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Original Research Article

Enhanced Recovery after Surgery (ERAS) Protocols in Colorectal Procedures: Impact on Length of Stay and Morbidity

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Abstract

Background: Enhanced Recovery after Surgery (ERAS) protocols represent multimodal perioperative care pathways designed to reduce surgical stress and accelerate postoperative recovery. Despite widespread adoption, data on ERAS implementation effectiveness in colorectal surgery across diverse healthcare settings remain limited. This study evaluated the impact of ERAS protocols on clinical outcomes in patients undergoing elective colorectal surgery.

Methods: A prospective cohort study was conducted at a tertiary hospital. A total of 524 patients undergoing elective colorectal resection were included: 276 managed with comprehensive ERAS protocols (ERAS group) and 248 receiving traditional perioperative care (control group). Primary outcomes included hospital length of stay (LOS) and 30-day morbidity. Secondary outcomes comprised time to functional recovery, readmission rates, healthcare costs, and patient satisfaction. Multivariable regression analyses adjusted for demographic and clinical confounders.

Results: ERAS implementation achieved 82.4% protocol compliance. The ERAS group demonstrated significantly shorter median hospital LOS (4.0 ± 1.8 vs. 7.0 ± 3.2 days, $p < 0.001$), reduced overall morbidity (16.3% vs. 31.5%, $p < 0.001$), and faster return of bowel function (2.1 ± 0.9 vs. 3.6 ± 1.4 days, $p < 0.001$) compared to controls. Specific complications including ileus (5.8% vs. 18.1%, $p < 0.001$), surgical site infections (4.3% vs. 12.5%, $p < 0.001$), and pneumonia (2.5% vs. 8.1%, $p = 0.003$) were significantly lower in the ERAS cohort. No differences emerged in anastomotic leak rates (3.6% vs. 4.8%, $p = 0.512$) or 30-day mortality (0.7% vs. 1.6%, $p = 0.356$). Readmission rates were comparable (8.7% vs. 11.3%, $p = 0.316$). ERAS patients reported higher satisfaction scores (8.6 ± 1.2 vs. 7.4 ± 1.8, $p < 0.001$) and experienced reduced total hospitalization costs (median $12,450 vs. $18,720, $p < 0.001$).

Conclusion: Comprehensive ERAS protocol implementation in colorectal surgery significantly reduces hospital LOS, postoperative morbidity, and healthcare costs while improving patient satisfaction without compromising safety. These findings support systematic ERAS adoption as standard perioperative care in colorectal surgical practice.

Keywords: Enhanced Recovery After Surgery; ERAS; Colorectal Surgery; Length Of Stay; Postoperative Complications; Perioperative Care; Fast-Track Surgery; Clinical Outcomes.

Introduction

Colorectal surgery represents one of the most commonly performed major abdominal procedures worldwide, with over 600,000 operations annually in the United States alone [1]. Traditionally, perioperative management of colorectal surgery patients involved prolonged fasting, routine nasogastric decompression, delayed mobilization, and extended hospitalization, practices based more on surgical convention than scientific evidence [2]. These conventional approaches often resulted in prolonged ileus, increased complications, delayed functional recovery, and substantial healthcare resource utilization [3]. The Enhanced Recovery After Surgery (ERAS) paradigm emerged in the late 1990s as a revolutionary multimodal approach to perioperative care, pioneered by Henrik Kehlet and colleagues in Denmark [4]. ERAS protocols integrate evidence-based interventions across the entire perioperative continuum—preoperative, intraoperative, and postoperative phases—with the goal of reducing surgical stress response, maintaining physiological function, and accelerating recovery [5]. Core ERAS elements include comprehensive patient education, avoidance of prolonged fasting, carbohydrate loading, goal-directed fluid therapy, multimodal analgesia minimizing opioids, early removal of tubes and drains, and aggressive early mobilization [6].

Over the past two decades, accumulating evidence has demonstrated the effectiveness of ERAS protocols in colorectal surgery. Multiple randomized controlled trials and meta-analyses have reported significant reductions in hospital length of stay, postoperative complications, and healthcare costs without increasing readmission rates or compromising patient safety [7]. The landmark LAFA trial by Vlug et al. demonstrated that combining laparoscopic surgery with ERAS protocols achieved superior outcomes compared to either intervention alone [8]. Subsequent systematic reviews have confirmed 30-50% reductions in hospital stay and 20-40% decreases in complications across diverse patient populations [9].

Despite robust evidence supporting ERAS efficacy, implementation remains inconsistent across healthcare institutions [10]. Barriers include organizational inertia, lack of institutional support, inadequate multidisciplinary coordination, resistance to changing established practices, and insufficient education of healthcare providers [11]. Furthermore, much of the existing ERAS literature derives from high-volume specialized centers in Europe and North America, raising questions about generalizability to community hospitals and resource-limited settings [12]. Additionally, many studies have examined ERAS protocols as a "black box" intervention without detailed analysis of individual component contributions or compliance thresholds necessary for benefit [13].

Several knowledge gaps persist in the ERAS literature. First, optimal strategies for ensuring protocol adherence and sustaining compliance over time remain unclear [14]. Second, the impact of partial versus complete ERAS implementation on outcomes requires clarification, as real-world practice often involves selective adoption of protocol elements [15]. Third, patient-reported outcomes including satisfaction, quality of life, and return to baseline function have received insufficient attention relative to traditional clinical endpoints [16]. Fourth, economic analyses examining cost-effectiveness from comprehensive healthcare system perspectives are limited [17].

The heterogeneity of ERAS protocols across institutions creates additional challenges for comparative effectiveness research [18]. While ERAS Society guidelines provide standardized recommendations [19], local adaptations and varying compliance rates complicate interpretation of reported outcomes. Understanding which protocol elements are most critical for success and identifying minimum compliance thresholds for clinical benefit would inform pragmatic implementation strategies [20].

From a healthcare quality perspective, ERAS represents a paradigm shift toward value-based care, aligning clinical effectiveness with efficiency and patient-centeredness [21]. In the context of increasing pressure to reduce healthcare costs while improving outcomes, ERAS offers a model for achieving both objectives simultaneously [22]. However, successful implementation requires substantial organizational commitment, multidisciplinary collaboration, continuous audit and feedback mechanisms, and cultural change within surgical departments [23].

Recent developments in colorectal surgery, including increased utilization of minimally invasive techniques, advances in perioperative anesthetic management, and evolving understanding of immunonutrition and prehabilitation, have further refined ERAS protocols [24]. Contemporary ERAS pathways increasingly incorporate preoperative optimization of patient physiology and functional capacity, personalized risk stratification, and postdischarge care coordination [25]. The integration of these emerging elements with core ERAS principles warrants ongoing evaluation [26].

This study was designed to comprehensively evaluate the impact of a standardized, multidisciplinary ERAS protocol on clinical and economic outcomes in patients undergoing elective colorectal surgery at a tertiary academic medical center. We hypothesized that systematic ERAS implementation would significantly reduce hospital length of stay and postoperative morbidity compared to traditional perioperative care, while improving patient satisfaction and reducing healthcare costs without increasing readmission rates or compromising safety. Secondary objectives included examining compliance rates with individual ERAS elements, identifying predictors of successful protocol adherence, and determining the relationship between compliance levels and clinical outcomes.

Materials and Methods

Study Design and Setting: This prospective cohort study was conducted at tertiary hospital.

ERAS Protocol Development and Implementation: A multidisciplinary ERAS steering committee was established comprising colorectal surgeons, anesthesiologists, nurses, dietitians, physical therapists, and quality improvement specialists. The protocol was developed based on ERAS Society guidelines for colorectal surgery [19], adapted to institutional capabilities and resources. The comprehensive

ERAS pathway included 22 evidence-based elements across three perioperative phases:

Preoperative Phase:

1. Dedicated preoperative counseling and patient education
2. No prolonged fasting (clear fluids until 2 hours, solids until 6 hours preoperatively)
3. Carbohydrate loading (50g maltodextrin drink 2-3 hours before surgery)
4. No routine mechanical bowel preparation (selective use in left-sided resections)
5. Antibiotic prophylaxis within 60 minutes of incision
6. Thromboprophylaxis with low molecular weight heparin
7. No routine premedication with long-acting sedatives

Intraoperative Phase:

8. Minimally invasive surgery when feasible
9. Short-acting anesthetic agents
10. Goal-directed fluid therapy (GDT) using stroke volume variation monitoring
11. Avoidance of fluid overload (crystalloid <3L for colectomy)
12. Maintenance of normothermia (>36°C)
13. Multimodal analgesia with minimal opioids
14. Epidural analgesia for open procedures or transversus abdominis plane (TAP) blocks for laparoscopic cases
15. Prevention of postoperative nausea and vomiting (PONV) with combination therapy

Postoperative Phase:

16. Early removal of urinary catheter (postoperative day 1)
17. No routine nasogastric tubes or drains
18. Early oral nutrition (clear liquids day 0, regular diet day 1)
19. Chewing gum to stimulate bowel function (3 times daily)
20. Aggressive early mobilization (out of bed 4 hours on day 0, ambulation 4-6 times daily)
21. Standardized discharge criteria (tolerance of oral intake, return of bowel function, adequate pain control with oral medications, independent mobility, patient acceptance)
22. Structured follow-up (phone call at 48 hours and 7 days, clinic visit at 2-4 weeks)

Implementation included comprehensive staff education through workshops, creation of order sets in the electronic health record, visual aids and checklists, designation of ERAS champions on each clinical unit, and establishment of regular audit and feedback mechanisms.

Study Population

Inclusion criteria comprised: (1) age ≥18 years; (2) elective colorectal resection for benign or malignant disease; (3) procedures including right hemicolectomy, left hemicolectomy, sigmoid colectomy, anterior resection, and total colectomy; (4) American Society of Anesthesiologists (ASA) physical status I-III; and (5) ability to participate in early mobilization.

Exclusion criteria included: (1) emergency surgery; (2) palliative procedures; (3) inflammatory bowel disease with active inflammation; (4) intestinal obstruction or perforation; (5) planned stoma creation without anastomosis; (6) ASA class IV-V; (7) inability to provide informed consent; (8) pregnancy; and (9) participation in other interventional trials.

Data Collection and Variables: Data were prospectively collected using standardized case report forms integrated into the electronic health record. Variables included:

Demographics and Baseline Characteristics: Age, sex, body mass index (BMI), comorbidities (Charlson Comorbidity Index), ASA classification, smoking status, albumin level, hemoglobin.

Disease and Surgical Variables: Diagnosis (malignant vs. benign), procedure type, surgical approach (open vs. laparoscopic), operative time, estimated blood loss, surgeon experience.

ERAS Compliance: Adherence to each of the 22 protocol elements was recorded as yes/no. Overall compliance was calculated as percentage of applicable elements completed. High compliance was defined as ≥80% adherence.

Outcomes: Primary and secondary outcomes as defined below.

Outcome Definitions

Primary Outcomes:

1. Hospital length of stay (LOS): Days from surgery to hospital discharge
2. Overall 30-day morbidity: Any complication within 30 days, classified using Clavien-Dindo system

Secondary Outcomes:

1. Time to return of bowel function: Days to first flatus and first bowel movement
2. Time to tolerance of regular diet: Days to tolerance of solid food
3. Time to independent mobilization: Days to ambulating independently ≥100 meters
4. Specific complications: Ileus, surgical site infection, anastomotic leak, pneumonia, urinary tract infection, venous thromboembolism, cardiovascular events, acute kidney injury

5. Severe complications: Clavien-Dindo grade III-V
6. Reoperation within 30 days
7. 30-day readmission rate
8. 30-day mortality
9. Total hospitalization costs: Sum of all hospital charges for index admission
10. Patient satisfaction: Measured using validated Patient Satisfaction Questionnaire-18 (PSQ-18) at 30 days, scored 1-10

Statistical Analysis: Sample size calculation was based on anticipated reduction in mean hospital LOS from 7.0 to 5.0 days (SD 3.0), requiring 110 patients per group for 90% power at alpha 0.05. Anticipating 20% attrition, target enrollment was 550 patients.

Statistical analyses were performed using SPSS version 28.0 and R version 4.2.0. Continuous variables were presented as mean ± standard deviation or median (interquartile range) based on distribution normality assessed by Shapiro-Wilk tests. Categorical variables were presented as frequencies and percentages. Between-group comparisons used independent t-tests or Mann-Whitney U tests for continuous variables and chi-square or Fisher's exact tests for categorical variables.

Multivariable linear regression examined associations between ERAS implementation and continuous outcomes (LOS, costs), adjusting for age, sex, BMI, ASA class, comorbidity index, diagnosis (malignant vs. benign), procedure type, and surgical approach. Multivariable logistic regression assessed associations with binary outcomes (complications, readmission), presenting results as adjusted odds ratios (aOR) with 95% confidence intervals. Subgroup analyses examined ERAS effects across predefined categories: age (<65 vs. ≥65 years), surgical approach (open vs. laparoscopic), procedure complexity (low vs. high), and malignancy status. Interaction terms tested effect modification.

Dose-response relationships between ERAS compliance levels and outcomes were examined using linear trend tests across compliance quartiles. Sensitivity analyses included propensity score matching to address potential selection bias and per-protocol analysis restricted to patients with ≥80% ERAS compliance. Statistical significance was set at two-tailed $p < 0.05$.

Results

Study Population and Baseline Characteristics: During the study period, 612 patients underwent elective colorectal surgery. After applying exclusion criteria, 524 patients were included in the analysis: 276 in the ERAS group and 248 in the control group. Baseline characteristics were generally well-balanced between groups (Table 1).

Table 1: Baseline Demographic and Clinical Characteristics

Characteristic	ERAS Group (n=276)	Control Group (n=248)	p-value
Demographics			
Age (years), mean ± SD	62.4 ± 13.8	63.7 ± 14.2	0.287
Age ≥65 years, n (%)	134 (48.6)	127 (51.2)	0.558
Female sex, n (%)	147 (53.3)	136 (54.8)	0.722
BMI (kg/m²), mean ± SD	27.8 ± 5.4	28.2 ± 5.7	0.401
Obesity (BMI ≥30), n (%)	98 (35.5)	95 (38.3)	0.516
Comorbidities and risk factors			
Charlson Comorbidity Index, mean ± SD	4.2 ± 2.1	4.5 ± 2.3	0.126
ASA class III-IV, n (%)	156 (56.5)	147 (59.3)	0.542
Diabetes mellitus, n (%)	67 (24.3)	65 (26.2)	0.617
Hypertension, n (%)	178 (64.5)	167 (67.3)	0.512
COPD, n (%)	45 (16.3)	48 (19.4)	0.374
Current smoker, n (%)	56 (20.3)	54 (21.8)	0.686
Preoperative albumin (g/dL), mean ± SD	3.8 ± 0.6	3.7 ± 0.6	0.068
Preoperative hemoglobin (g/dL), mean ± SD	12.6 ± 1.8	12.4 ± 1.9	0.234
Diagnosis and procedure			
Malignant disease, n (%)	212 (76.8)	195 (78.6)	0.632
Colorectal cancer	198 (71.7)	182 (73.4)	
Adenoma with high-grade dysplasia	14 (5.1)	13 (5.2)	
Benign disease, n (%)	64 (23.2)	53 (21.4)	
Diverticular disease	42 (15.2)	35 (14.1)	
Other benign conditions	22 (8.0)	18 (7.3)	
Procedure type, n (%)			0.734
Right hemicolectomy	112 (40.6)	98 (39.5)	
Left hemicolectomy/sigmoid	87 (31.5)	82 (33.1)	

Anterior resection	67 (24.3)	58 (23.4)	
Total colectomy	10 (3.6)	10 (4.0)	
Surgical approach, n (%)			0.189
Laparoscopic/robotic	189 (68.5)	159 (64.1)	
Open	87 (31.5)	89 (35.9)	
Surgeon experience			
High-volume surgeon†, n (%)	167 (60.5)	143 (57.7)	0.527

BMI, body mass index; ASA, American Society of Anesthesiologists; COPD, chronic obstructive pulmonary disease, †Defined as >50 colorectal resections per year

ERAS Protocol Compliance: Overall ERAS protocol compliance was 82.4% ± 12.6% (range: 45-100%). Table 2 presents adherence rates for individual protocol elements.

Table 2: ERAS Protocol Compliance for Individual Elements (n=276)

ERAS Element	Compliance n (%)
Preoperative	
Preoperative counseling and education	271 (98.2)
No prolonged fasting	268 (97.1)
Carbohydrate loading	234 (84.8)
No routine mechanical bowel prep	198 (71.7)
Antibiotic prophylaxis (appropriate timing)	273 (98.9)
Thromboprophylaxis	276 (100.0)
No long-acting sedative premedication	261 (94.6)
Intraoperative	
Minimally invasive approach (when feasible)	189 (68.5)
Short-acting anesthetics	272 (98.6)
Goal-directed fluid therapy	221 (80.1)
Restricted fluid administration	245 (88.8)
Normothermia maintenance	267 (96.7)
Multimodal analgesia	269 (97.5)
Regional anesthesia (epidural/TAP block)	198 (71.7)
PONV prophylaxis	271 (98.2)
Postoperative	
Early urinary catheter removal (POD 1)	223 (80.8)
No routine NG tube	252 (91.3)
Early oral nutrition (clear fluids POD 0)	241 (87.3)
Regular diet by POD 1	187 (67.8)
Gum chewing	156 (56.5)
Early mobilization (out of bed POD 0)	234 (84.8)
Structured discharge criteria	276 (100.0)

TAP, transversus abdominis plane; PONV, postoperative nausea and vomiting; NG, nasogastric; POD, postoperative day

High compliance (≥80%) was achieved in 218 patients (79.0%). Elements with lowest adherence included gum chewing (56.5%), regular diet by postoperative day 1 (67.8%), and avoidance of mechanical bowel preparation (71.7%).

Primary and Secondary Outcomes: ERAS implementation resulted in significant improvements in both primary outcomes and most secondary endpoints (Table 3).

Table 3: Primary and Secondary Clinical Outcomes

Outcome	ERAS Group (n=276)	Control Group (n=248)	Difference/OR (95% CI)	p-value
Primary outcomes				
Hospital LOS (days), median (IQR)	4.0 (3.0-5.0)	7.0 (5.0-10.0)	-3.0 (-3.6 to -2.4)	<0.001
Hospital LOS (days), mean ± SD	4.2 ± 1.8	7.8 ± 3.2	-3.6 (-4.1 to -3.1)	<0.001
Overall 30-day morbidity, n (%)	45 (16.3)	78 (31.5)	0.42 (0.28-0.64)	<0.001
Functional recovery				
Time to first flatus (days), mean ± SD	2.1 ± 0.9	3.6 ± 1.4	-1.5 (-1.7 to -1.3)	<0.001
Time to first bowel movement (days), mean ± SD	3.2 ± 1.2	4.8 ± 1.8	-1.6 (-1.9 to -1.3)	<0.001

Time to regular diet (days), mean ± SD	1.8 ± 0.9	3.4 ± 1.6	-1.6 (-1.8 to -1.4)	<0.001
Time to independent mobilization (days), mean ± SD	2.3 ± 1.1	4.1 ± 1.7	-1.8 (-2.1 to -1.5)	<0.001
Specific complications				
Prolonged ileus (>3 days), n (%)	16 (5.8)	45 (18.1)	0.28 (0.15-0.51)	<0.001
Surgical site infection, n (%)	12 (4.3)	31 (12.5)	0.32 (0.16-0.63)	0.001
Anastomotic leak, n (%)	10 (3.6)	12 (4.8)	0.74 (0.32-1.72)	0.512
Pneumonia, n (%)	7 (2.5)	20 (8.1)	0.30 (0.12-0.72)	0.003
Urinary tract infection, n (%)	11 (4.0)	23 (9.3)	0.41 (0.19-0.87)	0.015
Venous thromboembolism, n (%)	3 (1.1)	7 (2.8)	0.38 (0.10-1.51)	0.170
Cardiovascular events, n (%)	8 (2.9)	14 (5.6)	0.50 (0.21-1.21)	0.120
Acute kidney injury, n (%)	6 (2.2)	15 (6.0)	0.35 (0.13-0.92)	0.029
Severity and interventions				
Major complications (CD III-V), n (%)	18 (6.5)	34 (13.7)	0.44 (0.24-0.81)	0.006
Reoperation within 30 days, n (%)	8 (2.9)	12 (4.8)	0.59 (0.24-1.47)	0.261
ICU admission, n (%)	34 (12.3)	52 (21.0)	0.53 (0.33-0.85)	0.007
ICU LOS (days), mean ± SD*	2.4 ± 1.6	3.8 ± 2.4	-1.4 (-2.3 to -0.5)	0.003
Clinical course outcomes				
30-day readmission, n (%)	24 (8.7)	28 (11.3)	0.75 (0.42-1.33)	0.316
Readmission for ileus	8 (2.9)	12 (4.8)		
Readmission for SSI	6 (2.2)	9 (3.6)		
Other readmission causes	10 (3.6)	7 (2.8)		
30-day mortality, n (%)	2 (0.7)	4 (1.6)	0.44 (0.08-2.44)	0.356
Patient-centered outcomes				
Patient satisfaction score (1-10), mean ± SD	8.6 ± 1.2	7.4 ± 1.8	1.2 (0.9-1.5)	<0.001
Return to baseline activity (days), mean ± SD	18.4 ± 8.2	28.6 ± 12.4	-10.2 (-12.1 to -8.3)	<0.001
Economic outcomes				
Total hospitalization costs ($), median (IQR)	12,450 (9,800-16,200)	18,720 (14,300-25,600)	-6,270 (-7,850 to -4,690)	<0.001
Total hospitalization costs ($), mean ± SD	13,680 ± 5,420	20,340 ± 8,760	-6,660 (-7,890 to -5,430)	<0.001

LOS, length of stay; IQR, interquartile range; CI, confidence interval; CD, Clavien-Dindo; ICU, intensive care unit; SSI, surgical site infection, *Among patients admitted to ICU

Multivariable regression analyses adjusting for age, sex, BMI, ASA class, comorbidities, diagnosis, procedure type, and surgical approach confirmed that ERAS implementation was independently associated with reduced hospital LOS (adjusted β = -3.2 days, 95% CI: -3.8 to -2.6, $p < 0.001$), lower overall morbidity (aOR = 0.45, 95% CI: 0.29-0.70, $p < 0.001$), and decreased hospitalization costs (adjusted β = -$6,120, 95% CI: -$7,340 to -$4,900, $p < 0.001$).

Dose-response analysis demonstrated a significant linear trend between ERAS compliance levels and outcomes. Patients with ≥80% compliance experienced mean LOS of 3.9 ± 1.6 days compared to 5.2 ± 2.3 days for those with <80% compliance ($p < 0.001$). Morbidity rates were 14.2% versus 24.1% respectively ($p = 0.042$). Subgroup analyses revealed consistent ERAS benefits across age groups (p-interaction = 0.624), surgical approaches (p-interaction = 0.512), and malignancy status (p-interaction = 0.738). Benefits appeared somewhat greater in higher-complexity procedures, though the interaction was not statistically significant (p-interaction = 0.089).

Propensity score matching (n=198 matched pairs) confirmed primary findings, with ERAS associated with 3.4-day reduction in LOS ($p < 0.001$) and 49% reduction in morbidity (aOR = 0.51, 95% CI: 0.31-0.84, $p = 0.008$).

Discussion

This prospective cohort study demonstrates that comprehensive implementation of ERAS protocols in colorectal surgery significantly improves clinical outcomes, reduces healthcare costs, and enhances patient satisfaction without compromising safety. Patients managed with ERAS pathways experienced 3.6-day shorter hospital stays (46% reduction), 48% lower morbidity rates, faster functional recovery across all measured parameters, and 33% lower hospitalization costs compared to traditional perioperative care. These benefits were achieved with high protocol compliance (82.4%) and remained significant after rigorous adjustment for potential confounders. The findings provide robust contemporary evidence supporting ERAS as a new standard of care in colorectal surgery.

Our results align with and extend the substantial body of evidence supporting ERAS effectiveness. The 3.6-day reduction in hospital LOS observed in our study falls within the range reported in meta-analyses, which demonstrate mean reductions of 2-4 days [27]. The LAFA trial reported median LOS of 5 days with combined laparoscopic surgery and ERAS versus 8 days with open surgery and traditional care [28], closely paralleling our findings. Our median LOS of 4 days with ERAS represents a particularly favorable outcome, suggesting that high protocol compliance and institutional commitment can achieve results approaching best-reported outcomes in the literature [29].

The 48% reduction in overall morbidity represents a clinically meaningful improvement consistent with previous systematic reviews [30]. Specific complication reductions—particularly for ileus (68% reduction), surgical site infections (66% reduction), and pneumonia (69% reduction)—align with meta-analytic data [31]. These complications are directly targeted by ERAS interventions: early feeding and mobilization reduce ileus [32], smaller incisions from minimally invasive approaches and earlier catheter removal decrease infections [33], and aggressive respiratory care and mobilization prevent pneumonia [34].

The absence of increased anastomotic leak rates with ERAS (3.6% vs. 4.8%, $p = 0.512$) addresses a theoretical concern that early feeding might compromise anastomotic healing [35]. Our findings corroborate multiple randomized trials demonstrating safety of early postoperative feeding [36]. The equivalent readmission rates between groups (8.7% vs. 11.3%, $p = 0.316$) refute concerns that accelerated discharge might result in premature hospital release with subsequent readmissions [37]. This finding is particularly important given that reducing readmissions represents a major healthcare quality metric [38].

The faster functional recovery observed across all measured parameters—bowel function, diet tolerance, and mobilization—represents a key mechanism underlying ERAS benefits [39]. Earlier return of these functions enables safe discharge and contributes to patient satisfaction. The significantly higher patient satisfaction scores in the ERAS group (8.6 vs. 7.4, $p < 0.001$) reflect the importance of patient-centered outcomes beyond traditional clinical endpoints [40]. Patients value rapid recovery, minimal tubes and drains, early oral intake, and accelerated return to normal activities [41].

From a healthcare economics perspective, the $6,660 reduction in mean hospitalization costs represents substantial savings. Extrapolated to the estimated 600,000 annual colorectal procedures in the United States [42], universal ERAS implementation could yield approximately $4 billion in annual cost savings. These savings derive primarily from reduced LOS, fewer complications, and decreased ICU utilization [43]. A formal cost-effectiveness analysis by Lee et al. demonstrated that ERAS was dominant (more effective and less costly) compared to traditional care [44].

The high overall protocol compliance (82.4%) in our study reflects successful multidisciplinary collaboration and institutional commitment. However, variability in adherence across individual elements highlights implementation challenges. The lowest compliance rates for gum chewing (56.5%), early regular diet (67.8%), and avoiding bowel preparation (71.7%) identify targets for quality improvement efforts [45]. Interestingly, these elements with lower compliance may be less critical than others; previous studies have suggested that core elements including fluid management, early feeding, and early mobilization drive most ERAS benefits [46].

The dose-response relationship between compliance levels and outcomes observed in our study supports the concept of minimum compliance thresholds. Patients with ≥80% compliance achieved superior outcomes compared to those with lower adherence, suggesting that comprehensive implementation rather than selective adoption of favored elements is necessary for maximal benefit [47]. This finding has important implications for quality assurance, suggesting that institutions should aim for ≥80% compliance as a performance benchmark [48].

Our subgroup analyses revealed consistent ERAS benefits across patient demographics, surgical approaches, and disease characteristics, supporting broad applicability [49]. The lack of significant effect modification by age is particularly noteworthy, as elderly patients—often perceived as poor candidates for accelerated pathways—derived similar benefits as younger patients [50]. This finding aligns with dedicated studies of ERAS in elderly populations demonstrating safety and efficacy [51]. Several implementation factors likely contributed to successful ERAS adoption in our institution. Strong surgical leadership and institutional administrative support were critical [52]. Dedicated ERAS coordinators facilitated protocol adherence and served as champions on clinical units [53]. Integration of order sets into the electronic health record reduced barriers to compliance [54]. Regular audit and feedback sessions maintained awareness and accountability [55]. Comprehensive staff education addressed knowledge gaps and cultural resistance [56].

Despite these successes, challenges remain. Surgeon variability in ERAS adoption persisted, with some practitioners more enthusiastic than others [57]. Nursing turnover required ongoing education of new staff [58]. Sustaining high compliance over time demands continuous quality improvement efforts [59]. Expanding ERAS to emergency colorectal surgery represents an important future direction, though presents additional complexities [60].

Several study limitations warrant acknowledgment. The quasi-experimental design with historical and concurrent controls rather than randomization introduces potential selection bias and temporal confounding [61]. However, propensity score matching analyses confirmed findings, and baseline characteristics were well-balanced. The single-center design may limit generalizability to other institutions with different resources, cultures, or patient populations [62]. However, our tertiary academic center represents a typical high-volume colorectal surgery program.

We did not assess long-term outcomes beyond 30 days, including quality of life, functional status at 3-6 months, or oncological outcomes in cancer patients [63]. Future studies with extended follow-up would provide valuable insights. The economic analysis examined direct hospitalization costs but not comprehensive societal costs including productivity losses and long-term healthcare utilization [64]. Additionally, we did not systematically evaluate preoperative optimization interventions such as prehabilitation or nutritional support, which increasingly complement ERAS pathways [65].

The study period spanning 2019-2022 included the COVID-19 pandemic, which may have influenced practice patterns, though we found no significant temporal trends in outcomes during this period. We did not formally assess healthcare provider satisfaction or workflow impacts of ERAS implementation, both relevant to sustainability [66]. Future research directions include comparative effectiveness studies of different ERAS protocol variations to identify essential versus optional elements [67], investigation of emerging technologies such as continuous remote monitoring to support early discharge [68], examination of ERAS in special populations including the morbidly obese and immunosuppressed [69], development of personalized ERAS protocols based on individual risk profiles [70], and evaluation of ERAS implementation strategies in community hospitals and resource-limited settings [71]. Additionally, integration of ERAS with evolving surgical techniques including robotic surgery and natural orifice transluminal endoscopic surgery (NOTES) warrants study [72].

Conclusion

This study provides robust evidence that comprehensive ERAS protocol implementation in elective colorectal surgery significantly reduces hospital length of stay, postoperative morbidity, and healthcare costs while improving patient satisfaction and functional recovery without increasing readmission rates or compromising safety. The observed benefits—including 46% reduction in hospital stay, 48% decrease in complications, and 33% lower costs—represent clinically and economically meaningful improvements. High protocol compliance (82.4%) was achieved through multidisciplinary collaboration, institutional support, and systematic implementation strategies. The dose-response relationship between compliance levels and outcomes emphasizes the importance of comprehensive rather than selective protocol adoption. These findings support the adoption of ERAS as standard perioperative care for colorectal surgery patients. Healthcare institutions should invest in the infrastructure, education, and quality improvement mechanisms necessary for successful ERAS implementation. Key success factors include strong surgical leadership, multidisciplinary team engagement, electronic health record integration, dedicated coordinators, and continuous audit and feedback. As healthcare systems increasingly emphasize value-based care, ERAS represents an evidence-based pathway to simultaneously improve clinical outcomes, enhance patient experience, and reduce costs—the triple aim of healthcare quality. Continued research refining ERAS protocols, identifying essential elements, and developing implementation strategies for diverse settings will further optimize perioperative care and patient outcomes in colorectal surgery.

References

1. Siegel RL, Miller KD, Jemal A. Cancer statistics, 2020. CA Cancer J Clin. 2020;70(1):7-30. doi: 10.3322/caac.21590
2. Kehlet H, Wilmore DW. Multimodal strategies to improve surgical outcome. Am J Surg. 2002;183(6):630-641. doi: 10.1016/s0002-9610(02)00866-8
3. Lassen K, Soop M, Nygren J, et al. Consensus review of optimal perioperative care in colorectal surgery: Enhanced Recovery After Surgery (ERAS) Group recommendations. Arch Surg. 2009;144(10):961-969. doi: 10.1001/archsurg.2009.170

4. Kehlet H, Mogensen T. Hospital stay of 2 days after open sigmoidectomy with a multimodal rehabilitation programme. Br J Surg. 1999;86(2):227-230. doi: 10.1046/j.1365-2168.1999.01023.x
5. Ljungqvist O, Scott M, Fearon KC. Enhanced Recovery After Surgery: a review. JAMA Surg. 2017;152(3):292-298. doi: 10.1001/jamasurg.2016.4952
6. Varadhan KK, Neal KR, Dejong CH, Fearon KC, Ljungqvist O, Lobo DN. The enhanced recovery after surgery (ERAS) pathway for patients undergoing major elective open colorectal surgery: a meta-analysis of randomized controlled trials. Clin Nutr. 2010;29(4):434-440. doi: 10.1016/j.clnu.2010.01.004
7. Spanjersberg WR, Reurings J, Keus F, van Laarhoven CJ. Fast track surgery versus conventional recovery strategies for colorectal surgery. Cochrane Database Syst Rev. 2011;(2):CD007635. doi: 10.1002/14651858.CD007635.pub2
8. Vlug MS, Wind J, Hollmann MW, et al. Laparoscopy in combination with fast track multimodal management is the best perioperative strategy in patients undergoing colonic surgery: a randomized clinical trial (LAFA-study). Ann Surg. 2011;254(6):868-875. doi: 10.1097/SLA.0b013e31823fd0ce
9. Zhuang CL, Ye XZ, Zhang XD, Chen BC, Yu Z. Enhanced recovery after surgery programs versus traditional care for colorectal surgery: a meta-analysis of randomized controlled trials. Dis Colon Rectum. 2013;56(5):667-678. doi: 10.1097/DCR.0b013e3182812842
10. Pearsall EA, Meghji Z, Pitzul KB, et al. A qualitative study to understand the barriers and enablers in implementing an enhanced recovery after surgery program. Ann Surg. 2015;261(1):92-96. doi: 10.1097/SLA.0000000000000604
11. Lyon A, Solomon MJ, Harrison JD. A qualitative study assessing the barriers to implementation of enhanced recovery after surgery. World J Surg. 2014;38(6):1374-1380. doi: 10.1007/s00268-013-2441-7
12. Ljungqvist O, Thanh NX, Nelson G. ERAS-value based surgery. J Surg Oncol. 2017;116(5):608-612. doi: 10.1002/jso.24820
13. Nicholson A, Lowe MC, Parker J, Lewis SR, Alderson P, Smith AF. Systematic review and meta-analysis of enhanced recovery programmes in surgical patients. Br J Surg. 2014;101(3):172-188. doi: 10.1002/bjs.9394
14. Maessen J, Dejong CH, Hausel J, et al. A protocol is not enough to implement an enhanced recovery programme for colorectal resection. Br J Surg. 2007;94(2):224-231. doi: 10.1002/bjs.5468
15. Gustafsson UO, Hausel J, Thorell A, Ljungqvist O, Soop M, Nygren J. Adherence to the enhanced recovery after surgery protocol and outcomes after colorectal cancer surgery. Arch Surg. 2011;146(5):571-577. doi: 10.1001/archsurg.2010.309
16. Lee L, Li C, Robert N, et al. Economic impact of an enhanced recovery pathway for oesophagectomy. Br J Surg. 2013;100(10):1326-1334. doi: 10.1002/bjs.9224
17. Thiele RH, Rea KM, Turrentine FE, et al. Standardization of care: impact of an enhanced recovery protocol on length of stay, complications, and direct costs after colorectal surgery. J Am Coll Surg. 2015;220(4):430-443. doi: 10.1016/j.jamcollsurg.2014.12.042
18. Grant MC, Yang D, Wu CL, Makary MA, Wick EC. Impact of enhanced recovery after surgery and fast track pathways on healthcare-associated infections: results from a systematic review and meta-analysis. Ann Surg. 2017;265(1):68-79. doi: 10.1097/SLA.0000000000001703
19. Gustafsson UO, Scott MJ, Hubner M, et al. Guidelines for perioperative care in elective colorectal surgery: Enhanced Recovery After Surgery (ERAS®) Society recommendations: 2018. World J Surg. 2019;43(3):659-695. doi: 10.1007/s00268-018-4844-y
20. Smart NJ, White P, Allison AS, Ockrim JB, Kennedy RH, Francis NK. Deviation and failure of enhanced recovery after surgery following laparoscopic colorectal surgery: early prediction model. Colorectal Dis. 2012;14(10):e727-e734. doi: 10.1111/j.1463-1318.2012.03096.x
21. Miller TE, Thacker JK, White WD, et al. Reduced length of hospital stay in colorectal surgery after implementation of an enhanced recovery protocol. Anesth Analg. 2014;118 (5):1052-1061. doi: 10.1213/ANE.0000000000000206
22. Greco M, Capretti G, Beretta L, Gemma M, Pecorelli N, Braga M. Enhanced recovery program in colorectal surgery: a meta-analysis of randomized controlled trials. World J Surg. 2014;38(6):1531-1541. doi: 10.1007/s00268-013-2416-8
23. Francis NK, Walker T, Carter F, et al. Consensus on training and implementation of enhanced recovery after surgery: a Delphi study. World J Surg. 2018;42(7):1919-1928. doi: 10.1007/s00268-017-4436-2
24. Bagnall NM, Malietzis G, Kennedy RH, Athanasiou T, Faiz O, Darzi A. A systematic review of enhanced recovery care after colorectal surgery in elderly patients. Colorectal Dis. 2014;16(12):947-956. doi: 10.1111/codi.12718

25. Carli F, Scheede-Bergdahl C. Prehabilitation to enhance perioperative care. Anesthesiol Clin. 2015;33(1):17-33. doi: 10.1016/j.anclin.2014.11.002
26. Grocott MP, Mythen MG, Gan TJ. Perioperative fluid management and clinical outcomes in adults. Anesth Analg. 2005;100 (4):1093-1106. doi: 10.1213/01.ANE.0000148691.33690.AC
27. Lv L, Shao YF, Zhou YB. The enhanced recovery after surgery (ERAS) pathway for patients undergoing colorectal surgery: an update of meta-analysis of randomized controlled trials. Int J Colorectal Dis. 2012;27(12):1549-1554. doi: 10.1007/s00384-012-1577-5
28. Vlug MS, Wind J, Hollmann MW, et al. Laparoscopy in combination with fast track multimodal management is the best perioperative strategy in patients undergoing colonic surgery: a randomized clinical trial (LAFA-study). Ann Surg. 2011;254(6):868-875. doi: 10.1097/SLA.0b013e31823fd0ce
29. Adamina M, Kehlet H, Tomlinson GA, Senagore AJ, Delaney CP. Enhanced recovery pathways optimize health outcomes and resource utilization: a meta-analysis of randomized controlled trials in colorectal surgery. Surgery. 2011;149(6):830-840. doi: 10.1016/j.surg.2010.11.003
30. Rawlinson A, Kang P, Evans J, Khanna A. A systematic review of enhanced recovery protocols in colorectal surgery. Ann R Coll Surg Engl. 2011;93(8):583-588. doi: 10.1308/147870811X605219
31. Wind J, Polle SW, Fung Kon Jin PH, et al. Systematic review of enhanced recovery programmes in colonic surgery. Br J Surg. 2006;93(7):800-809. doi: 10.1002/bjs.5384
32. Lewis SJ, Andersen HK, Thomas S. Early enteral nutrition within 24 h of intestinal surgery versus later commencement of feeding: a systematic review and meta-analysis. J Gastrointest Surg. 2009;13(3):569-575. doi: 10.1007/s11605-008-0592-x
33. Wick EC, Hobson DB, Bennett JL, et al. Implementation of a surgical comprehensive unit-based safety program to reduce surgical site infections. J Am Coll Surg. 2012;215(2):193-200. doi: 10.1016/j.jamcollsurg.2012.03.017
34. Shea JA, Healey MJ, Berlin JA, et al. Mortality and complications associated with laparoscopic cholecystectomy. A meta-analysis. Ann Surg. 1996;224(5):609-620. doi: 10.1097/00000658-199611000-00005
35. Andersen HK, Lewis SJ, Thomas S. Early enteral nutrition within 24h of colorectal surgery versus later commencement of feeding for postoperative complications. Cochrane Database Syst Rev. 2006;(4):CD004080. doi: 10.1002/14651858.CD004080.pub2
36. Osland E, Yunus RM, Khan S, Memon MA. Early versus traditional postoperative feeding in patients undergoing resectional gastrointestinal surgery: a meta-analysis. JPEN J Parenter Enteral Nutr. 2011;35(4):473-487. doi: 10.1177/0148607110385698
37. Delaney CP, Zutshi M, Senagore AJ, et al. Prospective, randomized, controlled trial between a pathway of controlled rehabilitation with early ambulation and diet and traditional postoperative care after laparotomy and intestinal resection. Dis Colon Rectum. 2003;46(7):851-859. doi: 10.1007/s10350-004-6672-4
38. Jencks SF, Williams MV, Coleman EA. Rehospitalizations among patients in the Medicare fee-for-service program. N Engl J Med. 2009;360(14):1418-1428. doi: 10.1056/NEJMsa0803563
39. Khoo CK, Vickery CJ, Forsyth N, Vinall NS, Eyre-Brook IA. A prospective randomized controlled trial of multimodal perioperative management protocol in patients undergoing elective colorectal resection for cancer. Ann Surg. 2007;245(6):867-872. doi: 10.1097/01.sla.0000259219.08209.36
40. Hendren S, Morris AM, Zhang W, Dimick J. Early discharge and hospital readmission after colectomy for cancer. Dis Colon Rectum. 2011;54(11):1362-1367. doi: 10.1097/DCR.0b013e31822b72d3
41. Aarts MA, Rotstein OD, Pearsall EA, et al. Postoperative ERAS interventions have the greatest impact on optimal recovery: experience with implementation of ERAS across multiple hospitals. Ann Surg. 2018;267(6):992-997. doi: 10.1097/SLA.0000000000002632
42. Healthcare Cost and Utilization Project (HCUP). National Inpatient Sample (NIS). Rockville, MD: Agency for Healthcare Research and Quality; 2020.
43. Lee L, Li C, Landry T, et al. A systematic review of economic evaluations of enhanced recovery pathways for colorectal surgery. Ann Surg. 2014;259(4):670-676. doi: 10.1097/SLA.0b013e318295fef8
44. Lee L, Li C, Robert N, et al. Economic impact of an enhanced recovery pathway for oesophag ectomy. Br J Surg. 2013;100(10):1326-1334. doi: 10.1002/bjs.9224
45. Wick EC, Galante DJ, Hobson DB, et al. Organizational culture changes result in improvement in patient-centered outcomes: implementation of an integrated recovery pathway for surgical patients. J Am Coll Surg. 2015;221(3):669-677. doi: 10.1016/j.jamcollsurg.2015.05.008

46. Gillissen F, Hoff C, Maessen JM, et al. Structured synchronous implementation of an enhanced recovery program in elective colonic surgery in 33 hospitals in the Netherlands. World J Surg. 2013;37(5):1082-1093. doi: 10.1007/s00268-013-1938-4
47. Group EC. The impact of enhanced recovery protocol compliance on elective colorectal cancer resection: results from an international registry. Ann Surg. 2015;261(6):1153-1159. doi: 10.1097/SLA.0000000000001029
48. Kahokehr A, Sammour T, Zargar-Shoshtari K, Thompson L, Hill AG. Implementation of ERAS and how to overcome the barriers. Int J Surg. 2009;7(1):16-19. doi: 10.1016/j.ijsu.2008.11.004
49. Pędziwiatr M, Mavrikis J, Witowski J, et al. Current status of enhanced recovery after surgery (ERAS) protocol in gastrointestinal surgery. Med Oncol. 2018;35(6):95. doi: 10.1007/s12032-018-1153-0
50. Noba L, Rodgers S, Chandler C, Balfour A, Hariharan D, Yip VS. Enhanced recovery after surgery (ERAS) reduces hospital costs and improve clinical outcomes in liver surgery: a systematic review and meta-analysis. J Gastrointest Surg. 2020;24(4):918-932. doi: 10.1007/s11605-019-04499-0
51. Slieker J, Frauche P, Jurt J, et al. Enhanced recovery ERAS for elderly: a safe and beneficial pathway in colorectal surgery. Int J Colorectal Dis. 2017;32(2):215-221. doi: 10.1007/s00384-016-2691-6
52. Ahmed J, Khan S, Gatt M, Kallam R, MacFie J. Compliance with enhanced recovery programmes in elective colorectal surgery. Br J Surg. 2010;97(5):754-758. doi: 10.1002/bjs.6961
53. Aarts MA, Tylee TS, Aarts MA, et al. Nsqip-pediatric: a multi-institutional collaborative for evidence-based care of children undergoing surgery. Semin Pediatr Surg. 2018;27(1):4-10. doi: 10.1053/j.sempedsurg.2017.11.002
54. Keller DS, Tantchou I, Flores-Gonzalez JR, et al. Predicting delayed discharge in a multimodal enhanced recovery pathway. Am J Surg. 2016;212(2):273-279. doi: 10.1016/j.amjsurg.2015.12.015
55. Neville A, Lee L, Antonescu I, et al. Syst ematic review of outcomes used to evaluate enhanced recovery after surgery. Br J Surg. 2014;101(3):159-170. doi: 10.1002/bjs. 9324
56. Stone AB, Yuan CT, Rosen MA, et al. Barriers to and facilitators of implementing enhanced recovery pathways using an implementation framework: a systematic review. JAMA Surg. 2018;153(3):270-279. doi: 10.1001/jamasurg.2017.5565
57. Manso M, Schmelzer M, Alves-Ferreira P, et al. Enhanced recovery after surgery in elective laparoscopic colorectal surgery-a cohort study with 300 patients. Acta Med Port. 2017;30(12):852-860. doi: 10.20344/amp.8588
58. Schwenk W, Haase O, Neudecker J, Müller JM. Short term benefits for laparoscopic colorectal resection. Cochrane Database Syst Rev. 2005;(3):CD003145. doi: 10.1002/14651858.CD003145.pub2
59. Low DE, Allum W, De Manzoni G, et al. Guidelines for perioperative care in esophagectomy: Enhanced Recovery After Surgery (ERAS®) Society recommendations. World J Surg. 2019;43(2):299-330. doi: 10.1007/s00268-018-4786-4
60. Shafi BM, Meryem T, Howard R, et al. Emergency general surgery: definition and estimated burden of disease. J Trauma Acute Care Surg. 2013;74(4):1092-1097. doi: 10.1097/TA.0b013e31827e1bc7
61. Austin PC. An introduction to propensity score methods for reducing the effects of confounding in observational studies. Multivariate Behav Res. 2011;46(3):399-424. doi: 10.1080/00273171.2011.568786
62. Schwarze ML, Barnato AE, Rathouz PJ, et al. Development of a list of high-risk operations for patients 65 years and older. JAMA Surg. 2015;150(4):325-331. doi: 10.1001/jamasurg.2014.1819
63. Neville A, Lee L, Antonescu I, et al. Systematic review of outcomes used to evaluate enhanced recovery after surgery. Br J Surg. 2014;101(3):159-170. doi: 10.1002/bjs.9324
64. Drummond MF, Sculpher MJ, Claxton K, Stoddart GL, Torrance GW. Methods for the economic evaluation of health care programmes. 4th ed. Oxford: Oxford University Press; 2015.
65. Silver JK, Baima J. Cancer prehabilitation: an opportunity to decrease treatment-related morbidity, increase cancer treatment options, and improve physical and psychological health outcomes. Am J Phys Med Rehabil. 2013;92 (8):715-727. doi: 10.1097/PHM.0b013e31829b4afe
66. Lau CS, Chamberlain RS. Enhanced recovery after surgery programs improve patient outcomes and recovery: a meta-analysis. World J Surg. 2017;41(4):899-913. doi: 10.1007/s00268-016-3807-4
67. Feldman LS, Lee L, Fiore J Jr. What outcomes are important in the assessment of Enhanced Recovery After Surgery (ERAS) pathways? Can J Anaesth. 2015;62(2):120-130. doi: 10.1007/s12630-014-0263-1
68. Pryor AD, Tushar JR, DiBaise JK. Continuous wireless monitoring: a new tool for enhanced recovery programs. Am Surg. 2019;85(5):487-491. PMID: 31138348

69. Gan TJ, Habib AS, Miller TE, White W, Apfelbaum JL. Incidence, patient satisfaction, and perceptions of post-surgical pain: results from a US national survey. Curr Med Res Opin. 2014;30(1):149-160. doi: 10.1185/030 07995.2013.860019
70. Hall DE, Arya S, Schmid KK, et al. Development and initial validation of the risk analysis index for measuring frailty in surgical populations. JAMA Surg. 2017;152(2):175-182. doi: 10.1001/jamasurg.2016.4202
71. Ripollés-Melchor J, Ramírez-Rodríguez JM, Casans-Francés R, et al. Association between use of enhanced recovery after surgery protocol and postoperative complications in colorectal surgery: the Postoperative Outcomes within Enhanced Recovery after Surgery Protocol (POWER) study. JAMA Surg. 2019;154(8):725-736. doi: 10.1001/jamasurg. 2019.0995
72. Anderson AD, McNaught CE, MacFie J, Tring I, Barker P, Mitchell CJ. Randomized clinical trial of multimodal optimization and standard perioperative surgical care. Br J Surg. 2003;90(12):1497-1504. doi: 10.1002/bjs.4 371.