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Association Between ERAS Protocol Adherence and Short-Term Outcomes in Type 2 Diabetes: Retrospective Propensity-Matched Cohort Study

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Abstract **Background:** ERAS pathways have been proven to provide better outcomes for patients undergoing colorectal surgery. However, there is not enough evidence about the effects of these pathways on diabetic patients. This study aimed at assessing the relationship between ERAS compliance and short-term postoperative outcomes in diabetic patients. **Methods:** This single-centre retrospective study included 145 patients with type 2 diabetes mellitus who underwent elective colorectal cancer surgery between 1 July 2022 and 30 July 2026. Adherence was assessed using an 18-item Enhanced Recovery After Surgery (ERAS) composite; 93 patients had high (≥80%) and 52 had lower adherence. Propensity score matching retained 43 pairs (86 of 145 patients), restricting the matched comparison to those with adequate covariate overlap. **Results:** Compared with patients with lower ERAS adherence (<80%), those with high adherence had fewer 30-day postoperative complications (25.6% vs 53.5%; adjusted OR 0.30, 95% CI 0.12–0.72, p = 0.006), a shorter hospital stay (5.2±1.8 vs 7.1±2.6 days; mean difference −1.9 days, 95% CI −2.8 to −1.0, p<0.001), and better postoperative glycemic control. **Conclusion:** Higher recorded ERAS composite adherence was associated with fewer 30-day complications and shorter postoperative hospital stay in the matched sample. Because this was a single-centre retrospective study with substantial exclusions after matching, residual confounding, selection effects and limited precision prevent causal interpretation; prospective external validation is needed.

Key Words Enhanced Recovery after Surgery, ERAS, Diabetes Mellitus, Colorectal Surgery, Postoperative Outcomes, Propensity Score Matching, Saudi Arabia

INTRODUCTION

Despite improvements in surgical technique and management in recent years, the morbidity associated with colorectal surgery is still high, and complication rates have approached 20-30%. [1]. Diabetics are especially prone to these complications with substantially elevated risks of SSI, AL, and even hospital readmissions compared to non-diabetics. In a recent systematic review and meta-analysis of 55 studies with over 666,000 subjects, diabetes was shown to increase the risk of AL and SSI in colorectal surgery by more than twofold [2]. Considering the rising worldwide prevalence of diabetes, achieving good perioperative results in such patients is now considered a significant objective of medicine.

ERAS protocols have revolutionized perioperative care by incorporating evidence-based measures that help to reduce the stress response associated with surgery, maintain physiological function, and promote speedy recovery [3]. As per the current guidelines of the Enhanced Recovery After Surgery (ERAS) society, a multimodal strategy is advised, which comprises of preoperative counselling, carbohydrate loading, goal directed fluid administration, opioid sparing analgesia, and early mobilization [4]. Various randomized trials and meta-analyses have shown that using ERAS results in fewer postoperative complications, shorter hospital stay, and faster recovery than traditional medical management [5,6].

Increasing evidence suggests that the benefits of ERAS are not only dependent on the implementation of a protocol but also on the level of compliance with individual elements of ERAS. International ERAS registries have shown a clear correlation between higher compliance and better postoperative results. Clinical benefits are less clear when less than 70% of the protocol is adherent [7, 8]. However, whether this relationship applies equally to patients with significant metabolic comorbidities, particularly diabetes, remains uncertain.

Patients with diabetes may represent a unique subgroup within ERAS programs because impaired immune function, microvascular disease, and perioperative hyperglycemia predispose them to postoperative complications and may necessitate individualized perioperative management strategies [2]. However, there is limited evidence on the impact of ERAS adherence specifically in diabetic patients undergoing colorectal surgery, and it is mainly derived from retrospective single-center studies with heterogeneous definitions of compliance and outcomes [9,10].

The aforementioned gap in knowledge becomes particularly important in the context of Saudi Arabia, whose incidence rates of diabetes are considered to be among the highest in the world. According to epidemiological surveys, about one-quarter of Saudis are affected by diabetes, and a substantial proportion remain undiagnosed [11,12]. While there is growing utilization of ERAS protocols in the area, there has been little research on how these protocols are followed and their effect on diabetics undergoing colorectal surgery.

Accordingly, this study aimed to evaluate the association between ERAS protocol adherence and short-term postoperative outcomes in patients with diabetes undergoing elective colorectal resection at a tertiary care center in Saudi Arabia. We hypothesized that higher ERAS adherence would be independently associated with lower postoperative morbidity, even after adjustment for baseline clinical and metabolic confounders.

METHODS

Study Design and Institutional Setting

The purpose of this single-center retrospective cohort study is to examine the association between postoperative outcomes and adherence to the Enhanced Recovery After Surgery (ERAS) protocol in patients with type 2 diabetes mellitus (T2DM) who had elective colorectal cancer surgery. This study was carried out at King Abdulaziz Specialist Hospital (KASH) in Taif, Saudi Arabia, where a full ERAS protocol is implemented since 2019. Throughout the study period, the institutional ERAS pathway, perioperative protocols, and compliance assessment procedures remained unchanged, thereby minimizing temporal variations in perioperative practice.

Inclusion criteria for the study consisted of all consecutive patients who underwent treatment between 1 July 2022 and 30 July 2026 and were enrolled in the institutional ERAS registry and confirmed by means of EMR, operative reports, anesthetic records, nursing documents, laboratory reports, and follow-up data. This study was carried out in accordance with the STROBE guidelines for conducting and reporting observational studies in epidemiology. A prospective sample size calculation was not done because the study was retrospective and included all eligible patients.

Institutional Review Board approval was obtained from King Abdulaziz Specialist Hospital, Taif, Saudi Arabia (IRB No. 2025-THC-66EE; approval date: 19 January 2026; KACST registration No. H-02-T-150). Written informed consent was not required due to the retrospective design and anonymisation of patient data.

Eligibility Criteria and Patient Selection

Eligible participants met all of the following criteria: age ≥18 years; documented diagnosis of type 2 diabetes mellitus, established before surgery according to American Diabetes Association diagnostic criteria or documented physician diagnosis requiring glucose-lowering therapy for at least six months; Primary colorectal cancer with histological confirmation; elective colorectal excision with the goal of curing the condition via an open or minimally invasive technique; availability of sufficient perioperative documentation to calculate ERAS compliance.

Patients were excluded if they had: emergency surgery for obstruction, perforation, or uncontrolled bleeding; palliative surgery or non-resectional procedures; stage IV disease requiring non-curative treatment; multivisceral resection; American Society of Anesthesiologists (ASA) physical status class IV or V; newly diagnosed diabetes during the index admission; diabetic ketoacidosis or hyperosmolar hyperglycemic state within 30 days before surgery; severe uncontrolled diabetes (HbA1c >10%), consistent with institutional perioperative optimization policy; insufficient ERAS documentation (>20% missing ERAS items preventing accurate compliance assessment); or incomplete clinical follow-up for assessment of the primary 30-day outcomes.

Perioperative Diabetes Management

All patients underwent standardized perioperative glycemic management according to institutional protocols. Preoperative optimization was coordinated jointly by colorectal surgeons, anesthesiologists, endocrinologists, and diabetes educators whenever necessary.

Capillary blood glucose was routinely monitored before meals and at bedtime during hospitalization, with additional measurements performed according to clinical indication. The institutional target glucose range was 70–180 mg/dL, in accordance with international perioperative diabetes guidelines. Hyperglycemia was managed using standardized basal-bolus insulin protocols or intravenous insulin infusion when clinically indicated.

ERAS Protocol and Compliance Assessment

The institutional ERAS pathway was adapted from the 2018 ERAS Society Guidelines for Elective Colorectal Surgery,

with minor modifications reflecting local clinical practice while maintaining all essential evidence-based components. The protocol comprised 18 predefined ERAS elements spanning the preoperative, intraoperative, and postoperative phases.

Each ERAS element was scored as achieved (1) or not achieved (0). Individual compliance was calculated as the percentage of completed items out of the 18-item checklist. In accordance with previous ERAS studies, high adherence was defined as completion of ≥80% (i.e., ≥15 of 18 items) of ERAS components, whereas low adherence was defined as completion of <80% of components. Compliance scoring was independently performed by two investigators blinded to patient outcomes. Disagreements were resolved by consensus. Interobserver agreement was excellent (Cohen's $\kappa = 0.86$; 95% CI, 0.81–0.91).

Outcome Measures

The occurrence of any postoperative complications within 30 days following surgery was the main outcome, defined as Clavien–Dindo grade II or higher (Major complications (Clavien-Dindo III–IV) were analyzed as a secondary endpoint). Complications included: surgical site infection (Centers for Disease Control and Prevention criteria); anastomotic leak (International Study Group of Rectal Cancer definition); pneumonia (American Thoracic Society diagnostic criteria); urinary tract infection; acute kidney injury (KDIGO criteria); cardiovascular complications; wound healing complications.

Time to first ambulation, time to first bowel noises, time to first passage of flatus, time to first bowel movement, time to start oral intake, time to remove the urine catheter, and time to remove the drain were among the secondary outcomes.

The outcome measures that were considered specific to diabetes were: the mean postoperative blood glucose level between days 1-3 after surgery, the presence of any hyperglycemia (blood glucose level > 180 mg/dL), the presence of any severe hyperglycemia (blood glucose level > 250 mg/dL), severe hypoglycemia (blood glucose level < 60 mg/dL) requiring treatment intervention, the use of insulin in the hospital setting, and the attainment of the recommended target glycemic range of 70 – 180 mg/dL.

Follow-up Procedure

Patients were followed according to a standardized institutional colorectal cancer pathway. Clinical assessments were performed during hospitalization, at discharge, and 30 days after surgery. Inpatient records, outpatient clinic visits, and structured telephone interviews conducted by qualified ERAS nursing staff were used to gather short-term postoperative outcomes. Before being labelled as lost to follow-up, patients who failed to show up for scheduled follow-up visits were contacted at least three times.

Statistical Analysis

All statistical analyses were performed using R software (version 4.3.2; R Foundation for Statistical Computing, Vienna, Austria) and IBM SPSS Statistics (version 26.0; IBM Corp., Armonk, NY, USA).

Continuous variables were assessed for normality using the Shapiro–Wilk test, supplemented by visual inspection of histograms and quantile–quantile (Q–Q) plots.

The independent-samples Student's t-test was used to compare normally distributed variables, which are shown as mean±standard deviation (SD) prior to propensity score matching. The Mann-Whitney U test was used to compare non-normally distributed variables, which are shown as median and interquartile range (IQR). The chi-square test or Fisher's exact test, depending on the situation, were used to compare categorical variables, which are summarised as frequencies and percentages.

After propensity score matching, to account for the paired nature of the data, categorical variables were compared using McNemar's test (with exact binomial calculation for small counts). Continuous variables following a normal distribution were compared using the paired t-test, whereas non-normally distributed continuous variables were compared using the Wilcoxon signed-rank test. Effect sizes for binary outcomes are reported as odds ratios (ORs) with 95% confidence intervals, derived from conditional logistic regression for matched pairs. For ordinal outcomes (e.g., Clavien–Dindo grade), the Wilcoxon signed-rank test was used.

In order to determine independent predictors of the main outcome, which is any postoperative complication that occurs within 30 days and is classified as Clavien-Dindo grade II or above, a conditional logistic regression model was constructed using the 43 matched pairs. This approach accounts for the paired nature of the data by stratifying on the matched pair identifier.

Variables were selected a priori based on clinical relevance and included high ERAS adherence (≥80%), preoperative HbA1c ≥7%, and ASA class III–IV. The model was constrained to three predictors to maintain an adequate events-per-variable ratio (>10 events per predictor) given the 34 outcome events observed in the matched cohort. Adjusted odds ratios (aORs) with 95% confidence intervals (CIs) were reported. All variables were entered simultaneously using the forced-entry (enter) method, without automated variable selection.

RESULTS

Study Population and Baseline Characteristics

A total of 145 individuals with type 2 diabetes mellitus who had their colon cancer surgically removed met the eligibility criteria and were included in the study, including 93 (64.1%) high ERAS adherence patients (≥80%) and 52 (35.9%) low ERAS adherence patients. Main reasons for exclusion were emergency operation, Stage IV disease, lack of ERAS documentation, and inadequate follow-up period. Through 1:1 matching based on propensity score, 43 pairs (86 patients) were eventually selected for further analysis (Figure 1).

The patients with high adherence differed from those with low adherence in many baseline factors prior to matching, including ASA class, Charlson comorbidity index, preoperative HbA1c, insulin use, diabetic complications, and minimally invasive surgery. Following the matching process, all standardized mean differences were <0.10 (Table 1).

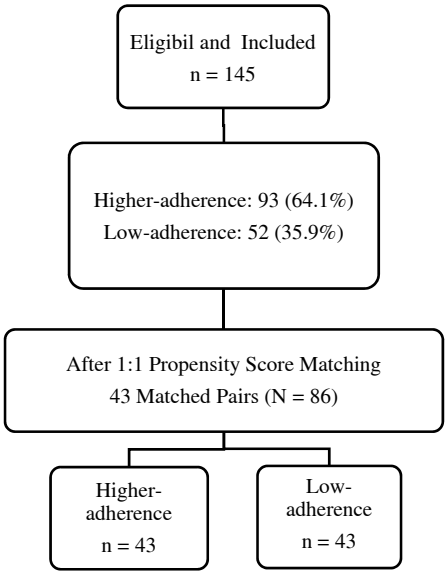


Figure 1: Study Population and Propensity Score Matching

Table 1: Baseline Characteristics Before and After Propensity Score Matching

Characteristic	High Adherence Before Matching (N = 93)	Low Adherence Before Matching (N = 52)	p-value	High Adherence After Matching (N = 43)	Low Adherence After Matching (N = 43)	SMD
Age, years	61.6±10.1	66.0±10.8	0.017	64.2±10.4	64.8±10.8	0.06
Male sex, n (%)	53 (57.0)	29 (55.8)	0.89	23 (53.5)	23 (53.5)	<0.01
BMI, kg/m²	28.3±4.7	29.2±5.0	0.28	28.6±4.8	29.0±5.0	0.08
ASA class III–IV, N (%)	33 (35.5)	30 (57.7)	0.011	19 (44.2)	20 (46.5)	0.05
Charlson Comorbidity Index, median (IQR)	5.0 (4.0–6.0)	6.0 (5.0–7.0)	0.008	5.0 (4.0–6.0)	5.0 (4.0–6.0)	0.07
Preoperative HbA1c, %	7.2±1.1	7.8±1.3	0.003	7.4±1.1	7.5±1.2	0.09
Diabetes duration, years, median (IQR)	8.0 (4.0–13.0)	9.0 (5.0–15.0)	0.11	8.0 (4.0–13.0)	8.0 (4.0–14.0)	0.05
Insulin use, N (%)	38 (40.9)	30 (57.7)	0.049	20 (46.5)	21 (48.8)	0.05
Diabetic complications, N (%)	25 (26.9)	23 (44.2)	0.033	15 (34.9)	15 (34.9)	<0.01
Rectal tumor location, N (%)	41 (44.1)	24 (46.2)	0.81	18 (41.9)	20 (46.5)	0.09
TNM stage III, N (%)	33 (35.5)	20 (38.5)	0.72	16 (37.2)	18 (41.9)	0.10
Minimally invasive surgery, N (%)	53 (57.0)	20 (38.5)	0.031	22 (51.2)	21 (48.8)	0.05

ASA: American Society of Anesthesiologists, BMI: Body Mass Index, HbA1c, Glycated Hemoglobin, IQR: Interquartile Range, SMD: Standardized Mean Difference

Table 2: ERAS Component Adherence in the Matched Cohort

ERAS Component	Overall (N = 86)	High Adherence (N = 43)	Low Adherence (N = 43)
Preoperative			
Structured patient education	79 (91.9)	42 (97.7)	37 (86.0)
Comorbidity optimization	81 (94.2)	43 (100.0)	38 (88.4)
Nutritional assessment	74 (86.0)	40 (93.0)	34 (79.1)
Anemia screening/correction	72 (83.7)	39 (90.7)	33 (76.7)
Antimicrobial prophylaxis	84 (97.7)	43 (100.0)	41 (95.3)
Mechanical bowel preparation	47 (54.7)	26 (60.5)	21 (48.8)
Carbohydrate loading	62 (72.1)	36 (83.7)	26 (60.5)
PONV prophylaxis	78 (90.7)	41 (95.3)	37 (86.0)
Intraoperative			
Standardized anesthesia	72 (83.7)	40 (93.0)	32 (74.4)
Goal-directed fluid therapy	69 (80.2)	38 (88.4)	31 (72.1)
Normothermia maintenance	74 (86.0)	40 (93.0)	34 (79.1)
Minimally invasive approach	41 (47.7)	21 (48.8)	20 (46.5)
Opioid-sparing analgesia	64 (74.4)	37 (86.0)	27 (62.8)
Postoperative			
Early mobilization	45 (52.3)	33 (76.7)	12 (27.9)
Early oral nutrition	60 (69.8)	36 (83.7)	24 (55.8)
Multimodal bowel stimulation	56 (65.1)	35 (81.4)	21 (48.8)
Urinary catheter removal ≤48 h	59 (68.6)	34 (79.1)	25 (58.1)
Structured discharge planning	66 (76.7)	38 (88.4)	28 (65.1)

PONV: Postoperative Nausea and Vomiting

Table 3: Postoperative, Recovery, and Diabetes-Specific Outcomes in the Matched Cohort

Outcome	High Adherence (N = 43)	Low Adherence (N = 43)	OR (95% CI)/ Effect Estimate (95% CI)	p-value
A. Clavien–Dindo–graded postoperative complications				
Any complication, Clavien–Dindo ≥II	11 (25.6)	23 (53.5)	0.30 (0.12–0.72)	0.006
Surgical site infection	6 (14.0)	13 (30.2)	0.37 (0.13–1.06)	0.058
Anastomotic leak	1 (2.3)	4 (9.3)	0.23 (0.02–2.04)	0.17
Pneumonia	3 (7.0)	4 (9.3)	0.73 (0.15–3.47)	0.69
Urinary tract infection	2 (4.7)	4 (9.3)	0.48 (0.08–2.78)	0.40
Acute kidney injury	2 (4.7)	7 (16.3)	0.25 (0.05–1.27)	0.08
Cardiovascular complications	2 (4.7)	3 (7.0)	0.65 (0.10–4.12)	0.64
Wound-healing complications	4 (9.3)	10 (23.3)	0.34 (0.10–1.18)	0.08
Clavien–Dindo III–IV	3 (7.0)	10 (23.3)	—	0.015
Postoperative death	0	0	—	—
B. Postoperative Recovery				
Length of hospital stay, days	5.2±1.8	7.1±2.6	MD, −1.9 (−2.8 to −1.0)	<0.001
Time to first ambulation, h	18 (16–24)	28 (24–36)	MD, −10 (−14 to −6)	<0.001
Time to first flatus, days	2 (2–3)	3 (3–4)	MD, −1 (−2 to −1)	<0.001
Time to first bowel sounds, days	1 (1--2)	2 (1--3)	MD, −0.9 (−1.3 to −0.5)	<0.001
Time to first bowel movement, days	3 (2–4)	4 (3–5)	MD, −1 (−1.5 to −0.5)	0.002
Time to tolerance of solid diet, days	2 (2–3)	4 (3–5)	MD, −2 (−3 to −1)	<0.001
Urinary catheter duration, days	1 (1--2)	2 (2--3)	MD, −0.9 (−1.4 to −0.4)	<0.001
Abdominal drain duration, days	2 (2–3)	3 (2–4)	MD, −1 (−1.5 to −0.2)	0.03
C. Diabetes-Specific Outcomes				
Mean postoperative glucose, mg/dL	158±24	184±31	MD, −26 (−38 to −14)	<0.001
Hyperglycemic episodes >180 mg/dL	10 (23.3)	22 (51.2)	OR, 0.29 (0.11–0.74)	0.009
Severe hyperglycemia >250 mg/dL	3 (7.0)	9 (20.9)	OR, 0.28 (0.07–1.07)	0.08
Severe hypoglycemia <60 mg/dL	1 (2.3)	2 (4.7)	OR, 0.48 (0.04–5.52)	0.56
Insulin requirement during hospitalization	17 (39.5)	28 (65.1)	OR, 0.35 (0.15–0.82)	0.016
Achievement of target glucose 70–180 mg/dL	34 (79.1)	22 (51.2)	OR, 3.60 (1.42–9.11)	0.006

CI: Confidence Interval, IQR: Interquartile Range, MD: Mean Difference, OR: Odds Ratio, SD: Standard Deviation

Table 4: Conditional Logistic Regression Analysis of Factors Associated with 30-Day Postoperative Complications

Variable	Adjusted OR	95% CI	p-value
High ERAS adherence (≥80%)	0.30	0.12–0.72	0.006
Preoperative HbA1c ≥7%	2.10	1.08–4.08	0.029
ASA class III–IV	1.85	0.95–3.60	0.070

ASA: American Society of Anesthesiologists, CI: Confidence Interval, ERAS: Enhanced Recovery After Surgery, HbA1c, Glycated Hemoglobin, OR: Odds Ratio

ERAS Protocol Adherence

Adherence was maximum in antimicrobial prophylaxis, comorbidity optimization, patient education, and prevention of PONV. However, minimum adherence was seen in minimally invasive surgery, mechanical bowel preparation, early mobilization, and multimodal bowel stimulation. High adherence was associated with more use of certain components of the perioperative process including early mobilization, early oral nutrition, multimodal bowel stimulation, pain relief with less opioids, and discharge planning (Table 2).

Postoperative Complications

Patients in the high ERAS group had a decreased incidence of postoperative complications at 30 days. Patients in the high-adherence group had Clavien-Dindo grade II or above complications in 11 (25.6%) cases compared with 23 (53.5%) patients in the low-adherence group (OR, 0.30; 95% CI, 0.12-0.72; P=0.006). Also, the incidence of Clavien-Dindo grade III and IV complications was significantly different (P=0.015) between groups, with fewer patients having complications of higher grade in the high ERAS group. No grade V complications or postoperative deaths occurred (Table 3).

Postoperative Recovery

There was a strong correlation between high adherence to ERAS and recovery after surgery. Patients who were highly adherent had a shorter hospital stay (5.2±1.8 vs. 7.1±2.6 days; mean difference, -1.9 days; 95% CI, -2.8 to -1.0; p<0.001). Key postoperative events such as ambulation, resumption of bowel activity, tolerance for a solid diet, removal of urinary catheter, and drain were reached more quickly by high adherents (Table 3).

Diabetes-Specific Outcomes

High ERAS adherence was also associated with better postoperative glycemic control. Mean postoperative glucose was lower in the high-adherence group than in the low-adherence group (158±24 vs 184±31 mg/dL; mean difference, −26 mg/dL; 95% CI, −38 to −14; p<0.001). Hyperglycemic episodes >180 mg/dL were less frequent in the high-adherence group (23.3% vs 51.2%; OR, 0.29; 95% CI, 0.11–0.74; p = 0.009), as was insulin requirement during hospitalization (39.5% vs 65.1%; OR, 0.35; 95% CI, 0.15–0.82; p = 0.016). Achievement of the target glucose range of 70–180 mg/dL was more frequent in the high-adherence group (79.1% vs 51.2%; OR, 3.60; 95% CI, 1.42–9.11; p = 0.006). Severe hyperglycemia >250 mg/dL occurred in 3

patients (7.0%) in the high-adherence group and 9 patients (20.9%) in the low-adherence group, but the difference was not statistically significant (OR, 0.28; 95% CI, 0.07–1.07; p = 0.08). Severe hypoglycemia <60 mg/dL occurred in 1 patient (2.3%) and 2 patients (4.7%), respectively, with no significant difference between groups (OR, 0.48; 95% CI, 0.04–5.52; p = 0.56) (Table 3).

Subgroup, Sensitivity, and Multivariable Analyses

The relationship between ERAS compliance and post-operative outcome was consistent in direction across levels of pre-operative glycemic control even though there was no statistical significance to the interaction between compliance and HbA1c level. Analysis based on an alternative ERAS compliance level of ≥75% generated results similar to the initial analysis.

High adherence to ERAS in conditional logistic regression among the 43 paired subjects was independently associated with decreased odds of 30-day postoperative complications (aOR, 0.30; 95% CI, 0.12–0.72; p = 0.006). Higher preoperative HbA1c level ≥7% was independently associated with higher odds of complications (aOR, 2.10; 95% CI, 1.08–4.08; p = 0.029), while increased ASA III–IV was only (aOR, 1.85; 95% CI, 0.95–3.60; p = 0.070) (Table 4).

DISCUSSION

This propensity score-matched cohort study showed that among diabetic patients following elective colorectal resection, strong adherence (≥80%) to ERAS protocols was independently linked to better short-term outcomes. High ERAS compliance was linked to considerably fewer surgical complications (aOR 0.30; 95% CI 0.12-0.72; p = 0.006), shorter hospital stays (mean difference -1.9 days; p<0.001), quicker postoperative recovery, and better perioperative glycaemic management as compared to lesser adherence. These results expand the well-established advantages of ERAS to a metabolically high-risk group that was not well-represented in earlier adherence studies.

The threshold of 80% compliance chosen in the current study was predetermined due to previous studies of the ERAS registry indicating the greatest benefits of the approach when compliance is above this value [7,8]. There is an established relationship between compliance and the clinical results, which have shown significantly lower morbidity and shorter hospitalization duration when compliance is ≥70-80% [14,16]. It is recognized, however, that the optimal threshold could vary for diabetic individuals.

ERAS Adherence and Postoperative Outcomes

This correlation between ERAS compliance and better surgical results has been consistently established for general colorectal patients. Indeed, the international POWER trial found considerable decreases in morbidity and length of stay among patients with increased adherence to protocol, with highest vs. lowest adherence resulting in a 66% decreased risk of complications (OR 0.34, 95% CI 0.25-0.46) [13]. Other studies have shown a progressive decrease in complications as ERAS compliance increases above approximately 70-80% [14,15]. Our results are in agreement with this, given that the adjusted odds ratio was 0.30 (95% CI 0.12-0.72) using conditional logistic regression, which indicates that the strength of the association in our diabetic population is roughly similar to that in other colorectal ERAS populations, but care must be taken when comparing because of different methodologies used in these studies. It is noteworthy that this study contributes to the body of literature by demonstrating that individuals with diabetes mellitus still benefit clinically from following the ERAS regimen.

Beyond reducing overall morbidity, high adherence was associated with lower rates of surgical site infection, acute kidney injury, and wound-related complications, together with fewer major (Clavien-Dindo III-IV) complications. Although anastomotic leak occurred less frequently in the high-adherence group, most likely due to the small number of incidents rather than the lack of a true link, the difference was not statistically significant.

Perioperative Glycemic Control

An important factor considered in this research is the evaluation of diabetes recovery factors. The patients who showed more adherence to ERAS had better glycemic control postoperatively as shown by their mean glucose levels, reduced cases of hyperglycemia, decreased need for insulin, and the achievement of glucose targets. This could be attributed to the effects of many aspects of ERAS, such as early ambulation, opioid-sparing anesthesia, and nutritional management. However, since this adherence was based on an observational study and not a randomized study, it would be impossible for this study to identify which specific components made this difference. [16-20].

Preoperative HbA1c ≥7% remained an independent predictor of postoperative complications, indicating that although ERAS adherence substantially improves perioperative outcomes, it does not fully offset the adverse effects of poor long-term glycemic control. These findings reinforce the importance of combining meticulous ERAS implementation with comprehensive preoperative diabetes optimization [21].

Clinical Implications

The clinical relevance of these findings is particularly important in Saudi Arabia, where diabetes prevalence remains among the highest worldwide and colorectal cancer incidence continues to increase [11,12]. Although ERAS implementation has expanded across the region, evidence specifically addressing diabetic colorectal patients remains limited. Our findings suggest that maintaining high protocol adherence should be considered a priority quality indicator for colorectal units managing patients with diabetes and support continued investment in multidisciplinary ERAS programs.

Strengths of this study include the clinically relevant research question, standardised implementation of ERAS, detailed assessment of compliance, propensity score

matching to minimise baseline imbalance, and comprehensive assessment of both surgical and diabetes specific outcomes. There are, however, a few caveats to be noted. Any causal inference is limited by the retrospective single-center design, and even with thorough statistical adjustment, residual confounding cannot be totally ruled out. For uncommon events like anastomotic leak, the small sample size made it more difficult to identify statistical significance. In addition, the 80% adherence threshold, although supported by prior literature, was pre-defined and may not be the optimal cutoff for diabetic populations. Finally, long-term outcomes including readmissions, oncologic results, and sustained metabolic control were beyond the scope of the present study.

Future prospective multicenter research is required to confirm these findings in bigger populations, to determine adherence thresholds for diabetes-specific ERAS, and to explore whether additional benefit is provided by tailored interventions, such as individualised carbohydrate loading, continuous glucose monitoring, and optimised perioperative diabetes management, beyond standard ERAS protocols [27,28].

CONCLUSION

The association reported in this retrospective cohort does not demonstrate that increasing adherence itself would cause improved outcomes. The 59 unmatched patients and unmeasured determinants of adherence may limit transportability to other patients with type 2 diabetes undergoing elective colorectal cancer surgery.

High ERAS adherence was associated with lower odds of 30-day postoperative complications, shorter hospital stay, faster postoperative recovery, and better perioperative glycaemic control in patients with type 2 diabetes mellitus undergoing elective colorectal cancer resection. These findings support rigorous ERAS implementation in this high-risk population; however, causal inference is not possible due to the retrospective observational methodology. To validate these correlations and ascertain whether customised diabetes-specific ERAS techniques offer extra benefits, more prospective multicenter research is required.

Conflict of Interest

The authors declare no conflicts of interest.

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Data Availability

The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

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