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RESEARCH

Enhanced recovery after surgery (ERAS) in colorectal surgery: implementation is still beneficial despite modern surgical and anesthetic care

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Abstract

Purpose Enhanced recovery after surgery (ERAS) protocols have shown beneficial outcomes in the last 20 years. Nevertheless, simultaneously implemented technical improvements such as minimally invasive access or modified anesthesia care may play a crucial role in optimizing patient outcome. The aim of the study was to investigate the effect of ERAS implementation in a highly specialized colorectal center.

Methods This is a propensity score matched single-center study comparing the short-term outcomes of patients undergoing elective colorectal surgery in a society-indepedent ERAS program from January 2021 to August 2022 to standard perioperative care from January 2019 to December 2020.

Results Four hundred fifty-six patients were included in the propensity score matched analysis with 228 patients per group (ERAS vs. standard care). Minimally invasive access was used in 80.2% vs. 77.6% ($p = 0.88$), and there were 16.6% vs. 18.8% ($p = 0.92$) rectal procedures in the ERAS and standard care group, respectively. Major complications occurred in 10.1% vs. 11.4% ($p = 0.65$) and anastomotic leakage demanding operative revision in 2.2% vs. 2.6% ($p = 0.68$) in the ERAS and standard care group, respectively. ERAS lead to a lower number of non-surgical complications compared to standard care (57 vs. 79; $p = 0.02$). Mean length of stay (LOS) and mean costs per case were lower in ERAS compared to standard care (9.2 ± 5.6 days vs. 12.7 ± 7.4 days, $p < 0.01$; costs 33,727 ± 15,883 USD vs. 40,309 ± 29,738 USD, $p < 0.01$).

Conclusion The implementation of an ERAS protocol may lead to a reduction of LOS, costs, and a lower number of non-surgical complications even in a highly specialized colorectal unit using modern surgical and anesthetic care. (ClinialTrials.gov number NCT05773248)

Keywords Colorectal surgery · ERAS · Length of stay · Perioperative management

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Introduction

Long-standing paradigms of perioperative care were widely questioned in the 1990s with an emphasis on faster patient recovery following major elective surgical interventions [1, 2]. In the face of a growing number and heterogeneity of perioperative programs, the enhanced recovery after surgery (ERAS) group published a first standardized program for colorectal surgery in 2005 [3].

The ERAS protocol has repeatedly proven to reduce postoperative morbidity for non-surgical complications and length of stay (LOS) along with faster patient recovery [4–6]. Furthermore, superior patient satisfaction [7] and cost reduction were observed, despite additional expenses needed for protocol implementation [8, 9]. Although ERAS programs have become broadly accepted and are expanding into a growing number of surgical fields [10, 11], it is not fully understood, which parts of the bundle of measures contribute most to the improved outcome [12].

Irrespective of dedicated ERAS programs, a significant number of the recommended measures have become part of standard perioperative care, such as minimally invasive access, opioid sparing anesthesia, and perioperative physical therapy [13]. The aim of this single-center cohort study is to explore the effect of late adoption of an ERAS protocol, independent of an official ERAS society, in a high-volume colorectal surgical unit.

Material and methods

Study design

This is a propensity-score matched single-center study evaluating the effect of the implementation of an ERAS protocol in colorectal surgery. Analysis of this prospectively collected data was approved by the national review board, and the trial was registered at www.clinicaltrials.gov (NCT05773248). All consecutive patients that signed written general informed consent and were treated at the colorectal unit between January 2019 and August 2022 were included in the analysis. During 2019 and 2020, the patients were treated according to a standard protocol and as of January 2021, according to an ERAS protocol. All patients undergoing an emergency procedure or a combined procedure with the colorectal procedure not being the main indication for surgical treatment (i.e., gynecological debulking and liver resection) were excluded from the analysis.

ERAS protocol

The ERAS protocol was developed and introduced independently of an ERAS society by a dedicated team of surgeons, anesthesiologists, nutritionists, nurses, and physical therapists. The bundle of ERAS measures for each patient is strictly controlled before, during, and after hospitalization by the ERAS nurse, and the ERAS program is audited twice yearly. The interventions in the ERAS protocol compared to standard care consisted of the measures displayed in Table 1. Good ERAS adherence was defined as compliance with at least 16/18 ERAS items in Table 1.

Operative technique

Minimally invasive access was chosen whenever possible. In right-sided resections, the anastomosis was routinely performed extra-corporally using a side-to-side hand-sutured technique. In left-sided resections, the anastomosis was routinely fashioned in a side-to-end technique using a transrectal circular stapler. Low anterior rectal resections received an abdominal drain in both groups. For further analysis, the procedures were differentiated into colon and rectal to define the major site of surgery. Colon procedures were further divided into two groups: ileocecal resections, right hemicolectomy, and transverse colon resections as one and left hemicolectomy, sigmoid resection, and proximal rectal resection (> 12 cm from the dentate line) as the second. Lastly, the procedures were separated according to indication into benign, inflammatory bowel disease (IBD), and cancer.

Outcome parameters

Demographic data such as age, sex, body mass index (BMI), American Society of Anesthesiologists (ASA) Score [14], Nutrition Risk Score (NRS) [15], Charlson's Comorbidity Index (CACI) [16], and substance abuse were prospectively recorded. Intraoperative outcomes included operation time and intraoperative complications according to the ClassIntra Classification [17]. The primary outcome of the analysis was LOS (the number of postoperative hospitalization days). This parameter was chosen, because it correlates directly with costs and is also a surrogate marker for postoperative complications. Secondary outcomes included overall postoperative complications according to the Clavien-Dindo classification as well as all major complications defined as grade 3a or higher [18], the comprehensive complication index (CCI) [19], and readmission rate. Each complication was defined as surgical or non-surgical, either explicitly specifying the complication (i.e., anastomotic leakage or pneumonia) or listing it under various. Various surgical complications included any complication directly related to the surgical procedure, i.e., mechanical bowl obstruction and lymphatic fistulas. Non-surgical complications included paralytic ileus, colitis, and arrhythmias, among others. Cost analysis was performed according to data from the in-hospital financial department, and the average length of stay

Table 1 Comparison of the perioperative measures according to the standard and the ERAS protocol

Measure	ERAS protocol	Standard protocol
Preoperative counselling with specialized ERAS nurse	✓	X
Correction of malnutrition in case of elevated nutrition risk score > 4.	✓	X
Avoidance of preoperative sedation	✓	X
Avoidance of oral bowel preparation	X	X
Carbohydrate preload	✓	X
Use of minimally invasive surgical access	✓	✓
Restrictive intraoperative fluid administration	✓	X
Restrictive intraoperative opioid administration	✓	X
Antiemetic prophylaxis	✓	X
Use of postoperative colorectal care map	✓	X
Daily visit with specialized ERAS nurse	✓	X
Early postoperative mobilization	✓	✓
Early postoperative stimulation (chewing gum, magnesium, Metoclopramide)	✓	X
Early removal of urinary catheter (before day 2)	✓	X
No abdominal drain/removal at latest at day 1–2	✓	X
Early food intake (liquid day 1, solid day 2)	✓	X
Daily physical therapy with breathing instruction	✓	✓
30-day follow-up visit with specialized ERAS nurse	✓	X

ERAS enhanced recovery after surgery

(ALOS) was obtained from in-hospital controlling, using the national catalogue of diagnosis-related groups (Swiss DRG). Swiss DRG calculates the ALOS for each procedure with regard to the patient's comorbidities. In case of readmission, the resulting costs were included in the same case for cost analysis. In the ERAS group, the adherence to the individual ERAS measures was explicitly recorded.

Statistical considerations

A weighted propensity score analysis was performed for both the ERAS and the standard care cohort to adjust for potential confounding variables at baseline using the R packages "MatchIt" and "optmatch" [20]. Matching criteria included sex, age at time of surgery, BMI, CACI, ASA score, indication for surgery (benign, IBD, and cancer), and type of surgery ("Operative technique" section). The outcome characteristics in the two cohorts were compared using Student's *t* test for continuous variables and χ^2 tests for categorical variables. Optimal LOS was defined as the difference between the patients' LOS and the ALOS according to Swiss DRG of 1 day or less. An interrupted time series analysis with Newey-West standard errors was performed to determine changes over time in the rate of patients with an optimal LOS. In the subgroup of patients under ERAS protocol, multivariable logistic regression models were used to evaluate the associations between optimal LOS and demographic and clinical variables. A two-sided alpha of 0.05 was used in all analyses to define statistical significance. Statistical analyses were performed using Stata/BC version 16.1 (StataCorp LLC, College Station, TX) and R statistical package (RStudio Version 2022.02.3, www.r-project.org).

Results

Standard protocol vs. ERAS

Between January 2019 and December 2020, 475 elective colorectal procedures were performed. From January 2021 until August 2022, 263 patients underwent a colorectal procedure according to the ERAS protocol. Table a (supplementary material) summarizes the demographic criteria of the two cohorts before matching. After propensity score matching, 228 patients were included in each group, not showing statistically significant differences in baseline characteristics as demonstrated in Table 2.

The predominant access in both groups was minimally invasive with 80.2% in the ERAS group vs. 77.6% in the standard protocol, respectively ($p = 0.9$). There was no difference in creation of any type of stoma and no difference in operative time between groups. There were 5 intraoperative complications in both groups: 4 minor (ClassIntra grade 0–II) and one grade III complication according to ClassIntra in each group, demanding conversion to an open procedure due to bleeding [17].

Seventy-one complications occurred within 30 days in the ERAS group, compared to 84 in standard protocol

Table 2 Patient demographics of propensity score-matched colorectal patients before and after implementation of an ERAS protocol

Factor	ERAS protocol	Standard protocol	*p* value
N	228	228	
Sex			1.00
Female	112 (49.1%)	112 (49.1%)	
Male	116 (50.9%)	116 (50.9%)	
Age at operation, mean (SD)	62.8 (11.4)	62.9 (13.2)	0.89
BMI, mean (SD)	25.2 (4.8)	25.4 (4.7)	0.56
CACI, mean (SD)	3.7 (2.5)	3.6 (2.6)	0.65
Nutrition Risk Score (SD)	1.9 (1.2)	1.8 (1.0)	0.35
Insurance status			0.86
Basic	136 (59.6%)	135 (59.2%)	
Private/semi-private	92 (40.4%)	93 (40.8%)	
ASA classification			0.61
1	5 (2.2%)	7 (3.1%)	
2	134 (58.8%)	127 (55.7%)	
3	87 (38.2%)	89 (39.0%)	
4	2 (0.9%)	5 (2.2%)	
Entity			0.95
Benign	129 (56.6%)	129 (56.6%)	
IBD/inflammatory	5 (2.2%)	6 (2.6%)	
Malignant	94 (41.2%)	93 (40.8%)	
Type of surgery			1.00
Ileocolic/right hemicolectomy/transverse colon resection	41 (17.9%)	38 (16.6%)	
Left hemicolectomy/sigmoid resection/anterior resection	143 (62.7%)	141 (61.8%)	
(Sub-)total colectomy/proctocolectomy	3 (1.3%)	3 (1.3%)	
Hartmann reversal	3 (1.3%)	3 (1.3%)	
Low anterior resection	29 (12.7%)	32 (14.0%)	
Abdominoperineal resection	9 (3.9%)	11 (4.8%)	

ERAS enhanced recovery after surgery, *SD* standard deviation, *BMI* body mass index, *CACI* Charlson's Comorbidity Index, *ASA* American Society of Anesthesiologists, *IBD* inflammatory bowel disease

patients ($p = 0.18$). Major complications occurred in 10.1% vs. 11.4% ($p = 0.65$) in the ERAS and standard care group, respectively. There was a significantly lower number of non-surgical complications in the ERAS group compared to the standard protocol group ($n = 79$ vs. $n = 57$; $p = 0.02$; details displayed in Table 3). The readmission rate in the ERAS group was 5.7% compared to 2.2% in the standard care group ($p = 0.054$).

There was a marked reduction in length of stay (9.2 ± 5.6 days vs. 12.7 ± 7.4 days; $p < 0.01$) and costs per case (33,727 ± 15,883 USD vs. 40,309 ± 29,738 USD; $p < 0.01$) in favor of the ERAS group. In the ERAS group, 74.1% of patients had an optimal length of stay according to Swiss DRG compared to 43% in the standard protocol group ($p < 0.01$). Fig. 1 shows the percentage of patients within the optimal length of stay before and after the implementation of the ERAS program using interrupted time series analysis. All perioperative data are demonstrated in Table 3.

ERAS adherence

Good ERAS adherence was documented in 144/228 patients (63.1%). Patients with good ERAS adherence tended to have a lower CACI compared to patients with a lower ERAS adherence (3.4 ± 2.3 vs. 4.0 ± 3; $p = 0.07$), and a laparoscopic approach was applied more often than in patients without good ERAS adherence (79.9% vs 67.9%; $p = 0.03$). Postoperative LOS (8.1 ± 4.6 vs. 11.3 ± 6.6 days; $p < 0.01$) and comprehensive complication index (5.5 ± 11.1 vs. 11.7 ± 15.3; $p < 0.01$) was notably lower in patients with good ERAS adherence compared to without good ERAS adherence. Detailed data on the comparison within the ERAS group with and without good adherence is displayed in table b (supplementary material). There were notable differences among the ERAS cohort when comparing the age groups over and under 65 years as well as colon versus rectal procedures. The patients older than 65 years showed significantly higher LOS, costs, and

Table 3 Comparison of perioperative outcomes between colorectal patients treated according to a standard protocol versus ERAS protocol

Factor	ERAS protocol	Standard protocol	*p* value
Total patients	228	228	
Approach			0.90
Laparoscopic	172 (75.4%)	167 (73.2%)	
Converted	13 (5.7%)	16 (7.0%)	
Open	32 (14.0%)	35 (15.4%)	
Robotic	11 (4.8%)	10 (4.4%)	
Ileostomy/colostomy			0.39
Protective ileostomy (double loop)	15 (6.6%)	11 (4.8%)	
Terminal ileostomy	2 (0.9%)	1 (0.4%)	
Protective colostomy	20 (8.8%)	11 (4.8%)	
Terminal colostomy	9 (3.9%)	11 (4.8%)	
Operative time, mean (SD)	250 (89.0)	241 (72.0)	0.25
Length of stay, mean (SD)	9.2 (5.6)	12.7 (7.4)	**< 0.001**
Postoperative complications (Clavien-Dindo)			0.21
0	157 (68.9%)	144 (63.2%)	
1	12 (5.3%)	17 (7.5%)	
2	36 (15.8%)	41 (18.0%)	
3a	8 (3.5%)	10 (4.4%)	
3b	14 (6.1%)	9 (3.9%)	
4a	0 (0.0%)	5 (2.2%)	
4b	1 (0.4%)	2 (0.9%)	
Major complications (CD ≥ 3a)	23 (10.1%)	26 (11.4%)	0.65
Comprehensive Complication Index, mean (SD)	7.8 (13.1)	10.4 (16.0)	0.06
Surgical complications	33	39	0.44
Anastomotic leakage	9 (3.9%)	8 (3.5%)	0.61
Treated conservatively	4 (1.8%)	2 (0.9%)	
Re-operation	5 (2.2%)	6 (2.6%)	
SSI	6 (2.6%)	16 (7.0%)	
Bleeding	6 (2.6%)	8 (3.5%)	
Various surgical	12 (5.3%)	7 (3.1%)	
Non-surgical complications	57 (25%)	79 (34.6%)	**0.02**
Pneumonia	6 (2.6%)	8 (3.5%)	
Cardiac decompensation	0 (0.0%)	3 (1.3%)	
Urinary tract infection	12 (5.3%)	20 (8.8%)	
Urinary retention	10 (4.4%)	5 (2.2%)	
Delirium	1 (0.4%)	5 (2.2%)	
Thrombosis/pulmonary embolism	7 (3.1%)	2 (0.8%)	
Various non-surgical	21 (9.2%)	36 (15.8%)	
Readmission	13 (5.7%)	5 (2.2%)	0.054
Costs (USD), mean (SD)	33,727 (15,883)	40,309 (29,738)	**0.004**
Revenue (USD), mean (SD)	31,927 (14,637)	36,514 (25,232)	**0.019**
Result (USD), mean (SD)	− 1799 (12,617)	− 3794 (16,867)	0.16
Optimal length of stay	169 (74.1%)	98 (43.0%)	**< 0.001**

ERAS enhanced recovery after surgery, *SD* standard deviation, *CD* Clavien-Dindo

complication rates. This difference was even more distinct when comparing procedures; colon procedures were associated with markedly lower LOS, costs, and complication rates than rectal procedures. Details are displayed in table c and d (supplementary material).

Discussion

The three main findings of our study are a lower LOS, a cost reduction, and a lower number of non-surgical complications in the ERAS group compared to the standard protocol

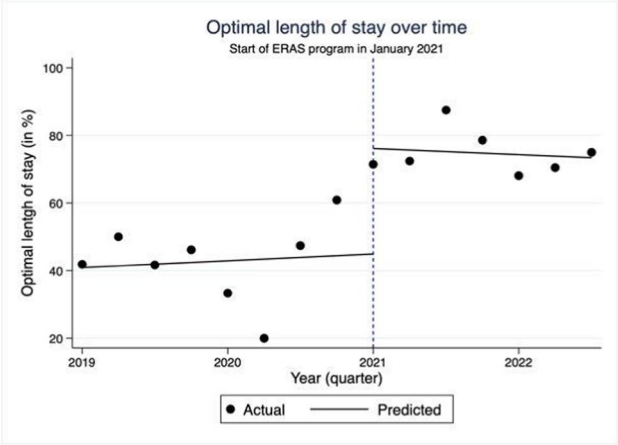

Fig. 1 The graph shows an interrupted time series analysis. Each black dot demonstrates the percentage of patients within the optimal length of stay in each time period, 2019–2020 before the ERAS protocol was implemented and as of 2021 after the ERAS protocol was implemented. ERAS, enhanced recovery after surgery

group. Although many ERAS items such as minimally invasive access, intraoperative normothermia, and early mobilization have become part of clinical routine irrespective of ERAS protocols, the introduction of a structured ERAS program leads to a significant improvement in care. This might be attributed to bundling of the various measures, the high attention to ERAS adherence, and the permanent auditing of ERAS compliance.

The most important items of the ERAS protocol include preoperative counselling and a daily visit through the specialized ERAS nurse. By guiding the patient through the intervention before, during, and after hospitalization, the perspectives are distinct and the motivation for a fast recovery is increased. Especially the achievement of daily goals during hospitalization makes patients feel that they contribute substantially to their fast recovery. Furthermore, adherence is strictly controlled on a daily basis, which cannot be ensured through regular staff which cares for a large variety of patients.

Another important factor is the sparse use of drains and catheters as well as early mobilization, bowel stimulation, and food intake—all measures that aim to regain physiological function as fast as possible. These measures as a bundle are mainly responsible for decreasing the amount of non-surgical complications, predominantly consisting of pulmonary and urinary tract infections and delirium in our cohort, as well as in literature [21, 22]. Altogether, education and integration of patients regarding their treatment lead to favorable outcomes by reducing complications, LOS, and thus costs.

Our results show as a primary outcome a LOS reduction of 3.5 days in the ERAS group, similar to what Forsmo et al. described in 2016 in a comparable cohort of patients [23]. An explanation for the high overall LOS in our study might be the heterogeneity of cases (i.e., rectal procedures, total colectomies) and a general tendency towards a longer hospital stay in Switzerland compared to other international cohorts, i.e., the national average length of stay (ALOS) after hemicolectomy in 2019 was 7.7 days [24]. Additionally, in a health care system based on per-case gratification and predetermined ALOS (as in Switzerland), a short hospital stay results in a considerably smaller reimbursement. Further factors favoring a longer LOS include patient and surgeon habits as well as problems with postoperative outpatient care. The shorter LOS might play a role regarding the increased, though not statistically significant, rate of readmissions in the ERAS group. The main reasons for readmissions were inadequate pain control and suboptimal education prior to discharge which should be amenable with more experience in ERAS management.

Our reported cost reduction of 16.3% per case in ERAS patients was substantially higher than comparable literature, with 6.1% in a Swiss study [25] and 9.9% in a Chinese study [26]. Due to variable reimbursement systems, lack of standards concerning cost reporting in medical literature and differing exchange values of medical services, however, comparing cost data between countries and studies must be done with caution [27].

The main drivers of the cost reduction are evidently the lower LOS and the reduction of non-surgical complications. On the other hand, part of the expenditures in ERAS cases such as preoperative counselling are not displayed because they are performed in an outpatient setting, although those costs are low compared to the overall costs.

As to the underlying reasons for the beneficial effects of ERAS, we could not identify single factors that significantly correlated with outcome parameters, which is in line with the current literature [28]. We did, however, observe a correlation between ERAS adherence and probability of optimal LOS. This might be due to the ERAS measures but also due to the increased awareness concerning costs and duration of hospitalization by the involved team. Furthermore, we noted a trend that patients with high ERAS adherence were more likely to have undergone a laparoscopic intervention, were younger, and exhibited a lower CCI, all three parameters independent of ERAS protocol as such. In this regard, we assume that in older and/or sicker patients, surgeons who chose an open approach tended to be more reluctant regarding ERAS measures and ERAS measures were generally less likely to be applied in elderly patients. This correlates with the difference in perioperative outcomes between the age groups over and under 65 years in the ERAS cohort.

Our analysis shows high adherence rates to ERAS measures which stayed constant over the whole review period. This study portrays the adopted measures in our institution

from day 1 of introduction, and the observed rates of adherence are above comparable literature [29].

There are multiple limitations regarding this study. It is a single-center trial, and there was no randomization but an institutional change in standard of care. We minimized the risk of confounders through propensity score matching but nevertheless cannot rule out possible selection bias. Time bias could theoretically also pose an issue since the patient collectives were treated in two distinct time periods; however, there was no significant change in any other perioperative setting within this period. Lastly, as specified in the "Material and methods" section, the cost data was not itemized into subgroups.

Conclusion

The implementation of an ERAS protocol may lead to a reduction of LOS, costs, and a lower number of non-surgical complications, even in a highly specialized colorectal unit using modern surgical and anaesthestic care.

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Author contribution Study conception and design: JS, RM, MVS, BPM, AW, and DCS. Acquisition of data: JS, RM, and AW. Analysis and interpretation of data: JS, RM, AW, and DCS. Drafting of manuscript: JS, RM, DCS, and MVS. Critical revision of manuscript: JS, RM, MVS, BPM, AW, and DCS.

Declarations

The abstract was presented at the Annual Meeting of the Swiss Society of Gastroenterology, the Swiss Society of Visceral Surgery, the Swiss Association for the Study of the Liver and the Swiss Society of Endoscopy Nurses and Associates in Interlaken, Switzerland, 2023 and at the Annual Meeting of the Swiss College of Surgeons in Basel, Switzerland, 2023.

Dr. Julian Süsstrunk, Remo Mijnssen, PD Dr. Marco von Strauss, Prof. Beat Peter Müller, Dr. Alexander Wilhelm and PD Dr. Daniel C. Steinemann have no conflicts of interest to declare. All procedures performed were in accordance with the ethical standards of the local research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Research data supporting this publication is available upon reasonable request.

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