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Original Research Article

# The impact of ERAS protocols on postoperative outcomes in robotic, laparoscopic, and open colorectal surgery: A multicenter retrospective study

Bushra Mohandes[a,s], Saido Haji Abukar[b,s], Florian Ponholzer[c], Dietmar Öfner[c], Bassey Enodien[d], Niklas Ortlieb[e], Mariana Flaifel[f], Daniel M. Frey[g], Stephan Vorburger[h], Baraa Saad[i], Sophie Müller[j], Cathérine Kollmann[j], Lars Kollmann[j], Sven Flemming[j], Julia Kristin Grass[k], Nathaniel Melling[k], Michael Rousek[l], Vilius Abeciūnas[m], Tomas Poskus[m], Ovunc Bardakcioglu[n], Katerina Neumann[o], Boris L. Gala-Lopez[o], Michael Drew Honaker[p], Daniel Steinemann[q], Beat P. Müller[q], Jasmin Zeindler[b,r], Otto Kollmar[r], Andres Heigl[r], Robert Rosenberg[r], Stephanie Taha-Mehlitz[q,t], Anas Taha[b,c,r,*,t]

[a] *Department of General Surgery, Mohammed Bin Rashid University, Dubai Health, United Arab Emirates*
[b] *Faculty of Medicine, University of Basel, Basel, Switzerland*
[c] *Department of Visceral, Transplant and Thoracic Surgery, Center of Operative Medicine, Medical University of Innsbruck, Innsbruck, Austria*
[d] *Department of Visceral Surgery, Cantonal Hospital Glarus, Glarus, Switzerland*
[e] *Medoc Swiss, Data Science and Healthcare Management, Basel, Switzerland*
[f] *Faculty of Medicine, Royal Surrey County Hospital, Guildford, UK*
[g] *Department of Visceral Surgery, Cantonal Hospital Baden, Baden, Switzerland*
[h] *Department of Visceral Surgery, Teaching Hospital Emmental, Berne, Switzerland*
[i] *Department of Surgery, Royal Lancaster Infirmary, Lancaster, UK*
[j] *Department of General-, Visceral-, Transplant-, Vascular- and Pediatric Surgery, University Hospital of Wuerzburg, Wuerzburg, Germany*
[k] *University Medical Centre Hamburg Eppendorf, Department of General, Visceral and Thoracic Surgery, University Medical Center, Hamburg-Eppendorf, Hamburg, Germany*
[l] *Military University Hospital Prague, Department of Surgery, Prague, Czech Republic*
[m] *Department of Visceral Surgery, Faculty of Medicine, Vilnius University, Vilnius, Lithuania*
[n] *Division of Colon and Rectal Surgery, Kirk Kerkorian School of Medicine at UNLV, Las Vegas, USA*
[o] *Department of Surgery, Dalhousie University, Halifax, Nova Scotia, Canada*
[p] *Department of Surgery, East Carolina University, Brody School of Medicine, Greenville, North Carolina, USA*
[q] *Clarunis, University Center for Gastrointestinal and Liver Diseases, St. Clara Hospital and University Hospital Basel, Basel, Switzerland*
[r] *Department of Visceral Surgery, Cantonal Hospital Basel-Land, Liestal, Switzerland*

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## ABSTRACT

*Background:* Enhanced recovery after surgery (ERAS) protocols improve outcomes in colorectal surgery, but the impact of ERAS on comparative effectiveness across robotic, laparoscopic, and open approaches is unclear.
*Methods:* In this multicenter retrospective study, 5503 patients undergoing elective colorectal surgery from 13 centers could be included. Patients were compared regarding surgical technique and ERAS adherence. Primary outcomes included postoperative complications and anastomotic leakage; secondary outcomes included length of hospital stay (LOS) and Comprehensive Complication Index (CCI). Multivariate regression assessed ERAS impact.
*Results:* ERAS was used in 890 patients and associated with significantly shorter LOS across all modalities (robotic: 5.5 vs. 8.5 days; laparoscopic: 8.5 vs. 9.0 days; open: 13.1 vs. 14.5 days; $p \leq 0.02$). ERAS independently reduced complication rates ($p = 0.016$) and anastomotic leaks ($p = 0.007$). Robotic surgery was protective against complications and linked to the greatest LOS reduction. ERAS did not significantly affect CCI.

* Corresponding author. Faculty of Medicine, University of Basel, Basel, Switzerland.
*E-mail address:* anas.taha@unibas.ch (A. Taha).
[s] Bushra Mohandes and Saido Haji Abukar share first authorship.
[t] Stephanie Taha-Mehlitz and Anas Taha share last authorship.

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*Conclusions:* ERAS protocols improve postoperative outcomes across colorectal surgical techniques, with the greatest benefits in robotic surgery, supporting their broad clinical implementation.

## 1. Introduction

Enhanced Recovery After Surgery protocols (ERAS) in colorectal surgery include strategies that aim to optimize postoperative management and accelerate recovery times. The ERAS approach involves a multidisciplinary framework in the preoperative, intraoperative, and postoperative periods to enhance physiologic recovery and subsequently reduce postoperative complications and shorten hospital stays.[1,2] In the most recently updated ERAS protocol for perioperative care in colorectal surgeries (2018), the laparoscopic technique was part of the intraoperative component of the protocol due to its established superiority over the open technique in terms of lower complication rates and reduced surgical trauma.[3] However, the use of robotic surgery in ERAS are yet to be established.

ERAS implementation for colorectal surgery leads to reduced complication rates, fewer readmissions, shorter hospital stays, and improved patient satisfaction.[3] However, applying ERAS across different surgical modalities—open, laparoscopic, and robotic—presents unique challenges and may vary significantly, especially as minimally invasive techniques become more widespread and ERAS principles are increasingly integrated into surgical training and practice.[4,5] Although laparoscopic surgery is now routinely within ERAS pathways, open surgery continues to play a vital role, particularly in complex or high-risk cases. Importantly, ERAS principles can be implemented across all surgical modalities.

Notably, the use of ERAS protocols can vary significantly based on surgical methods, with laparoscopic surgeries frequently demonstrating enhanced recovery potential as compared to traditional open approaches.[6] Nevertheless, with the introduction of robotic surgery in several aspects of colorectal surgery despite its ability to minimize tissue trauma and inflammatory response, the ERAS efficacy remains to be comprehensively evaluated.[2,7] As individualized surgical pathways evolve, understanding how ERAS influences outcomes with each approach is essential to optimize patient care.

To date, the literature lacks large-scale, multicenter studies that directly compare ERAS outcomes across robotic, laparoscopic, and open surgery within a standardized protocol. Single-center studies are limited by population homogeneity and institutional bias. A multicenter design improves statistical power, heterogeneity, and generalizability,[8] allowing a more accurate evaluation of how surgical modality influences ERAS effectiveness.[9,10]

Although ERAS has transformed perioperative care, previous studies often report outcomes without explicitly attributing improvements to ERAS adherence.[11–13] Previous studies either do not compare ERAS with non-ERAS protocols or fail to separate the impact of the protocol itself from the effect of the surgical technique. This creates challenges and difficulties in interpreting the main causative factor of the improved outcomes.

Therefore, the aim the study was to evaluate the influence of ERAS protocol adherence on postoperative outcomes in colorectal surgery and investigate systematic differences across robotic, laparoscopic, and open approaches. The 2018 ERAS Society Guidelines for Elective Colorectal Surgery was implemented to guide perioperative care.[2] By addressing this gap in the literature, findings of the study could optimize the ERAS protocol, guide decision-making regarding the optimal operative modality to minimize specific complications, and consequently provide improved patient care strategies.

## 2. Methods

### 2.1. Study design and data source

Data from several national and international surgical centers out of thirteen centers in Europe and North America were retrospectively collected and placed it into a database. IRB (ethics board/institutional review board) approval was obtained for each center (Ethikkommission Nordwest- und Zentralschweiz EKNZ:2021–02105). After approval, the centers collected retrospective data in a de-identified manner and uploaded it into the RedCap database provided by the sponsor.

### 2.2. Patient selection

All patients who underwent elective colorectal surgery (open, laparoscopic, or robotic) for indications including neoplasia, diverticulitis, or Crohn's disease were included. Patients who did not give general consent or who could not be followed for more than three months after surgery were excluded, as the occurrence of postoperative complications can neither be confirmed nor excluded. All emergency surgeries along with indications such as perforation or ischemia were excluded to align with the elective surgery setting of the ERAS protocol. Comprehensive preoperative data were collected, including age, gender, body mass index (BMI), Charlson Comorbidity Index (CCI),[14] American Society of Anesthesiologists (ASA) score, nutritional status, smoking, surgical indication, type of procedure, surgical approach, and use of preoperative steroids. Laboratory values such as hemoglobin levels were recorded.

### 2.3. Outcome measures

The primary endpoints of this study included postoperative complication rates and the occurrence of anastomotic leakage. Secondary endpoints included operative time, length of hospital stay, and the Comprehensive Complication Index (CCI). All data were collected and analyzed to compare outcomes between ERAS and non-ERAS protocols within each surgical modality. The essential components included preoperative counseling, carbohydrate loading, multimodal analgesia, early mobilization, and early oral feeding.[15] The protocol used by each institution was collected through institutional ERAS checklists. However, the specific elements contributing to compliance and the ERAS protocol varied within each institution included in the study.

### 2.4. Statistical analysis

Descriptive statistics were used to summarize patient characteristics and outcome measures. Continuous variables were expressed as mean ± standard deviation (SD) or median with interquartile range (IQR), and categorical variables as frequencies and percentages. Between-group comparisons (ERAS vs. non-ERAS and across surgical modalities) were performed using the Wilcoxon signed-rank test for the non-normally distributed data and the chi-square or Fisher's exact tests for categorical variables, depending on the expected counts.[16,17] Subgroup analyses were conducted to compare ERAS vs. non-ERAS outcomes within each surgical modality (robotic, laparoscopic, or open). Multivariate regression analyses were used to assess the independent effects of ERAS on multiple outcomes. Statistical significance was defined as $p < 0.05$ (two-sided). All analyses were conducted using SPSS version 16 and validated using Stata 17.0 for regression diagnostics.

## 3. Results

### 3.1. Patient population and baseline characteristics

A total of 5503 patients undergoing colorectal surgery across the thirteen centers from January 2012 to December 2020 were included. Among these, 890 patients underwent the ERAS protocol (ERAS group) whereas the other 4613 out of 5503 patients were treated without an ERAS protocol (non-ERAS). Within the ERAS group, 389 laparoscopic, 287 open, and 214 robotic surgeries were performed, while 1739 laparoscopic, 2478 open, and 396 robotic surgeries were performed without ERAS protocol. The baseline characteristics of both groups are summarized in Table 1 and further subdivided based on the surgical modality.

### 3.2. Primary outcomes

The intraoperative and postoperative outcomes for each surgical approach and ERAS status are summarized in Table 2. Significant differences were observed in operative and perioperative characteristics across surgical approaches between ERAS and non-ERAS groups. Detailed multivariate regression analyses assessing the independent effects of ERAS and other variables on key outcomes are presented below; complete statistical models and additional analyses are provided in supplementary material 1.

#### 3.2.1. Postoperative complications

In the unadjusted analysis, the complication rates varied across the surgical modalities. In the robotic cases, the total complication rates were not significantly lower in the ERAS group (18.7 % vs. 24.7 %, $p = 0.09$) (Fig. 2). However, in the laparoscopic and open groups, the complication rates were significantly lower in the ERAS group as compared to non-ERAS (20.3 % vs. 31.9 %, $p < 0.001$) and (33.8 % vs. 49 %, $p < 0.001$), respectively.

In the multivariate model, ERAS implementation was independently associated with a lower overall complication rate. Specifically, patients who did not receive ERAS care had a significantly higher risk of postoperative complications ($p = 0.016$), indicating a protective effect of ERAS protocols. Among other predictors, increasing age ($p < 0.001$), poor nutritional status ($p = 0.012$), and open surgical approach ($p < 0.001$) were independently associated with higher complication rates. In contrast, robotic surgery was significantly associated with reduced complication rates ($p = 0.002$), while prior abdominal surgery was linked to increased complication risk ($p < 0.005$). Crohn's disease was associated with a higher risk ($p < 0.001$), whereas tumor-related surgeries were linked to fewer complications ($p = 0.012$). The operation type (Colectomy, ileocecal resection, Hartmann conversion) did not independently affect the complication rate.

#### 3.2.2. Anastomotic leakage

In the unadjusted analysis, AL rates differed in ERAS status and surgical techniques. In the open group, anastomotic leakage rate was significantly lower in ERAS patients (3.8 % vs. 9.5 %, $p = 0.001$). However, in the laparoscopic and robotic cases, were lower but did not reach statistical significance (a) and (5 % vs. 21 %, $p = 0.09$), respectively (Fig. 3).

On regression, several factors were significantly associated with anastomotic leakage. The use of ERAS protocols was independently associated with lower leak rates, with non-ERAS patients showing a significant increase in leaks ($p = 0.007$). Preoperative steroid non-use was similarly associated with a significantly lower risk of leak ($p = 0.014$). Active smoking was also significantly associated with higher leakage risk ($p = 0.019$). Open surgical approach was a strong predictor of increased anastomotic leak risk ($p < 0.001$). Other factors like age, operation type, BMI, inflammatory markers, nutritional status, and sex did not demonstrate a statistically significant effect.

### 3.3. Secondary outcomes

#### 3.3.1. Operative time

The mean operative time was significantly longer across all three modalities (Fig. 1). This was most pronounced in open surgery (235.7 ± 114.8 vs. 186.0 ± 93.7 min, $p < 0.001$), followed by the laparoscopic (192.8 ± 82.6 vs. 180.6 ± 84.9 min, $p < 0.001$), and the robotic group (290.5 ± 154.9 vs. 264.6 ± 90.9 min, $p = 0.03$).

#### 3.3.2. Length of hospital stay (LOS)

ERAS use was associated with a reduction in LOS across all modalities. The robotic had a significantly shorter LOS (5.5 ± 4.6 vs. 8.5 ± 16.4 days, $p < 0.001$), similar to the laparosocopic group (8.5 ± 7.8 vs. 9.0 ± 6.7, $p < 0.001$), and the open group (13.1 ± 9.5 vs. 14.5 ± 11.8, $p = 0.02$).

In the multivariate analysis, the group with the ERAS protocol showed a significant reduction in LOS ($p = 0.001$), and the main contributing factors included robotic technique and better baseline hemoglobin levels. In contrast, steroids use, open surgery approach, indications of diverticulitis, and high ASA were independently associated with prolonged LOS.

#### 3.3.3. Comprehensive Complication Index (CCI)

In the robotic group, the average CCI score was significantly lower (5.1 ± 11.4 vs. 11.9 ± 58.9, $p = 0.02$), unlike the laparoscopic group, with CCI showing no difference (7.1 ± 13.3 vs. 8.3 ± 15.8, $p = 0.18$).

On regression, ERAS application was not independently associated with a reduction in CCI ($p = 0.75$). Several variables were strongly

**Table 1**
Patient characteristics by surgical approach and ERAS status.

| Characteristics | Robotic (n = 610) | | | Laparoscopic (n = 2128) | | | Open (n = 2765) | | |
|---|---|---|---|---|---|---|---|---|---|
| | ERAS (n = 214) | No ERAS (n = 396) | P value | ERAS (n = 214) | No ERAS (n = 396) | P value | ERAS (n = 214) | No ERAS (n = 396) | P value |
| **Mean Age** | 60.9 ± 13.0 | 62.1 ± 11.8 | 0.57 | 65.1 ± 14.4 | 60.3 ± 15.3 | <0.001 | 64.9 ± 13.5 | 65.7 ± 13.7 | 0.23 |
| **Mean BMI** | 28.9 ± 7.1 | 28.1 ± 5.7 | 0.37 | 26.7 ± 5.2 | 26.6 ± 5.1 | 0.75 | 27.1 ± 7.0 | 26.8 ± 7.1 | 0.69 |
| **Active smoking N (%)** | 39 (18.2) | 82 (20.7) | 0.17 | 81 (20.8) | 286 (16.4) | 0.48 | 47 (16.4) | 325 (13.1) | 0.14 |
| **Preoperative Hb level (g/dL)** | 12.5 ± 2.1 | 13.1 ± 2.0 | 0.01 | 12.9 ± 2.1 | 13.1 ± 1.9 | 0.31 | 12.0 ± 2.1 | 11.9 ± 2.1 | 0.69 |
| **Steroid use N (%)** | 6 (2.8) | 9 (2.3) | 0.08 | 3 (0.8) | 96 (5.5) | 1.0 | 4 (1.4) | 105 (4.2) | 0.67 |
| **CCI** | 3.87 ± 2.76 | 4.02 ± 2.42 | 0.356 | 2.63 ± 2.80 | 3.56 ± 2.84 | <0.001 | 3.09 ± 2.70 | 5.27 ± 2.93 | <0.001 |
| **ASA score** | 2.45 ± 0.58 | 2.49 ± 0.60 | 0.567 | 2.53 ± 0.60 | 2.22 ± 0.65 | <0.001 | 2.59 ± 0.61 | 2.47 ± 0.70 | 0.007 |
| **Nutritional status** | 1.13 ± 1.04 | 0.75 ± 0.95 | <0.001 | 0.59 ± 1.03 | 1.11 ± 1.16 | <0.001 | 1.40 ± 1.48 | 1.71 ± 1.42 | <0.001 |
| **Indication** | | | | | | | | | |
| **Tumor** | 168 (78.5) | 307 (77.5) | | 253 (65) | 927 (53.3) | | 255 (88.9) | 2105 (84.9) | |
| **Diverticulitis** | 44 (20.6) | 89 (22.5) | | 131 (33.7) | 644 (37) | | 26 (9.1) | 260 (10.5) | |
| **Crohn's disease** | 2 (0.9) | 0 | | 5 (1.3) | 168 (9.7) | | 6 (2.1) | 113 (4.6) | |

**Table 2**
Intraoperative and postoperative outcomes by surgical approach and ERAS status.

| Characteristics | Robotic (n = 610) | | | Laparoscopic (n = 2128) | | | Open (n = 2765) | | |
|---|---|---|---|---|---|---|---|---|---|
| | ERAS (n = 214) | No ERAS (n = 396) | P value | ERAS (n = 389) | No ERAS (n = 1739) | P value | ERAS (n = 287) | NO ERAS (n = 2478) | P value |
| **Operative time (min)** | 290.5 ± 154.9 | 264.6 ± 90.9 | 0.03 | 192.8 ± 82.6 | 180.6 ± 84.9 | <0.001 | 235.7 ± 114.8 | 186.0 ± 93.7 | <0.001 |
| **Length of stay** | 5.5 ± 4.6 | 8.5 ± 16.4 | <0.001 | 8.5 ± 7.8 | 9.0 ± 6.7 | <0.001 | 13.1 ± 9.5 | 14.5 ± 11.8 | 0.02 |
| **Total complications N (%)** | 40 (18.7) | 98 (24.7) | 0.09 | 79 (20.3) | 555 (31.9) | <0.001 | 97 (33.8) | 1215 (49) | <0.001 |
| **Comprehensive complication index** | 5.1 ± 11.4 | 11.9 ± 58.9 | 0.02 | 7.1 ± 13.3 | 8.3 ± 15.8 | 0.18 | 11.1 ± 15.0 | 17.5 ± 23.2 | <0.001 |
| **Anastomotic leakage N (%)** | 5 (2.3) | 21 (5.3) | 0.09 | 15 (3.9) | 90 (5.2) | 0.27 | 11 (3.8) | 236 (9.5) | 0.001 |

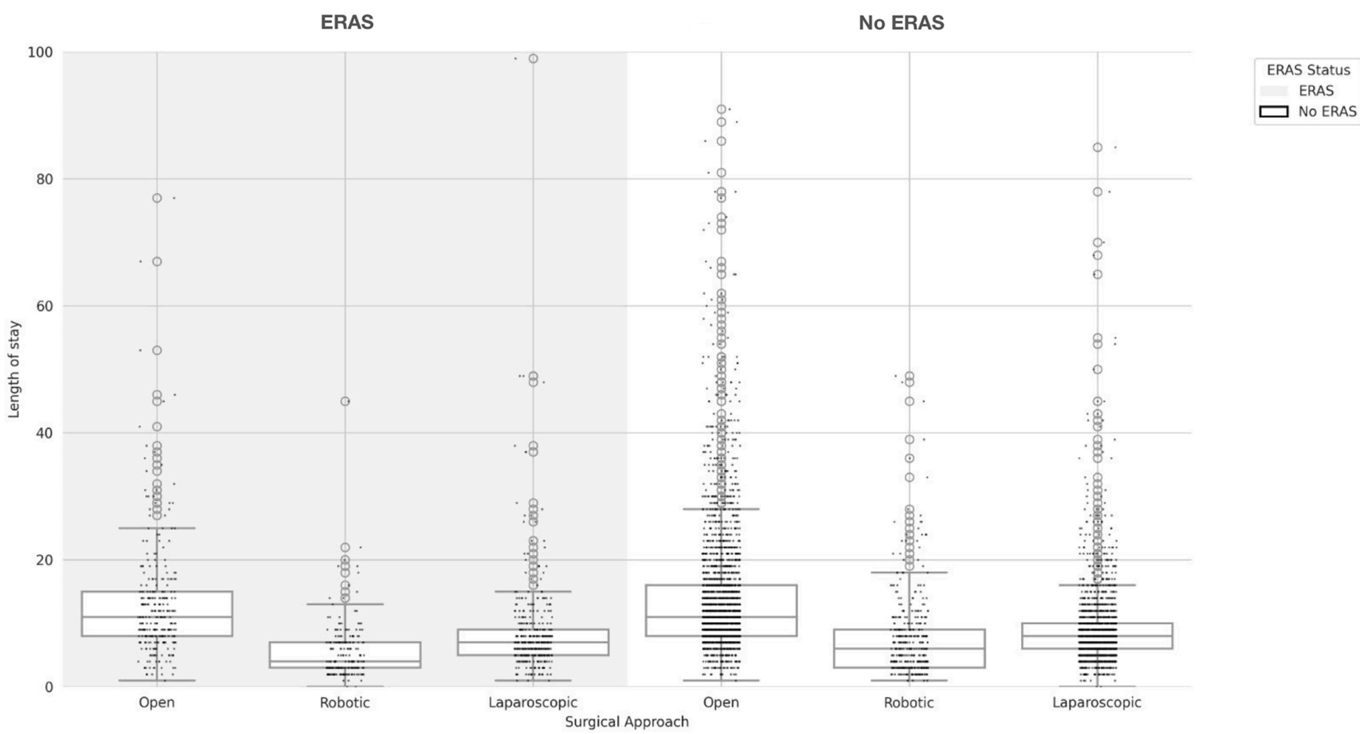


**Fig. 1.** Length of hospital stay by surgical approach and ERAS group.

associated with higher CCI scores, including Higher ASA score ($p < 0.001$), poor nutritional status ($p < 0.001$), and elevated CRP ($p = 0.012$).

## 4. Discussion

This large multicenter retrospective study offers a comprehensive evaluation of the effects of ERAS protocols in elective colorectal surgery by systematically integrating evidence-based practices to minimize surgical stress and accelerate recovery. By utilizing a robust dataset and large sample size, we thoroughly assessed ERAS use across varied clinical settings. Our findings significantly contribute to the growing number of publications by providing one of the most detailed comparisons to date of surgical techniques within a unified ERAS framework, allowing for a nuanced understanding of how operative modality influences ERAS outcomes.

Patients managed under ERAS protocols generally had better preoperative profiles, reflecting the effectiveness of the methods of patient optimization. In the robotic group, patients showed significantly better nutritional status. Although ERAS patients in the laparoscopic group were generally older, they also had lower comorbidity scores and used steroids less frequently, which may indicate that ERAS helped reduce some risk factors prior to surgery. Comparable patterns were observed in the open group, whereas ERAS patients exhibited improved nutritional status and reduced comorbidity. These trends imply that patients enrolled in ERAS pathways may have been selectively chosen based on their ability to adhere to active participation in preoperative optimization and postoperative recovery measures. Hence, ERAS was linked to better baseline characteristics which partially explain the improved outcomes.

A central finding of our study is that ERAS care was associated with a significantly lower hospital stay in all three surgical modalities. This effect remained statistically significant in the multivariate regression after controlling for key clinical and surgical confounders, including ASA score, nutritional status, preoperative inflammation (CRP), hemoglobin level, and surgical approach. Remarkably, compared to laparoscopic surgery, open surgery increased LOS by more than 4 days, whereas robotic surgery was independently linked to a reduction in LOS of about 1.4 days. These results may point to a synergistic effect between ERAS protocols and minimally invasive techniques, such as improved fluid management and less surgical trauma.[18] These results are consistent with a meta-analysis of 16 randomized controlled trials that found that ERAS reduced length of stay by 2.3 days without increasing readmission rates,[19] although surgical technique was not taken into consideration in that study. Similar LOS reductions of 30–50 % across a range of surgical specialties were reported in a more comprehensive review.[20]

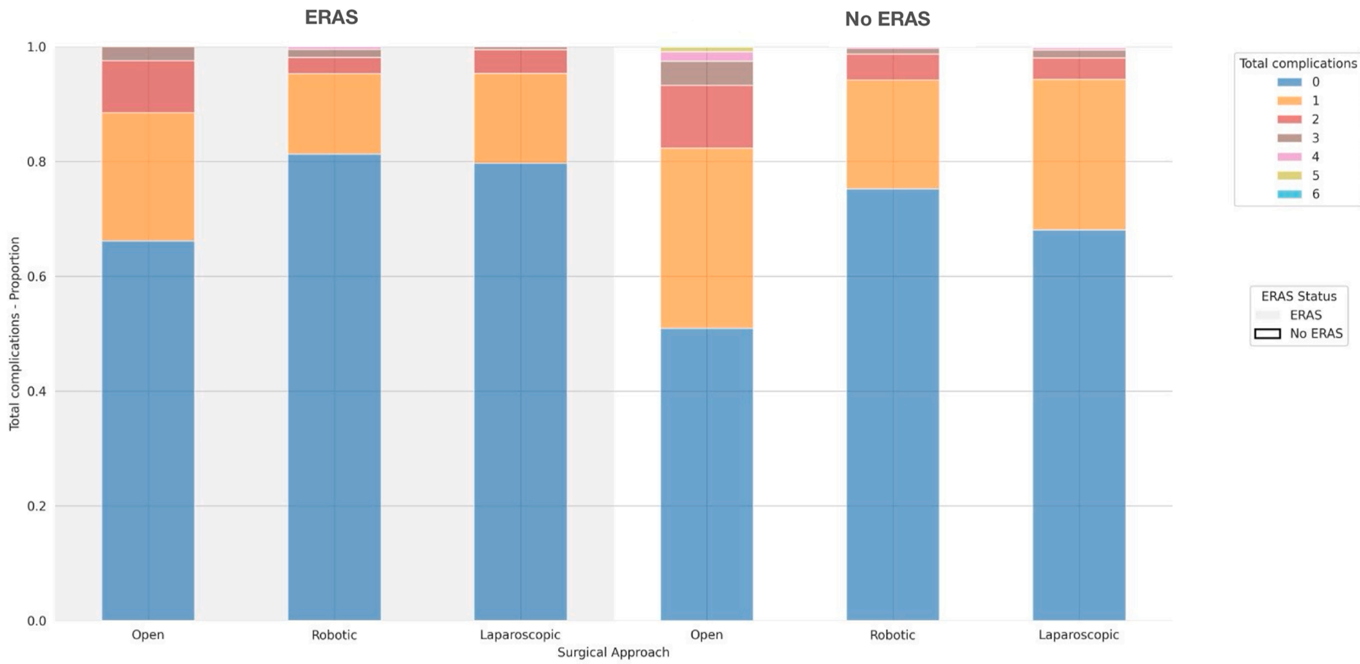


**Fig. 2.** Total complication proportion by surgical approach and ERAS group.

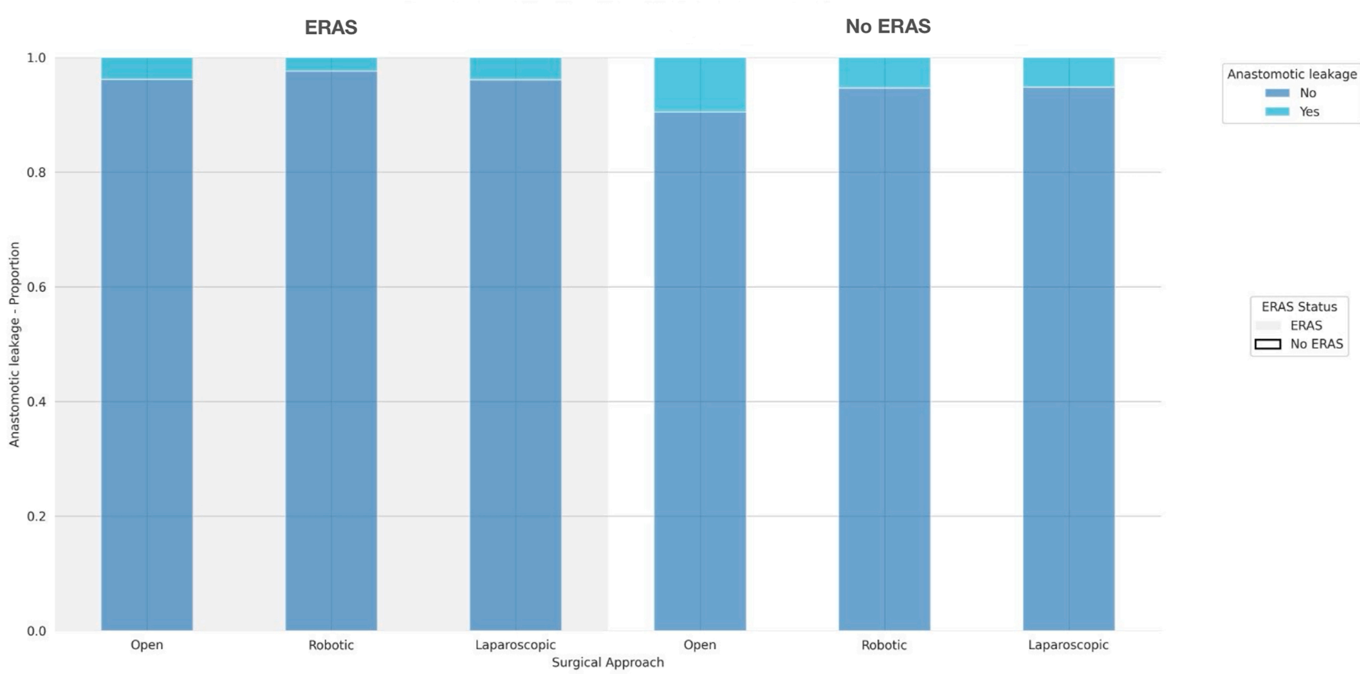


**Fig. 3.** Anastomotic leakage by surgical approach and ERAS group.

In the multivariate analysis, non-ERAS patients were independently associated with a significantly higher complication rate ($p = 0.016$), indicating a protective role of ERAS use. Also, the benefit of minimally invasive procedures was highlighted by the fact that robotic surgery was linked to a significantly lower complication rate ($p = 0.002$), whereas open surgery was independently linked to a significant increase in complication rate ($p < 0.001$). These findings align with previous systematic reviews and meta-analyses that have consistently shown lower complication rates following the use of ERAS in colorectal surgery.[19–21] The heterogeneity of our large sample further reinforces the generalizability of the results. In the univariate analyses, CCI was significantly lower in the ERAS group in the robotic and open techniques; with only comparable values in the laparoscopic group. ERAS did not, however, independently predict CCI in the multivariate analysis; this could be because ERAS largely reduces the chance of complications rather than their severity after they develop.

The results showed a strong association between ERAS protocols and the risk of anastomotic leakage. ERAS patients had a significant reduction in the risk of anastomotic leakage. In particular, ERAS patients were less likely to develop leaks than non-ERAS patients ($p = 0.007$). This finding is particularly crucial as anastomotic leak remains an important complication that affects morbidity, mortality, and long-term oncological outcomes. Several ERAS components potentially contribute to this effect. For instance, avoiding fluid overload will reduce bowel wall edema and improve tissue perfusion. Early mobilization enhances pulmonary function and tissue oxygenation, thereby enhancing the healing mechanism. In contrast, factors such as steroid use and active smoking will disrupt the healing process and hence increase the risk of AL, as shown in our analysis.[2,22] Previous single-center studies have mainly focused on assessing factors associated with anastomotic leak in an ERAS-applied setting.[23,24]

Our findings imply that the combination of ERAS and robotic surgery in elective surgery provides a synergistic effect reducing both complication rates and complication severity, and in turn reducing LOS and postoperative morbidity. These findings support a shift toward systematic changes that enable the integration of both approaches into routine practice. While there is potential for financial benefit and systematic re-evaluation of resource management, this would require long-term, multicenter cost-benefit analyses to fully evaluate.

There are a number of limitations to this study. In order to emphasize elective colorectal surgery, we excluded emergency cases; however, this limits the generality of our results to greater surgical populations. As there are specific ERAS principles for emergency surgeries, future research should include both elective and emergency cases with their respective protocols. Furthermore, although we examined ERAS as a single pathway, adherence to ERAS protocols was not systematically measured or controlled across participating centers. While some centers may have high adherence rates, this information was not consistently available, and future studies should aim to incorporate adherence data to better contextualize the findings. Since the data collected covers an extended period (2012–2020), the adherence to the ERAS guidelines and the surgeon's experience in terms of open versus minimally invasive techniques varied, which may have influenced the outcomes. Endpoints like length of stay and discharge timing may be impacted by baseline variations between European and American centers. Finally, the retrospective aspect of the study increases the risk of selection bias and confounding factors, including patient demographics and medical and surgical history.

## 5. Conclusion

This retrospective multicenter study is one of the largest analysis on assessing the impact of ERAS protocols across robotic, laparoscopic, and open colorectal surgeries. Our findings show that the use of ERAS significantly reduces hospital length of stay across all surgical modalities, with the greatest benefit particularly after robotic surgery. ERAS was associated with lower complication rates, specifically anastomotic leakage rates, and a lower CCI.

This study supports the vast application of ERAS protocols in clinical practice and emphasizes their significance in colorectal surgery. There is still potential for improvement, particularly in terms of the ERAS pathway in complex cases and high-risk patients. Future studies should focus on determining which ERAS components are the most important and how to apply them most effectively to various surgical techniques.

## CRediT authorship contribution statement

**Bushra Mohandes:** Writing – original draft, Formal analysis, Data curation. **Saido Haji Abukar:** Writing – original draft, Data curation, Conceptualization. **Florian Ponholzer:** Writing – review & editing, Data curation, Conceptualization. **Dietmar Öfner:** Writing – review & editing, Supervision, Data curation, Conceptualization. **Bassey Enodien:** Writing – review & editing, Validation, Supervision, Project administration, Data curation, Conceptualization. **Niklas Ortlieb:** Methodology, Formal analysis. **Mariana Flaifel:** Writing – original draft. **Daniel M. Frey:** Writing – review & editing, Resources, Data curation. **Stephan Vorburger:** Writing – review & editing, Validation, Project administration, Data curation. **Baraa Saad:** Writing – review & editing, Visualization, Project administration. **Sophie Müller:** Data curation. **Cathérine Kollmann:** Writing – review & editing, Investigation, Data curation. **Lars Kollmann:** Writing – review & editing, Validation, Data curation. **Sven Flemming:** Writing – review & editing, Validation, Project administration, Data curation. **Julia Kristin Grass:** Project administration, Data curation. **Nathaniel Melling:** Writing – review & editing, Validation, Project administration, Data curation. **Michael Rousek:** Writing – review & editing, Data curation. **Vilius Abeciūnas:** Validation, Data curation. **Tomas Poskus:** Writing – review & editing, Supervision, Project administration, Investigation. **Ovunc Bardakcioglu:** Validation, Project administration, Data curation. **Katerina Neumann:** Writing – review & editing, Validation, Data curation. **Boris L. Gala-Lopez:** Validation, Project administration, Data curation. **Michael Drew Honaker:** Writing – review & editing, Project administration, Conceptualization. **Daniel Steinemann:** Resources, Data curation, Validation, Data curation. **Beat P. Müller:** Resources, Data curation. **Jasmin Zeindler:** Validation, Supervision, Project administration, Data curation, Conceptualization. **Otto Kollmar:** Writing – review & editing. **Andres Heigl:** Data curation. **Robert Rosenberg:** Writing – review & editing, Supervision, Project administration, Funding acquisition, Data curation, Conceptualization. **Stephanie Taha-Mehlitz:** Writing – review & editing, Validation, Project administration, Data curation, Conceptualization. **Anas Taha:** Writing – review & editing, Validation, Supervision, Funding acquisition, Formal analysis, Data curation, Conceptualization.

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## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.amjsurg.2025.116679.

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