac surgery programs remains limited. Our findings may therefore provide useful insights for institutions seeking to introduce structured perioperative optimization pathways in comparable healthcare settings.

An important observation was the higher baseline risk profile of patients in the ERAS group. These patients were older, had a higher prevalence of hypertension and ischemic heart disease, a greater proportion of ASA physical status III-IV, and lower left ventricular ejection fraction. These differences may reflect the progressive evolution of our institutional cardiac surgery program and changes in the characteristics of patients referred for surgery over time. Despite these unfavorable baseline characteristics, several postoperative outcomes improved following ERAS implementation. However, these findings should not be interpreted as demonstrating an independent causal effect of ERAS, since differences in patient characteristics, surgical complexity, and temporal changes in clinical practice may have influenced postoperative outcomes.

Enhanced recovery pathways were initially developed in colorectal surgery before being progressively adopted across multiple surgical specialties. Over the last decade, increasing evidence has supported their application in cardiac surgery, leading to the publication of dedicated recommendations by the ERAS Society. These recommendations advocate a multidisciplinary perioperative approach incorporating patient education, preoperative optimization, opioid-sparing analgesia, goal-directed fluid management, early extubation, early mobilization, and nutritional support [1]. Our institutional pathway was developed according to these principles while allowing adaptations to local resource availability and organizational constraints. This pragmatic approach illustrates the potential feasibility of introducing enhanced recovery strategies in healthcare settings where access to certain technologies and specialized interventions may be limited.

Perioperative multimodal analgesia and regional anesthesia

Effective perioperative pain management is a fundamental component of enhanced recovery after cardiac surgery, as adequate analgesia facilitates respiratory rehabilitation, early mobilization, and functional recovery. Contemporary ERAS recommendations emphasize multimodal, opioid-sparing analgesic strategies to optimize postoperative pain control while minimizing opioid-related adverse effects [8]. In our institution, the ERAS pathway incorporated a structured multimodal analgesic regimen combining paracetamol, nefopam, ketamine, and selective use of ketoprofen, with intravenous morphine administered as rescue analgesia when required. This approach was intended to facilitate early postoperative recovery while limiting routine opioid exposure. Beyond systemic analgesia, ultrasound-guided regional anesthesia techniques, particularly fascial plane chest wall blocks such as the erector spinae plane, pectointercostal fascial plane,

and transversus thoracic muscle plane blocks, have emerged as potential adjuncts to multimodal analgesia in cardiac surgery [9,10]. These techniques may improve postoperative pain control and reduce opioid requirements, although their effectiveness and safety depend on the specific technique, available evidence, and patient-related factors, including perioperative anticoagulation. However, regional anesthesia techniques were not routinely incorporated into our institutional pathway. Furthermore, although multimodal analgesia formed part of our ERAS protocol, the lack of systematic quantitative analysis of postoperative pain scores and opioid consumption limits our ability to determine its independent contribution to the observed improvements in clinical outcomes. Future prospective studies should incorporate standardized pain assessment, opioid consumption measurements, and evaluation of regional analgesic techniques to better characterize their role in enhanced recovery after cardiac surgery.

One of the most notable findings of our study was the significant reduction in extubation time after ERAS implementation. Early extubation is considered a cornerstone of enhanced recovery programs in cardiac surgery because prolonged mechanical ventilation is associated with pulmonary complications, longer ICU stays, and greater healthcare resource utilization. In our cohort, the mean extubation time decreased significantly following introduction of the ERAS pathway. This finding is consistent with the recommendations of Engelman et al. and previous fast-track cardiac surgery studies demonstrating that early extubation may facilitate postoperative recovery and reduce ICU resource utilization [1,11]. Moreover, systematic reviews and meta-analyses have reported that fast-track cardiac anesthesia facilitates earlier extubation and may shorten ICU stays without clear evidence of increased postoperative morbidity or mortality [12,13]. Similar findings have been reported in randomized and observational studies evaluating early extubation after cardiac surgery [14-18]. Nevertheless, early extubation should be considered part of a comprehensive perioperative strategy rather than an isolated intervention, and its contribution to postoperative outcomes cannot be independently established from our study design.

Improved respiratory recovery was accompanied by a reduction in postoperative pulmonary complications. Acute respiratory distress and reintubation rates were lower following implementation of the ERAS protocol. These findings are clinically relevant because respiratory complications remain important contributors to postoperative morbidity after cardiac surgery. Several mechanisms may explain the observed associations. Earlier liberation from mechanical ventilation may reduce exposure to ventilator-associated complications, while adequate analgesia, respiratory physiotherapy, and early mobilization may facilitate pulmonary recovery. Our findings are therefore consistent with previous reports identifying respiratory outcomes as an important domain potentially benefiting from ERAS implementation in cardiac surgery [1,2].

Another important finding was the reduction in postoperative infectious complications following ERAS implementation. The overall infection rate decreased from 25% to 12.5%. Importantly, this association remained statistically significant after adjustment for selected baseline differences between groups, suggesting that the observed association was not fully explained by the measured patient characteristics included in the model. Nevertheless, residual confounding cannot be excluded. The reduction in infectious complications is likely multifactorial. Earlier extubation may reduce exposure to invasive mechanical ventilation, while shorter ICU stays may decrease exposure to healthcare-associated pathogens. In addition, improved mobilization and nutritional optimization may contribute to postoperative recovery. Similar reductions in infectious morbidity have been reported in enhanced recovery programs across various surgical specialties [1,6].

Blood conservation is an important component of contemporary ERAS pathways in cardiac surgery. Blood conservation strategies were incorporated into our institutional protocol in accordance with established recommendations for perioperative blood management. However, the present analysis did not specifically determine the independent contribution of these interventions to postoperative outcomes. Future studies should further evaluate the impact of ERAS implementation on perioperative blood product utilization and transfusion practices [19].

We also observed a significant reduction in cardiopulmonary bypass duration and aortic cross-clamp time following ERAS implementation. However, this finding should be interpreted with caution, as ERAS protocols do not directly modify surgical techniques and the distribution of surgical procedures differed between groups. Shorter cardiopulmonary bypass and cross-clamp durations may therefore reflect differences in surgical case mix, evolving surgical experience, procedural standardization, or perioperative coordination rather than a direct effect of the ERAS protocol. These intraoperative differences may also have influenced postoperative recovery and should be considered potential confounding factors when interpreting the observed outcomes [20,21].

One of the most clinically relevant findings of our study was the reduction in ICU LOS. The median ICU LOS decreased significantly from four to three days ($p = 0.009$) following implementation of the ERAS protocol. This reduction may reflect improvements in respiratory recovery, postoperative stabilization, and multidisciplinary care coordination. Although these findings are consistent with international studies demonstrating that enhanced recovery pathways may improve resource utilization, the observational design prevents definitive attribution of the reduction in ICU LOS to ERAS implementation alone [1,2].

Reduced ICU LOS is particularly relevant in cardiac surgery, where ICU occupancy frequently represents a limiting factor for surgical activity and healthcare efficiency. In resource-constrained healthcare systems, including Morocco, ICU bed availability remains limited and perioperative resource utilization represents a major organizational challenge. Strategies associated with shorter ICU stays may therefore help optimize critical care capacity and facilitate access to specialized surgical services. However, shorter ICU stays should not automatically be interpreted as evidence of reduced healthcare costs without a formal economic evaluation.

Although in-hospital mortality decreased from 15.4% in the conventional care group to 8.3% in the ERAS group, this difference did not reach statistical significance. The relatively modest sample size and limited number of mortality events restrict the precision of this comparison. Accordingly, the observed difference should be considered hypothesis-generating rather than evidence of a mortality benefit. Larger, adequately powered studies are required to determine whether ERAS implementation is associated with improved survival following adult cardiac surgery.

Strengths and limitations

This study has several strengths. It provides real-world data regarding ERAS implementation in a tertiary cardiac surgery center and contributes to the limited body of evidence available from North African countries regarding enhanced recovery pathways in cardiac surgery. Furthermore, the comparison of outcomes before and after implementation offers a pragmatic assessment of ERAS in routine clinical practice.

Nevertheless, several limitations should be acknowledged. First, the retrospective observational design introduces potential selection and information biases and precludes causal inference. Second, the single-center setting may limit the generalizability of the findings to institutions with different patient populations, surgical volumes, and perioperative resources. Third, the relatively modest sample size may have reduced statistical power to detect differences in infrequent outcomes, particularly mortality.

Our institution is a regional tertiary referral cardiac surgery center serving Eastern Morocco. Although it is one of the main referral centers in the region, its annual volume of adult cardiac surgery remains lower than that of large high-volume centers in high-income countries. Therefore, the present cohort reflects the real-world clinical activity of our institution, and extrapolation to other healthcare settings should be undertaken cautiously.

Although multivariable adjustment was performed to account for selected baseline differences between groups, residual confounding cannot be excluded because of the observational before-and-after design. Furthermore, improvements in surgical techniques, perioperative practices, institutional experience, and clinical organization over time may have contributed to the observed outcomes independently of the ERAS protocol. Because ERAS implementation involved multiple simultaneous interventions, it was not possible to determine the relative contribution of each individual component to the observed improvements.

An additional limitation concerns the evaluation of perioperative analgesia. Although a structured multimodal analgesic strategy was incorporated into the institutional ERAS pathway, postoperative pain scores and opioid consumption were not systematically analyzed as study outcomes. Moreover, regional anesthesia techniques were not routinely incorporated into the protocol. Consequently, the specific contribution of analgesic optimization to earlier extubation, respiratory recovery, and mobilization could not be independently assessed.

Future multicenter prospective studies are needed to confirm these findings and evaluate the long-term impact of ERAS implementation on quality of life, functional recovery, healthcare costs, and survival. Such studies should also incorporate standardized pain assessment, opioid consumption measurements, and evaluation of regional analgesic techniques to better characterize the contribution of individual ERAS components to postoperative recovery.

In summary, implementation of an ERAS pathway in adult cardiac surgery was associated with earlier extubation, fewer respiratory and infectious complications, and shorter ICU stays. These associations were observed despite a higher baseline risk profile among patients in the post-implementation group. Although causal relationships cannot be established, our findings support the feasibility of implementing a structured enhanced recovery pathway in a resource-constrained cardiac surgery setting and provide a rationale for further prospective evaluation.

Conclusions

Implementation of an ERAS protocol in adult cardiac surgery was associated with earlier extubation, fewer respiratory and infectious complications, and shorter ICU stays. These benefits were observed despite a higher baseline risk profile among patients managed within the ERAS pathway. Although no statistically significant reduction in in-hospital mortality was demonstrated, the observed decrease was clinically encouraging, particularly in a resource-limited setting. Our findings support the feasibility of ERAS

implementation in cardiac surgery and suggest that enhanced recovery strategies may improve both clinical outcomes and healthcare efficiency in lower-middle-income countries. Prospective multicenter studies are warranted to confirm these findings.

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

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Disclosures

Human subjects: Informed consent for treatment and open access publication was obtained or waived by all participants in this study. **Animal subjects:** All authors have confirmed that this study did not involve animal subjects or tissue. **Conflicts of interest:** In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info:** All authors have declared that no financial support was received from any organization for the submitted work. **Financial relationships:** All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

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