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RESEARCH

Short-term outcomes of minimally invasive surgery in older colorectal cancer patients in the era of enhanced recovery after surgery: is a "one-size-fits-all" strategy sufficient?

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Abstract

Background An enhanced recovery protocol (ERP) comprises a series of elements aimed at optimizing and standardizing perioperative care. Therefore, in this study, we aimed to evaluate the safety and feasibility of a modified enhanced recovery after surgery (ERAS) protocol following colorectal surgery in older adults aged ≥ 65 years.

Why does this paper matter? This manuscript addresses a critical gap in colorectal cancer (CRC) surgery by evaluating the safety and feasibility of a modified Enhanced Recovery After Surgery (ERAS) protocol in older adults undergoing minimally invasive surgery (MIS). While ERAS protocols are well-established for improving outcomes, their application in high-risk groups, particularly patients aged ≥ 65 years, remains underexplored.

As the largest single-center analysis to date, this study includes over 1,000 patients and provides a detailed age-stratified analysis. It demonstrates significant benefits of the modified ERAS protocol in patients aged 65–80 years, including fewer early complications, shorter hospital stays, and faster recovery. However, for patients aged > 80 years, the benefits were less pronounced, highlighting the challenges of adhering to intensive ERAS components such as early mobilization and rapid diet advancement.

The study's findings have broad implications for perioperative care and healthcare resource management. By demonstrating shorter hospital stays and faster recovery, the study underscores the cost-effectiveness of ERAS protocols while improving patient satisfaction thorough expedited recovery. Additionally, it highlights the need for tailored interventions, such as enhanced prehabilitation and better adherence monitoring, to optimize outcomes for older adults, particularly those aged > 80 years.

This manuscript is timely and relevant, offering valuable insights into refining ERAS protocols for an aging population. Its findings provide a roadmap for improving surgical outcomes, enhancing patient recovery, and advancing perioperative care strategies for older adults with CRC.

Highlights

- The ERAS protocol may require further adaptation for patients aged > 80 years.
- The modified ERAS protocol improves outcomes in older patients with CRC, especially in patients aged 65–80.
- The ERAS protocol significantly reduced overall morbidity in patients aged 65–80.

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Materials and Methods Patients aged ≥ 65 years who underwent minimally invasive colorectal cancer surgery at a tertiary referral hospital in Taiwan between 2018 and 2022 were reviewed retrospectively. Patients were divided into ERAS and traditional care groups according to the perioperative care strategy. The primary outcome was the short-term complication rate. However, the secondary outcomes were postoperative hospital stay, reoperation, readmission, and 30-day mortality rates.

Results Overall, 1392 patients were enrolled, including 550 and 842 in the ERAS and traditional care groups, respectively. Demographic characteristics, including comorbidities, perioperative characteristics, and pathological staging, were not statistically significant. The patients' short-term complication rate was lower in the ERAS group (aged 65–80 years) than in the traditional care group (29 (7.2%) vs. 75 (11.5%), P = 0.026). However, the short-term complication rate did not differ between patients aged > 80 years (24 (16%) vs. 36 (19%), P = 0.438). In addition, the mean postoperative hospital stay was shorter in the ERAS group (7.5 ± 8.9 days vs 9.7 ± 10.0 days, P < 0.001). However, there were no differences in other secondary outcomes, including reoperation, readmission, and 30-day mortality rates.

Conclusion Minimally invasive colorectal cancer surgery within the ERAS program is safe and effective in patients aged 65–80 years.

Keywords Older patients · Colorectal cancer · Enhanced recovery protocol · ERAS · Surgery

Introduction

Minimally invasive surgery is considered a precursor to the concept of enhanced recovery after surgery (ERAS). Dr. Erich Mühe was the first to perform laparoscopic surgery [1]. He successfully performed laparoscopic cholecystectomy in 1985; furthermore, many reports on laparoscopic surgery have been published since the early 1990s. In 1991, Jacobs et al. documented the first laparoscopic colorectal surgery, which marked a significant advancement in the field of colorectal surgery [2]. Minimally invasive surgery offers significant short-term advantages over open surgery. Minimally invasive colectomy is associated with significantly lower analgesia requirements and pain scores, less blood loss, faster recovery of bowel function, and a shorter length of hospital stay. Notably, several studies have also reported reduced postoperative morbidities, including wound infections. Furthermore, many other trials, including the COST, COLOR, CLASICC, and COREAN trials, have demonstrated the advantages of short-term outcomes after laparoscopic colectomy for colorectal cancer (CRC) [3–6].

In the early days of minimally invasive colorectal surgery, surgeons were cautious about high-risk patients, particularly older adults. This group had more comorbidities, such as diabetes, chronic kidney disease, cardiovascular disease, and pulmonary disease, which increased the morbidity and mortality associated with surgery. The introduction of pneumoperitoneum during minimally invasive surgery poses challenges to the patient's cardiopulmonary balance under anesthesia, particularly for those with preexisting health concerns [7, 8]. Prolonged surgical procedures also increase the risks associated with anesthesia. Therefore, minimally invasive colorectal surgery has been developed and stabilized. Notably, many studies have shown that minimally invasive colorectal surgery is beneficial in older patients [9]. The long-term prognosis is the same as that of open surgery, and the short-term prognosis also decreases the length of hospital stay and the risk of postoperative pulmonary-related morbidity and mortality [10–12]. Therefore, even in older patients, minimally invasive surgery remains the preferred choice for CRC surgery [13].

Minimally invasive surgery shortens hospital stays; however, the concept of ERAS also accelerates patient recovery. ERAS protocols are multidisciplinary, evidence-based approaches used in CRC surgery to optimize patient outcomes, minimize complications, and expedite postoperative recovery [14, 15]. ERAS originated from efforts to improve perioperative care and postoperative recovery and has evolved. Compared with traditional care, ERAS significantly reduces the risk of postoperative complications, improves pain management, accelerates bowel function recovery, shortens hospital stays, enhances patient satisfaction, and provides comparable long-term outcomes [16, 17]. These advantages are consistent with the findings previously published by our hospital. Therefore, the ERAS concept has gained global recognition and continues to evolve [18].

Notably, existing evidence endorsing the ERAS protocol applies only to the general population. However, whether this applies to all subgroups requires further validation. Furthermore, similar to the development of laparoscopic surgery, there may have been initial skepticism regarding high-risk subgroups, particularly older adults. However, the current literature on the benefits of ERAS for older adults is limited. Notably, most studies have covered a broader age range or included open and minimally invasive surgeries [19, 20]. Therefore, in our research, we performed an enhanced subgroup analysis to assess the safety and feasibility of a modified ERAS protocol following minimally invasive colorectal surgery, specifically in adults aged ≥ 65 years.

Materials and methods

Study design and patient selection

Between January 2018 and December 2022, comprehensive data from patients who underwent colorectal resection for malignancy at a single medical institute, Chang Gung Memorial Hospital, were prospectively collected and retrospectively reviewed. Patient allocation to the study groups was non-randomized and primarily determined by the attending surgeon's practice patterns. Among the 16 attending colorectal surgeons at our institution, four adopted and implemented the modified ERAS protocol during the study period, while the remaining 12 continued to follow the conventional standard of care. Consequently, assignment to the ERAS or traditional care group was surgeon-dependent. Short-term outcomes were compared between patients in the ERAS group and those receiving traditional standards of care (non-ERAS group). The Institutional Review Board of Chang Gung Memorial Hospital approved this study (IRB No. 202401646B0) and waived the requirement for informed consent due to the retrospective design of the study.

In this study, we enrolled all consecutive patients who met the following criteria: (1) underwent radical resection for CRC, (2) underwent minimally invasive surgery, and (3) were aged ≥ 65 years. Exclusion criteria included patients who underwent emergency surgery, palliative resection, or required conversion from minimally invasive surgery to open surgery.

Intervention description: modified ERAS protocols

The modified ERAS protocols include various primary components to improve patient outcomes and accelerate postoperative recovery. Beginning with preadmission strategies, patients receive personalized counseling and undergo optimization procedures to ensure that they are well physically and mentally prepared for surgery. This involves educating patients about the upcoming procedure, addressing concerns, and optimizing their health status to minimize surgical risks.

In the preoperative phase, specific interventions are used to effectively prepare patients for surgery. Nutritional support was provided to ensure that patients were adequately nourished and ready for physiological stress intraoperatively. Additionally, strategies have been implemented to manage anemia, a typical concern in patients with CRC, and optimize their preoperative hemoglobin levels. Mechanical bowel preparation and oral antibiotics were administered on the basis of evolving best practices to minimize the risk of postoperative surgical site infections.

Notably, at least 8 h before surgery, preoperative nil per os was initiated following the anesthesiologist's advice. During the perioperative period, meticulous attention has been given to various aspects of patient care to promote optimal surgical outcomes. Efforts have been made to minimize the risk of surgical site infections via minimally invasive surgical techniques and appropriate antiseptic agents. Furthermore, measures have been implemented to prevent postoperative nausea and vomiting, which are typical surgical complications that can significantly impact patient recovery and comfort.

In the postoperative phase, the modified ERAS protocols continue to guide patient care, with a focus on facilitating smooth recovery and minimizing complications. Following surgery, patients are closely monitored to ensure early mobilization and prevent postoperative complications such as ileus, a common concern after colorectal surgery. Gradual progression from clear liquid to full liquid and soft diets was initiated on the basis of the patient's condition and the physician's discretion, with the aim of reintroducing nutrition safely while minimizing gastrointestinal discomfort.

Notably, the modified ERAS protocols largely aligned with the standard guidelines; however, notable differences were tailored to the unique needs and circumstances of the patient population being studied. These included variations in preoperative carbohydrate loading, fluid intake, pain management strategies, and the utilization of intra-abdominal and pelvic drains. These adjustments were carefully evaluated to balance the advantages of accelerated recovery with individual needs due to institutional constraints.

Outcomes and covariables

The measured outcomes included short-term postoperative complications, recovery trajectory, and hospital readmission within 30 days. Postoperative complications were carefully recorded and rated via the Clavien–Dindo classification system, which provides a standardized severity evaluation. Postoperative complications are essential for evaluating surgical results and patient safety. Early complications were defined as those that occurred during the initial hospitalization or within 30 days postoperatively. However, late complications develop after discharge.

Additionally, the study closely monitored postoperative recovery, with a focus on restoring gastrointestinal function and length of hospital stay. Early discharge was defined as a postoperative length of stay of less than 6 days. This cut-off was selected to align with the median length of stay (5 days) observed in the ERAS cohort of our study population. Parameters such as the resumption of bowel movements and oral intake provided insights into patients' recuperative progress, informing the refinement of postoperative care protocols.

Moreover, data collection on hospital readmissions within 30 days is a critical indicator of the effectiveness of postoperative management strategies in preventing complications and ensuring a smooth transition to outpatient care. These outcomes collectively facilitated a comprehensive evaluation of the impact of the modified ERAS protocols on patient outcomes, guiding ongoing improvements in perioperative care practices for older patients with CRC.

Statistical analysis

Data analyses were conducted via IBM SPSS Statistics (version 24.0; Armonk, NY, USA). Clinicopathological characteristics represented by categorical variables are expressed as frequencies and proportions, and comparisons were made via the chi-square test. Continuous variables are presented as the means with standard deviations and were analyzed via Student's t test. Statistical significance was set at a P value < 0.05.

Results

Our study compared 550 patients managed under the ERAS protocol with 842 patients receiving traditional care after colorectal surgery (Fig. 1). The demographic and clinical characteristics of both cohorts were similar, with no significant differences in mean age (ERAS: 74.8 years vs. traditional care: 74.4 years; P = 0.264) or body mass index (BMI) (ERAS: 24.7 vs. traditional care: 24.2; P = 0.142). The sex distribution was also balanced between the two groups, with females comprising 46.4% and 43% of the ERAS and traditional care groups, respectively (P = 0.216). A significant difference was observed in the history of previous abdominal surgery, with a greater incidence in the traditional care group (P = 0.025) (Table 1).

Furthermore, the distribution of case types (new cases, second primary cases, and recurrences) did not differ significantly between the groups (P = 0.333). The comorbidity profiles were also similar between the two groups, with no significant differences in the prevalence of hypertension, heart disease, lung disease, cerebrovascular accidents, diabetes mellitus, hepatitis, peptic ulcer disease, thyroid disorders, or other comorbidities (P = 0.217–0.777).

There were no significant differences in the distribution of tumor locations or operative methods between the groups, indicating comparable surgical approaches and tumor

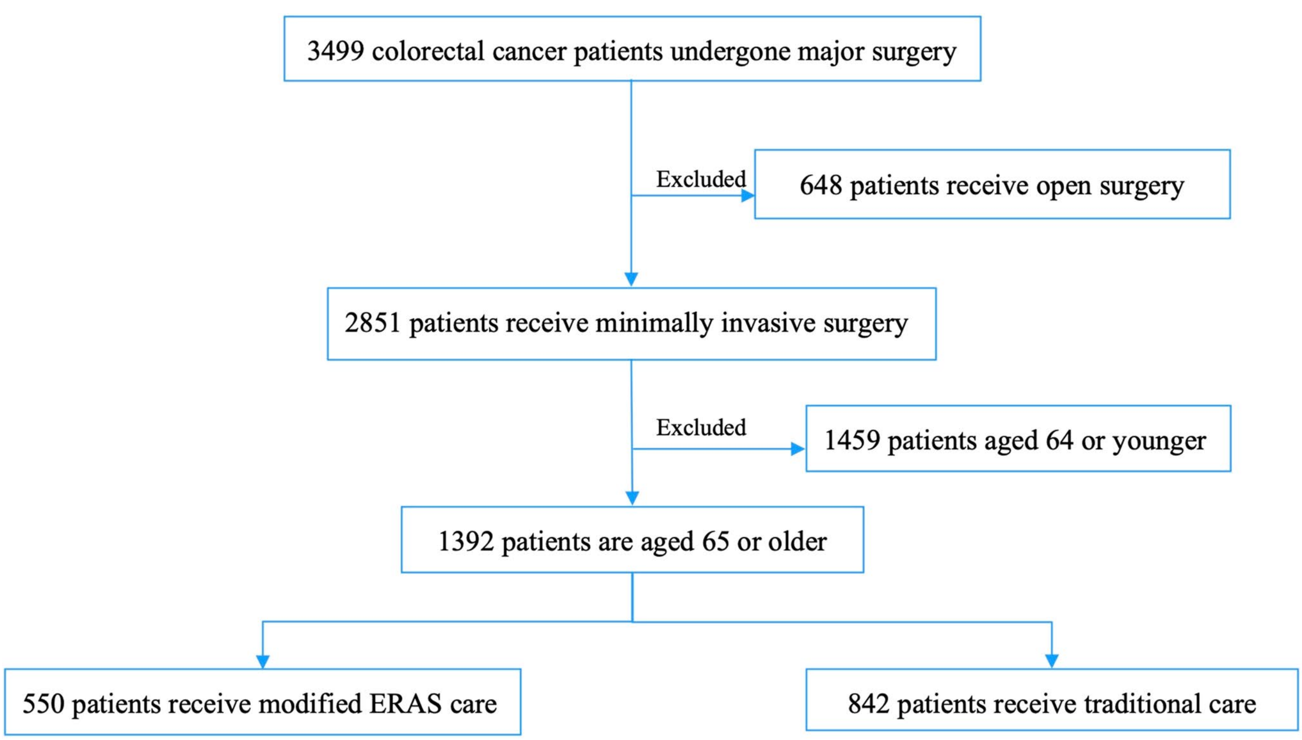

Fig. 1 Study flow chart

Table 1 Demographics and clinical features

	Modified ERAS (n = 550)	Traditional Care (n = 842)	*p*
Male	295 (53.6%)	480 (57%)	0.216
Previous Abd. surgery	143 (26%)	266 (31.6%)	0.025
Type of cases			
Primary	483 (87.8%)	744 (88.4%)	0.333
Second primary	67 (12.2%)	95 (11.3%)	
Recurrence	0	3 (0.4%)	
Age (year, mean, sd)	74.8 (±7.5)	74.4 (±7.4)	0.264
BMI (*kg/m^2, mean, sd*)	24.7 (±3.0)	24.2 (±3.8)	0.142
Comorbidities, total	417 (75.8%)	631 (74.9%)	0.711
hypertension	317 (57.6%)	462 (54.9%)	0.309
Heart	91 (16.5%)	119 (14.1%	0.343
Lung	14 (2.5%)	27 (3.2%)	0.476
CVA	45 (8.2%)	55 (6.5%)	0.244
Diabetes mellitus	162 (29.5%)	254 (30.2%)	0.777
Hepatitis	29 (5.3%)	52 (6.2%)	0.482
Peptic ulcer disease	30 (5.5%)	34 (4%)	0.217
Thyroid	14 (2.5%)	24 (2.9%)	0.733
Others	150 (27.3%)	242 (28.7%)	0.552
Pre-op Lab			
CEA (ug/L)	16.2 (±47.4)	25.6 (±87.1)	**0.008**
Hemoglobin (g/dL)	11.5 (±2.4)	11.8 (±2.4)	**0.037**
White blood cell (/uL)	7039 (±2316)	7195 (±2498)	0.242
Lymphocyte (%)	25.3 (±10.1)	24.5 (±9.1)	0.147
Segment (%)	66.2 (±29.2)	66.1 (±9.9)	0.907
Albumin (g/dL)	3.95 (±0.48)	3.97 (±0.50)	0.401
Phosphorous (mg/dL)	3.5 (±0.7)	3.4 (±0.6)	0.149
Alk-P (IU/L)	75.0 (±51.6)	70.2 (±33.0)	**0.036**
GOT (U/L)	24.1 (±12.5)	23.3 (±11.0)	0.255
Total bilirubin(mg/dL)	0.49 (±0.27)	0.53 (±0.34)	**0.036**
BUN (mg/dL)	18.9 (±10.8)	22.1 (±54.5)	0.094
Creatinine (mg/dL)	1.03 (±0.98)	1.04 (±0.99)	0.982

Abd. Abdominal, BMI body mass index, CVA, cerebrovascular accident, CEA carcinoembryonic antigen, Alk-P Alkaline phosphatase GOT *glutamate oxaloacetate transaminase, BUN blood urea nitrogen*

Table 2 Surgical and pathological outcomes

	Modified ERAS (n = 550)	Traditional Care (n = 842)	*p*
Tumor location			
Right colon	203 (36.9%)	203 (36.9%)	***0.715***
Left colon	192 (34.9%)	192 (34.9%)	
Rectum	155 (28.2%)	155 (28.2%)	
Procedure			
Right hemicolectomy	178 (32.4%)	270 (32.1%)	0.298
Left hemicolectomy	56 (10.2%)	72 (8.6%)	
Anterior resection	273 (49.6%)	436 (51.8%)	
Abdominoperineal resection	8 (1.5%)	22 (2.6%)	
Segmental colectomy	6 (1.1%)	14 (1.7%)	
Subtotal/total colectomy	6 (1.1%)	5 (0.6%)	
Hartman procedure	23 (4.2%)	23 (2.7%)	
T staging			
Is	14 (2.5%)	22 (2.6%)	0.527
T1	51 (9.3%)	103 (12.2%)	
T2	77 (14%)	108 (12.8%)	
T3	304 (55.3%)	435 (51.7%)	
T4a	77 (14%)	136 (16.2%)	
T4b	27 (4.9%)	38 (4.5%)	
N staging			
0	308 (56%)	461 (54.8%)	0.460
1	173 (31.5%)	254 (30.2%)	
2	69 (12.5%)	127 (15.1%)	
M staging			
M0	457 (83.1%)	719 (85.4%)	0.365
M1	93 (11.3%)	123 (14.6%)	
TNM staging			
0	12 (2.2%)	21 (2.5%)	0.548
I	106 (19.3%)	184 (21.9%)	
II	164 (29.8%)	240 (28.5%)	
III	175 (31.8%)	274 (32.5%)	
IV	93 (16.9%)	123 (14.6%)	

Significant values are in bold

burdens (Table 2). Preoperative carcinoembryonic antigen levels were significantly greater in the traditional care group (P = 0.008), and hemoglobin levels were marginally lower in the ERAS group (P = 0.037) (Table 3).

In terms of postoperative outcomes, the ERAS protocol tended to decrease overall (11.8% vs. 14.6%, P = 0.137) and early morbidity (9.5% vs. 12.8%, P = 0.054) in the study population; however, these differences were not statistically significant. Upon age-stratified analysis, early morbidity was significantly lower in the ERAS group compared with traditional care for patients aged 65–80 years (7.0% vs. 11.5%, P = 0.026). Conversely, no significant difference in early morbidity was observed for patients aged > 80 years (16.0% vs. 17.6%, P = 0.438). In addition, no significant differences were observed in patients aged > 80 years. The ERAS group also experienced a shorter mean postoperative stay, a consistent finding across age subgroups, and a quicker return to bowel function, as indicated by the shorter time to the first passage of flatus and stool and earlier tolerance of liquid and soft diets, with all differences being statistically significant (P < 0.001).

The reoperation and 30-day mortality rates did not differ between the groups, nor did the 30-day mortality rate, suggesting that the ERAS protocol is associated with faster recovery without increasing severe adverse events. Multivariate analysis revealed a significant reduction in the

Table 3 postoperative outcomes

	Modified ERAS (n = 550)	**Traditional Care (n = 842)**	***p***
Morbidity (All)	65 (11.8%)	123 (14.6%)	0.137
Early	52 (9.5%)	108 (12.8%)	0.054
Late	15 (2.7%)	23 (2.7%)	0.996
Early morbidity			
None	498 (90.5%)	734 (87.2%)	0.142
Wound	4 (0.7%)	14 (1.7%)	
Lung	13 (2.4%)	12 (1.4%)	
Cardiovascular	1 (0.2%)	4 (0.5%)	
Urologic	8 (1.5%)	21 (2.5%)	
Gastrointestinal	8 (1.5%)	22 (2.6%)	
Abdomen	6 (1.1%)	4 (0.5%)	
Anastomosis	7 (1.3%)	19 (2.3%)	
Others	5 (0.9%)	12 (1.4%)	
C-D Classification			
I-II	28 (5.1%)	65 (7.7%)	0.055
> III	24 (4.4%)	43 (5.1%)	0.527
30-day Reoperation	19 (3.5%)	26 (3.1%)	0.705
30-day Readmission	9 (1.6%)	17 (2.0%)	0.606
30-day Mortality	1 (0.2%)	3 (0.4%)	0.552
Post-operative stay			
Mean	7.5 ± 8.85	9.7 ± 10.0	**< 0.001**
Mean (no complication)	5.6 ± 2.8	7.7 ± 3.6	**< 0.001**
Median	5 (2–102) (4, 8)	7 (2–135) (6, 10)	**< 0.001**
First flatus passage	2.07 ± 1.71	2.51 ± 1.57	**< 0.001**
First stool passage	3.23 ± 2.14	4.15 ± 2.31	**< 0.001**
Tolerated liquid diet	2.90 ± 4.08	4.44 ± 4.41	**< 0.001**
Tolerated soft diet	4.28 ± 3.77	6.12 ± 4.23	**< 0.001**

C-D classification Clavien-Dindo classification, *mean (standard deviation); Significant values are in bold

odds ratio (OR) for early complications in the ERAS group (OR = 0.697, 95% confidence interval [CI]: 0.486–0.999, P = 0.049), indicating a substantial reduction in the risk of adverse outcomes (Table 4). Female sex was associated with improved outcomes (OR = 0.763, 95% CI: 0.133–0.763, P = 0.133). Tumor location was significantly associated with outcomes; right and left colon tumors were associated with better outcomes than were rectal tumors according to univariate and multivariate analyses (P < 0.001 for both). Obesity (BMI > 25) was not associated with outcomes in the multivariate analysis (OR = 1.255, 95% CI: 0.869–1.814, P = 0.226). Furthermore, patients aged 65–80 years had better outcomes than those aged > 80 years according to univariate and multivariate analyses (OR = 0.616, 95% CI: 0.424–0.895, P = 0.011). Low albumin levels (< 3.5) were significantly associated with worse outcomes in both analyses (multivariate OR = 2.575, 95% CI: 1.682–3.942; P < 0.001). Comorbidities were not significantly associated with outcomes in the multivariate analysis, suggesting that the observed benefits of the ERAS protocol were consistent across various patient comorbidity profiles.

Patients adhering to the ERAS protocol were significantly more likely to be discharged early from the hospital (OR = 3.586, 95% CI: 2.862–4.495, P < 0.001; univariate; OR = 4.183, 95% CI: 3.279–5.337, P < 0.001; multivariate) (Table 5). Compared with their male counterparts, female patients and those aged 65–80 years were more likely to be discharged earlier. Anatomical tumor location influenced discharge timing, with right and left colon tumors associated with a greater chance of early discharge than rectal tumors did (OR = 1.810, 95% CI: 1.346–2.432, P < 0.001; OR = 2.012, 95% CI: 1.497–2.704, P < 0.001, respectively, multivariate). Hypoalbuminemia (Alb < 3.5 g/dL) was strongly associated with delayed discharge across the univariate and multivariate models (OR = 0.250, 95% CI: 0.168–0.371, P < 0.001). Comorbidities generally did not affect discharge timing, except for cirrhosis, which was associated with a delay (OR = 0.203, 95% CI: 0.064–0.646, P = 0.007, multivariate) (Table 6).

Table 4 Postoperative outcomes stratified by age of 80

	Age 65–80			**Age > 80**		
	Modified ERAS (n = 400)	**Traditional Care (n = 655)**	***p***	**Modified ERAS (n = 150)**	**Traditional Care (n = 187)**	***p***
Post-OP stay*	6.8 ± 8.3	8.8 ± 6.8	**< 0.001**	8.9 ± 10.3	12.8 ± 16.5	**0.013**
Early morbidity	28(7.0%)	75(11.5%)	**0.026**	24(16.0%)	33(17.6%)	0.438
Early morbidity						
None	371 (92.8%)	580 (88.5%)	0.113	127 (84.7%)	154 (82.4%)	0.100
Wound	1 (0.3%)	11 (1.7%)		3 (2.0%)	3 (1.6%)	
Lung	6 (1.5%)	8 (1.2%)		7 (4.7%)	4 (2.1%)	
Cardiovascular	0	4 (0.6%)		1 (0.7%)	0	
Urologic	4 (1.0%)	12 (1.8%)		4 (2.7%)	9 (4.8%)	
Gastrointestinal	4 (1.0%)	13 (2.0%)		4 (2.7%)	9 (4.8%)	
Abdomen	5 (1.3%)	4 (0.6%)		1 (0.7%)	0	
Anastomosis	6 (1.5%)	12 (1.8%)		0	7 (3.7%)	
Others	2 (0.5%)	11 (1.7%)		4 (2.7%)	1 (0.5%)	
First flatus passage*	1.98 ± 1.57	2.40 ± 1.51	**< 0.001**	2.32 ± 2.01	2.87 ± 1.74	**< 0.001**
First stool passage*	3.16 ± 2.00	3.99 ± 2.20	**< 0.001**	3.42 ± 2.46	4.72 ± 2.56	**< 0.001**
Tolerated liquid diet*	2.64 ± 3.94	4.25 ± 3.86	**< 0.001**	3.6 ± 4.36	5.08 ± 5.91	**< 0.001**
Tolerated soft diet*	4.15 ± 3.87	6.01 ± 4.42	**< 0.001**	4.64 ± 3.72	6.53 ± 3.41	**< 0.001**

Post-OP stay postoperative hospital stay, C-D classification Clavien-Dindo classification, *mean (standard deviation); Significant values are in bold

Table 5 Univariate and multivariate logistic regression for early complications

Characteristics	Univariate			Multivariate		
	OR	95% CI	*p*	OR	95% CI	*p*
ERAS +	0.710	0.500–1.007	0.055	0.697	0.486–0.999	**0.049**
Female gender	0.795	0.568–1.113	0.181	0.763	0.536–1.086	0.133
Tumor location						
Right colon	0.446	0.300–0.664	**< 0.001**	0.396	0.261–0.600	**< 0.001**
Left colon	0.447	0.298–0.671	**< 0.001**	0.421	0.278–0.637	**< 0.001**
Rectum	ref	0.300–0.664	**< 0.001**	ref		
Obesity (BMI > 25)	1.463	1.027–2.082	**0.035**	1.255	0.869–1.814	0.226
Age 65–80 (REF: > 80)	0.549	0.386–0.780	**0.001**	0.616	0.424–0.895	**0.011**
Hb < 10 (g/dL)	1.494	1.041–2.145	**0.030**	1.172	0.774–1.775	0.454
Alb < 3.5 (g/dL)	2.811	1.930–4.094	**< 0.001**	2.575	1.682–3.942	**< 0.001**
Comorbidities						
Hypertension	1.317	0.939–1.848	0.110			
Heart disease	0.998	0.670–1.485	0.991			
Old CVA	1.519	0.866–2.664	0.145			
Lung	1.072	0.414–2.772	0.886			
Diabetes mellitus	1.111	0.780–1.584	0.559			
PUD	1.105	0.517–2.363	0.796			
Hepatitis	1.367	0.723–2.583	0.336			
Cirrhosis	2.059	0.758–5.594	0.156			
Thyroid disease	0.421	0.100–1.763	0.236			

ERAS + perioperative care with modified enhanced recovery after surgery protocols, Hb hemoglobin, Alb albumin, CVA cerebrovascular accident, PUD peptic ulcer disease; Significant values are in bold

Table 6 Univariate and multivariate logistic regression for early discharge (< POD 6)

Characteristics	Univariate			Multivariate		
	OR	95% CI	*p*	OR	95% CI	*p*
ERAS +	3.586	2.862–4.495	**< 0.001**	4.183	3.279–5.337	**< 0.001**
Female gender	1.262	1.021–1.561	**0.032**	1.351	1.064–1.714	**0.013**
Tumor location	1.581	1.213–2.062	**0.001**	1.810	1.346–2.432	**< 0.001**
Right	1.779	1.358–2.329	**< 0.001**	2.012	1.497–2.704	**< 0.001**
Left	ref			ref		
Rectum						
Obesity (BMI > 25)	0.790	0.636–0.980	**0.032**	0.890	0.700–1.132	0.343
Age 65–80 (REF: > 80)	1.706	1.325–2.197	**< 0.001**	1.708	1.285–2.271	**< 0.001**
Hb < 10 (g/dL)	0.645	0.501–0.831	**0.001**	0.813	0.603–1.097	0.175
Alb < 3.5 (g/dL)	0.250	0.175–0.355	**< 0.001**	0.250	0.168–0.371	**< 0.001**
Comorbidities						
Hypertension	0.935	0.756–1.156	0.536	0.784	0.486–1.264	0.318
Heart disease	0.896	0.689–1.164	0.411	0.203	0.064–0.646	**0.007**
Old CVA	0.669	0.439–1.019	0.061			
Lung	0.743	0.393–1.405	0.361			
Diabetes mellitus	1.034	0.822–1.302	0.775			
PUD	0.907	0.547–1.504	0.706			
Hepatitis	0.795	0.504–1.255	0.324			
Cirrhosis	0.230	0.078–0.675	**0.007**			
Thyroid disease	1.465	0.765–2.797	0.251			

ERAS + perioperative care with modified enhanced recovery after surgery protocols, Hb hemoglobin, Alb albumin, CVA cerebrovascular accident, PUD peptic ulcer disease; Significant values are in bold

Discussion

In this study, we examined the short-term outcomes of minimally invasive surgery in older patients undergoing ERAS. We aimed to clarify the ongoing uncertainty about whether older patients may benefit from the more "aggressive" approach of the modified ERAS protocol and whether a more proactive stance needs to be adopted for a broader range of older patients. Our results revealed that patients aged 65–80 years benefited significantly from the modified ERAS protocol, with fewer early postoperative complications and shorter hospital stays than those in the traditional care group did. Among patients aged > 80 years, there was no statistically significant difference in early complication rates; however, the ERAS group still had shorter hospital stays and faster recovery of gastrointestinal function. Therefore, to our knowledge, this study enrolled the largest number of patients in a single center to analyze the ERAS strategies applied to older individuals.

Previous studies have consistently demonstrated positive outcomes in older adults, including shorter postoperative hospital stays and fewer complications; however, there is a need to establish whether these benefits extend to all older patients, particularly those aged > 80 years [21, 22]. Notably, our study included a cohort of over 1,000 patients, making it the largest cohort to date. Each treatment group comprised > 150 patients aged > 80 years. Therefore, our initial analysis revealed a trend in early complication rates between the ERAS and traditional care groups (9.5% vs. 12.8%, P = 0.054), which differs from previous findings; however, this difference was not statistically significant.

There are several reasons why patients aged > 80 years do not experience significant benefits from the modified ERAS protocol. First, adherence to the "aggressive" aspects of the protocol, such as early mobilization and rapid dietary advancement, can be difficult in older patients. The ERAS protocol involves an "aggressive" approach that includes rapid mobilization, early feeding, and strict pain management strategies. Older patients, especially those aged > 80 years, may find it challenging to keep up with the required pace of recovery, as their physical and mental resilience is often diminished compared with that of younger individuals. Notably, several studies, such as the POWER study, have demonstrated a strong correlation between adherence to ERAS guidelines and reduced postoperative complications [23]. Therefore, higher compliance with ERAS recommendations improves short-term outcomes and contributes to long-term survival rates. Pisarska et al. revealed that low adherence to the ERAS protocol is an independent risk factor for poor survival, regardless of the cancer stage or the presence of complications [16].

Another factor influencing the lack of significant benefits from the ERAS protocol in patients aged > 80 years is the inadequate tracking of early mobilization, which is a cornerstone of the recovery process. In our study, we could not clearly monitor the level of patient adherence, particularly in areas such as early mobilization, which is crucial in recovery. Notably, without adequate mobilization, older patients are more prone to postoperative complications, such as paralytic ileus and lung atelectasis. In addition, early mobilization helps prevent complications, such as deep vein tORombosis, lung infections, and bowel dysfunction, all of which are critical for postoperative recovery [24]. However, without a clear system to monitor how much physical activity patients, particularly older individuals, are actually engaging in, it becomes difficult to ensure that they meet the protocol's requirements. For example, our study revealed that the time to first flatus passage, a marker of bowel recovery, was similar between the ERAS and traditional care groups (2.1 vs. 2.5 days, P < 0.001), despite a statistically significant difference. This could be because insufficient mobilization may have contributed to delayed gastrointestinal recovery, as patients may not have been moving as much as intended. Turan et al. reported that every additional 4 min of mobilization was associated with a reduction in postoperative complications and a decrease in hospital stay by an estimated 0.12 days [25]. These small increases in activity seem insignificant; however, they can have a profound effect on recovery. The lack of sufficient data on patient movement and mobilization highlights the need for improved monitoring systems, such as wearable devices, which could offer a more accurate picture of patient adherence and physical activity levels in the future. These improvements could help reduce the gap between expected and actual recovery outcomes.

Furthermore, patients aged > 80 years may not have benefited significantly from the modified ERAS protocol because of the weakness of prehabilitation efforts. Prehabilitation, which involves preparing patients physically and mentally preoperatively, significantly improves postoperative outcomes. Studies, such as those conducted by Heil et al., have demonstrated that prehabilitation can reduce complication rates and shorten hospital stays [26]. The number needed to treat or prevent one complication was 4.2, meaning that for every four patients who underwent prehabilitation, one would avoid a postoperative complication. Moreover, prehabilitation reduced hospital stays by an average of 2 days, from 5–7 days [27]. Another randomized trial, the PREHAB study, also showed that a multimodal prehabilitation program, which includes physical exercise, nutritional support, and mental preparation, effectively decreased medical complications and improved postoperative functional capacity [28]. In our study, the lack of a structured and tailored prehabilitation program may have contributed to the absence of significant improvements in outcomes for those over 80 years of age. Therefore, we propose implementing a tiered framework for prehabilitation, which would allow for a more systematic approach; the current absence of such a program means that older patients are not fully optimized for surgery. However, selecting the right candidates for prehabilitation is crucial, as an extended exercise regimen lasting a minimum of 3 weeks preoperatively may increase the risk of complications such as bowel obstruction. Therefore, while prehabilitation holds great potential, its absence or insufficient implementation in older patients may have limited the benefits of the ERAS protocol in reducing early complications.

In our multivariate logistic regression analysis, we aimed to identify early complications and discharge risk factors and highlighted several vital variables. Notably, in addition to the influence of modified ERAS protocols, age, and tumor location, hypoalbuminemia was also a significant risk factor. The serum ALB level is not a perfect marker; however, it is a widely used, objective, and cost-effective measure of nutritional status. According to Truong et al., hypoalbuminemia reflects malnutrition and cORonic inflammation, which can contribute to extended hospital stays, higher rates of surgical site infections, an increased risk of enterocutaneous fistulas, and deep vein tORombosis [29]. Similarly, Hennessey et al. reported that hypoalbuminemia is an independent risk factor for surgical site infections following gastrointestinal surgery, often leading to deeper infections and prolonged hospital stays [30]. In our study, the prevalence of hypoalbuminemia was comparable between the two groups (15.1% vs. 15.3%, P = 0.923), suggesting that preoperative nutritional intervention may have been insufficient. This underscores the need for enhanced nutritional support beyond that typically included in the modified ERAS protocol, particularly in older patients with CRC undergoing surgery.

Therefore, with our growing experience, we have become more confident in facilitating the recovery of older patients undergoing CRC surgery. However, the current modified ERAS protocol may not be sufficient, particularly for patients aged > 80 years. ERAS effectively reduces hospital stay and speeds up recovery; however, older patients often struggle to fully adhere to its more intensive aspects, such as early mobilization and rapid diet advancement. This limited adherence may have reduced the overall effectiveness of the protocol in this age group. Thus, enhancing prehabilitation programs to address these challenges is crucial, as they can improve patients' physical condition preoperatively and reduce the risk of postoperative complications. Moreover, better monitoring and support for early mobilization are crucial, as older patients may require more structured assistance to meet their recovery goals. The current ERAS protocol may need further adaptation for older patients, particularly those aged > 80 years, by incorporating stronger prehabilitation and adherence measures to optimize outcomes.

The findings of this study offer valuable insights, although its implementation in older adults aged > 80 years may require refinement. First, adherence to the ERAS protocol significantly reduced overall and early morbidity in patients aged 65–80 years who underwent colorectal surgery, demonstrating its effectiveness in improving outcomes and lowering complications in this group. These findings underscore the potential of ERAS for enhancing surgical recovery in older patients. Second, the protocol accelerated recovery and improved quality of life by reducing pain and strengthening postoperative outcomes. Faster recovery leads to a better patient experience and increased satisfaction by enabling a quicker return to daily activities. Third, patients were more likely to be discharged earlier, which has critical implications for healthcare resource management, cost savings, and system efficiency because shorter hospital stays can lower healthcare costs. These findings emphasize the importance of ERAS in older patients, suggesting the need for a more tailored approach for patients aged > 80 years to optimize outcomes.

This study has several limitations. First, its retrospective design introduces the potential for bias, which is prevalent in such analyses. Second, due to the retrospective nature of data collection and the use of historical controls, we were unable to systematically quantify adherence to every specific element of the modified ERAS protocol. Granular data regarding compliance with preoperative measures (such as the completeness of carbohydrate loading and exact fasting duration) and postoperative targets (such as the precise frequency and duration of early mobilization) were not consistently documented in the electronic medical records. Consequently, while we compared the intent-to-treat protocols, we could not assess the degree of compliance or determine which specific protocol deviations may have influenced outcomes, particularly in the oldest-old cohort. Third, the allocation of patients was non-randomized and largely surgeon-dependent, which may have introduced selection bias related to individual surgeon expertise or preferences. Furthermore, potential time-period effects cannot be ruled out, as the adoption of the ERAS protocol occurred over a specific timeframe, and general improvements in perioperative care during this period may have contributed to the observed outcomes**.** Therefore, these factors should be considered when the findings of this study are interpreted.

In conclusion, this study highlights the benefits of the modified ERAS protocol in improving outcomes in older patients with CRC, particularly those aged 65–80 years. This protocol was associated with reduced morbidity, faster recovery, and shorter hospital stays, demonstrating its effectiveness in enhancing postoperative care. In addition, our findings suggest that the ERAS protocol may require further adaptation for patients aged > 80 years, as their responses are less favorable. Therefore, future research should focus on optimizing ERAS protocols for older adults and improving adherence to ensure better outcomes across all age groups.

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Authors' contributions Z.H.Y. and J.F.Y. conceived the study design. B.K.J. and C.C.C. acquired the data for the study. Y.J.H. and C.K.L. performed data analysis and interpretation. Z.H.Y. drafted the manuscript. Y.J.C. and J.F.Y. critically revised the manuscript.

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Data availability The datasets generated and analyzed during the current study available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate The study protocol was approved by the institutional review board of Chang Gung Memorial Hospital Linkou branch as approval number 202401646B0. Due to the retrospective design of the study, the local ethic committee confirmed that informed consent was not necessary from participants.

Consent for publication All authors have read and approved the final manuscript and consent to its publication.

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