Implementation of the pre-operative rehabilitation recovery protocol and its effect on the quality of recovery after colorectal surgeries

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Abstract

Background: Patients' recovery after surgery is the major concern for all perioperative clinicians. This study aims to minimize the side effects of peri-operative surgical stress and accelerate patients' recovery of gastrointestinal (GI) function and quality of life after colorectal surgeries, an enhanced recovery protocol based on pre-operative rehabilitation was implemented and its effect was explored.

Methods: A prospective randomized controlled clinical trial was conducted, patients were recruited from January 2018 to September 2019 in this study. Patients scheduled for elective colorectal surgeries were randomly allocated to receive either standardized enhanced recovery after surgery (S-ERAS) group or enhanced recovery after surgery based on pre-operative rehabilitation (group PR-ERAS). In the group PR-ERAS, on top of recommended peri-operative strategies for enhanced recovery, formatted rehabilitation exercises pre-operatively were carried out. The primary outcome was the quality of GI recovery measured with I-FEED scoring. Secondary outcomes were quality of life scores and strength of handgrip; the incidence of adverse events till 30 days post-operatively was also analyzed.

Results: A total of 240 patients were scrutinized and 213 eligible patients were enrolled, who were randomly allocated to the group S-ERAS ($n = 104$) and group PR-ERAS ($n = 109$). The percentage of normal recovery graded by I-FEED scoring was higher in group PR-ERAS (79.0% *vs.* 64.3%, $P < 0.050$). The subscores of life ability and physical well-being at post-operative 72 h were significantly improved in the group PR-ERAS using quality of recovery score (QOR-40) questionnaire ($P < 0.050$). The strength of hand grip post-operatively was also improved in the group PR-ERAS ($P < 0.050$). The incidence of bowel-related and other adverse events was similar in both groups till 30 days post-operatively ($P > 0.050$).

Conclusions: Peri-operative rehabilitation exercise might be another benevolent factor for early recovery of GI function and life of quality after colorectal surgery. Newer, more surgery-specific rehabilitation recovery protocol merits further exploration for these patients.

Trial Registration: ChiCTR.org.cn, ChiCTR-ONRC-14005096

Keywords: Enhanced recovery after surgery; Gastrointestinal function; Peri-operatively; Rehabilitation

Introduction

Colorectal cancer and other benign diseases are the main causes of colorectal surgery worldwide.[1] The surgical wound of the intestine and peri-operative stress often cause pain and delayed recovery of the gastrointestinal (GI) function.[2] Compared with conventional care, enhanced recovery after surgery (ERAS) has been reported to improve patients' prognosis and satisfaction and shorten the length of hospitalization.[3] ERAS implementation facilitates the development of minimally invasive surgery, mitigation of surgery-related stress, nutritional support, and multimodal analgesia that contributes to superior outcomes; hence, it is a multidisciplinary approach.[4,5]

The primary goal after colorectal surgery is the early recovery of the GI function.[6] Despite a paradigm shift in the traditional peri-operative management toward early initiation of oral intake and other modalities, GI dysfunction remains one of the most common morbidities after colorectal surgery and is also the primary cause of prolonged hospital stay.[7] Post-operative gastrointestinal dysfunction (POGD) was previously described as "ileus"; however, this definition failed to recognize a broad spectrum of GI dysfunction.[8] To better classify the functional status of the GI tract after surgery, the I-FEED scoring system was used to interpret the most important aspects of GI function recovery after surgery that included a consistent objective definition of the impaired post-operative GI function.[9]

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After more than one decade of the implementation of the ERAS protocol for colorectal surgery, the incidence of POGD remains as high as 30% to 50%.[10]

During the surgical procedure, ERAS elements for colorectal surgery such as peri-operative nutritional support, multimodal analgesia, and optimization of fluid therapy have been used in practice to improve patients' functional recovery.[11,12] Other important risk factors that are yet to be dealt with include peri-operative immobility and fatigue. Previous studies have identified that inappropriate bed rest induces skeletal muscle atrophy and weakness and increases the risk of post-operative atelectasis, poor wound healing, and mortality.[13,14] Individuals confined to bed in a supine position could experience a linear decline in their capacity to exercise, a reduced cardiovascular reserve, and an increased risk of post-operative thrombosis and infection, whereas preoperative rehabilitation seemed to ameliorate these situations.[15,16] Rehabilitation exercise in healthy volunteers has also been demonstrated to exert a protective effect on the GI function, which might be attributed to the modulation of mesenteric blood flow; however, this effect has not been observed in patients receiving colorectal surgery.[17,18]

Aerobic and resistance training has been shown to improve surgical patients' muscle function and promote ambulation before and after surgery in patients with colorectal cancer.[19,20] Yet, these studies mainly evaluated the patients' functional capacity and cardiopulmonary function.[21,22] To optimize recovery of the GI function and quality of life, we explored the effect of a novel enhanced recovery protocol based on a preoperative rehabilitative exercise in patients receiving colorectal surgery. We also explored the effects of this rehabilitative recovery protocol on short-term prognoses, such as post-operative complications and mortality 30 days after surgery.

Methods

Ethical approval

The procedure of this study was conducted in accordance with the requirement of the *Declaration of Helsinki*, and the protocol of this study was approved by the Institutional Review Board of the First Affiliated Hospital of Chongqing Medical University (No. 2013-9-19).

Study design and participants

This prospective, randomized controlled study was conducted in the First Affiliated Hospital of Chongqing Medical University. Patients were recruited from January 2018 to September 2019 in this study. For the reporting of this trial, we followed the Consolidated Standards of Reporting Trials Statement (CONSORT) statement. The patients were recruited from the Department of Colorectal Surgery. The age of the patients ranged from 16 years to 85 years. Inclusion criteria for the patients were: received colorectal surgeries and signed informed consent for the follow-up study; body mass index between 18 kg/m^2 and 30 kg/m^2, and American Society of Anesthesiology (ASA) grading between I and III. Exclusion criteria were as follows: ASA grading over III; patients having signed informed consents before surgery but denied participation for the follow-up; patients with intraoperative cardiac arrest and peri-operative mental diseases; pregnancy; and patients who could not be extubated 2 h after surgery.

Sample size calculation

According to a study,[11] the estimated overall incidence of POGD is approximately 30% to 40%. A difference of 15% in the incidence of POGD between the treatment group (enhanced recovery protocol based on pre-operative rehabilitation) and the control group (standardized enhanced recovery group) was used to estimate the sample size required in the present study. Statistical power of 80% at the 0.05 significance level indicated that 100 participants were required in each group, assuming a 10% dropout rate. It also indicated that a total of at least 200 patients should be randomly allocated in a 1:1 ratio to either the standardized enhanced recovery after surgery (S-ERAS) group or the enhanced recovery after surgery based on the pre-operative rehabilitation (PR-ERAS) group. On the day of out-patient referral, the diagnosis of the disease was confirmed and surgery was scheduled. After obtaining informed consent from the patients, the patients were screened, and the eligible patients were randomly allocated into two groups. The SAS (SAS Institute Software, Cary, NC, USA) proc plan procedure was used to generate a random number. A sealed opaque envelope containing the group allocation was prepared for each patient. The envelope was not opened until the enrollment of the patient was completed.

Patient characteristics and anesthesia

Data for the following preoperative characteristics were collected by interviewing the patients before surgery: age; gender; weight; height; presurgical diagnosis; malignancy of disease; pre-operative ASA grading; pre-operative levels of hemoglobin and albumin; and New York Heart Association grading. Informed consent was obtained from the participants. Intraoperative parameters such as time of anesthesia and surgery, fluid infusion, estimated blood loss, use of opioids (transformed to equianalgesic ratio to morphine), use of nerve block agents, and dosages of reversal agents were also compared between the two groups.

General anesthesia with endotracheal intubation was administered to all the participants. For anesthesia induction, midazolam 0.02 to 0.08 mg/kg (Etomidate 0.12–0.15 mg/kg for the patients aged >65 years); propofol 2.0 to 2.5 mg/kg; sufentanil citrate 0.3–1.0 μg/kg; and vecuronium 0.08–0.12 mg/kg were administered. Anesthesia was maintained by administering 1–3% sevoflurane inhalation, continuous intravenous infusion of remifentanil 0.15–0.2 $\mu g \cdot kg^{-1} \cdot min^{-1}$, and propofol 25 to 75 $\mu g \cdot kg^{-1} \cdot min^{-1}$ by using a microperfusion pump. The anesthetic depth was kept between 50 and 60 with bispectral index monitoring. All the patients were extubated in the postanesthesia care unit after administering them flumazenil and neostigmine for full reversal to

meet the criteria for extubation. If the patients reported a score >4 in the visual analog scale of pain, rescue analgesia (intravenous parecoxib [40 mg] or intravenous flubiprofen [50 mg]) was administered before transferring the patients to surgical wards, and we further ensured that a Steward score of ≥4 was achieved in all the patients before their discharge from the postanesthesia care unit. Our perioperative care protocol suggests using hemoglobin levels of 7 g/dL as a transfusion threshold for healthy patients and 10 g/dL for patients with pulmonary or cardiac disease. Body temperature of >36°C was maintained during surgery in both groups. Post-operative pain control was achieved with intravenous opioid patient-controlled analgesia (the formula included sufentanil 75 μg with saline added up to a volume of 100 mL in total). The parameters were set as follows: a loading dose of 2 mL, followed by an infusion rate of 0.5 to 1 mL/h and a lock time of 30 min. Patient-controlled analgesia was not used for >96 h after surgery; in case the patients still complained of having pain during hospitalization, rescue analgesia was administered at the discretion of attending surgeons.

Pre-operative rehabilitation-based enhanced recovery protocol

For patients in the PR-ERAS group, a pre-operative rehabilitative exercise program was designed, which consisted mainly of formatted exercise guidance, on top of the standardized enhanced recovery protocol in the S-ERAS group [Supplementary Digital Content, 1, http://links.lww.com/CM9/A729]. On the day of scheduled elective surgery, a rehabilitation therapist explained the details of exercise to the patients by using videotapes. The patients performed these exercises at home if they could not be admitted for surgery, and as soon as they were admitted for surgery, they would perform the exercise at their bedside. The exercise program comprised three elements: (i) strengthening of the upper and lower extremities; (ii) thoracic and abdominal breathing exercises; and (iii) exercise of abdominal muscles (mainly rectus abdominis); Table 1 shows the types of movement involved. The participants were encouraged to perform this set of movements twice in the morning and afternoon, and 10 to 15 repetitions of the movements were recommended. The intensity of exercise was formatted and printed in a diary, which was dispatched to the patients to enable them to record their timing and types of exercise. The patients were advised to follow the protocol for exercise and were followed up (telephonically or face-to-face) every day by the rehabilitation therapist. Hence, the exercise was performed under a close supervision but not designated to a specific intensity (such as 25 W or 50 W) and was individualized on the basis of patients' tolerance. Patients were also encouraged to resume rehabilitation exercise after surgery under the guidance of the rehabilitation therapist. If the patients complained of any discomfort (such as heart rate >100/min, chest tightness, and dizziness), the rehabilitation exercise program was suspended, and the rehabilitation therapist was consulted. Supplementary Figure 1, http://links.lww.com/CM9/A729 describes the duration and conduction of exercise.

Outcome assessments

The primary outcome of this study was the early recovery of the GI function, which included time to recovery and I-FEED scores.[11] The I-FEED system classified the early recovery of the GI function after surgery into three grades on the basis of the total score: a score of 0–2 was considered normal; a score of 3–5 indicated post-operative gastrointestinal intolerance (POGI); and a score of ≥6 indicated POGD. Thus, the higher the score, the worse was the GI function [Supplementary Table 1, http://links.lww.com/CM9/A729]. Secondary outcomes included the quality of recovery score (QOR-40).[23] The 40-item QOR-40 provided a total score and subscores in five dimensions, namely patient support; comfort; emotions; life ability; and physical well-being, and pain, at three-time points, the day scheduled for surgery, 72 h after surgery, and 30 days after surgery. The strength of handgrip was measured at three-time points, namely the day scheduled for surgery; the day before surgery, and 72 h after surgery. Dominant handgrip strength was measured using a hydraulic dynamometer (Saehan Corporation, Masan, Korea).[24] During the measurement, the patients were instructed to remain seated on a chair, with a straight back and no support for the arms, shoulder adducted and neutrally rotated, elbow flexion at 90°, forearm and wrist in a neutral position between 0° and 30° of extension and between 0° and 15° of ulnar deviation. The strength was

Table 1: Preoperative rehabilitation exercise regime.

Exercise elements	Types of Movement
Upper and lower extremities	Hands squeeze and relaxation
	Biceps flexion and extension
	Shoulder abduction
	Ankle rotation and pronation
	Quads contraction and relaxation
Thoracic breathing	Chest wall expansion
	Deep inhalation and slow exhalation with chest wall
	Deep inhalation and gentle cough
Abdominal breathing	Deep inhalation and slow exhalation with abdominal wall
Abdominal muscles exercise	Abdominal curl
	Pelvic muscle contraction
	Lumbar extension and relaxation

measured thrice, and the arithmetic mean of the two highest readings of the dominant hand was used for the analysis.

The patients were followed up for adverse events until 30 days after surgery. Bowl-related events included any episode of nausea or vomiting, anastomotic leakage, and unexpected reoperation and replacement of the nasogastric tube after initial removal following surgery. Other major adverse events included post-operative pulmonary infection, deep vein thrombosis, acute coronary syndrome, stroke, poor wound healing, and all-cause death. The patients were assessed by anesthesiologists blinded to the allocation and treatment of the patients during the pre-operative and post-operative periods. The total length of hospital stay was calculated as the hours of hospitalization after surgery or for re-admission because of post-operative complications. The intraoperative and post-operative opioid consumptions were calculated as an equianalgesic ratio to morphine.[25]

Statistical methods

Data were entered using Epidata 3.1 (Epidata institution, Denmark) and statistically analyzed using SPSS 21.0 for Windows (SPSS Inc, Chicago, IL, USA). The data of all the variables were analyzed descriptively. Measurement data (such as I-Feed scorings and muscle strength) are presented as mean ± standard deviation and range (interquartile range), whereas the enumeration data (such as post-operative mortality in hospital, incidence of post-operative thrombosis, and post-operative pulmonary complication) are presented as the total size of sample and percentage. Other statistical analyses were performed using the Student's *t*-test, Wilcoxon rank-sum test, Kruskal-Wallis test, and chi-square test according to data distribution. The principle of the intention-to-treat analysis was applied for the data analysis. A P value of < 0.050 was considered statistically significant.

Results

A total of 223 patients were screened for enrollment after obtaining informed consent, and 10 patients not meeting the eligibility criteria or denying participation were excluded. The remaining participants were included and randomized into the PR-ERAS ($n = 109$) and S-ERAS ($n = 104$) groups; all the patients in the two groups were included in the intention-to-treat analysis. The duration of rehabilitation exercise in the PR-ERAS group before surgery was 14.3 ± 5.2 days. Neither surgery was postponed or canceled nor the case of fall or injury was reported because of exercise in any of the patients in the PR-ERAS group. The workflow of this study was presented as a diagram following CONSORT Statement [Figure 1]. No statistical difference was found in the pre-operative characteristics, intraoperative management, and post-operative analgesia between the two groups [Table 2].

Compliance with enhanced recovery measure

The compliance rate for every element of the peri-operative rehabilitation recovery protocol in both groups ranged from 92% to 100%; 1 patient did not follow the instructions for exercise, which was considered as the protocol violation. Compliance rates were not found to vary significantly with other elements such as oral intake of carbohydrates, blood glucose control, and multimodal management of post-operative pain [$P > 0.050$; Figure 2].

I-FEED scorings and time to recovery

According to the I-FEED scoring system, normal recovery of the GI function was reported in 78.9% (86/109) patients in the PR-ERAS group and 64.4% patients (87/104) in the S-ERAS group ($P = 0.019$) during the follow-up. A statistically significant difference was also noted in the incidence of POGI (10.1% [11/109] and 23.1% [24/104] in the PR-ERAS and S-ERAS groups, respectively, $P = 0.011$); however, no significant difference was observed in the incidence of POGD between the groups (11.0% [12/109] and 12.5% [13/104] in the PR-ERAS and S-ERAS groups, respectively, $P = 0.898$). The value of I-FEED scoring was found to be statistically similar between the two groups, and the medium and interquartile range for the two groups was 1 (0–3) and 2 (1–3), respectively ($P = 0.058$) [Figure 3].

Quality of life and dominant handgrip strength

Before the scheduled anesthesia and surgery, no significant difference between the groups was observed in the QOR-40 scores for pain, emotional status, psychological support, ability to perform activities of daily life, and physical well-being. At 72 h after surgery, the subscores for life ability and physical well-being were found to be significantly superior in the PR-ERAS group compared with those in the S-ERAS group (19.6 ± 3.1 *vs.* 15.7 ± 2.8, $P = 0.032$ and 43.4 ± 5.3 *vs.* 39.2 ± 6.1, $P = 0.029$, respectively). No statistical difference was found between the two groups in five dimensions 30 days after surgery, although the average scores for physical well-being and emotional status of all the patients from the day of scheduled surgery to 30 days after surgery were found to increase (52.8 ± 2.0 *vs.* 49.1 ± 3.3, $P = 0.041$ and 38.3 ± 4.1 *vs.* 27.8 ± 2.5, $P < 0.010$, respectively) [Figure 4]. The strength of dominant hand grip in the PR-ERAS group was found to be stronger than that in the S-ERAS group after exercise (30.1 ± 5.4 kg *vs.* 25.4 ± 4.9 kg on the day before surgery, $P = 0.037$; and 25.7 ± 4.8 kg *vs.* 22.3 ± 8.2 kg, $P = 0.018$) [Figure 5].

Major post-operative complications and length of hospital stay

No statistical difference was found between the two groups with respect to the incidence of bowel-related adverse events at the end of post-operative 30-day follow-up (7.1% and 10.8% in the PR-ERAS and S-ERAS groups, respectively, $P = 0.276$). The incidence of nonbowel-related adverse events 30 days after surgery was also found to be statistically similar between the two groups (5.8% and 6.7% in the PR-ERAS and S-ERAS groups, respectively, $P = 0.709$). The chronological patterns of these events were plotted using the Kaplan-Meier analysis [Figures 6 and 7]. The total length of hospital stay after surgery was 58.4 h (interquartile range [IQR]: 41.6–69.8)

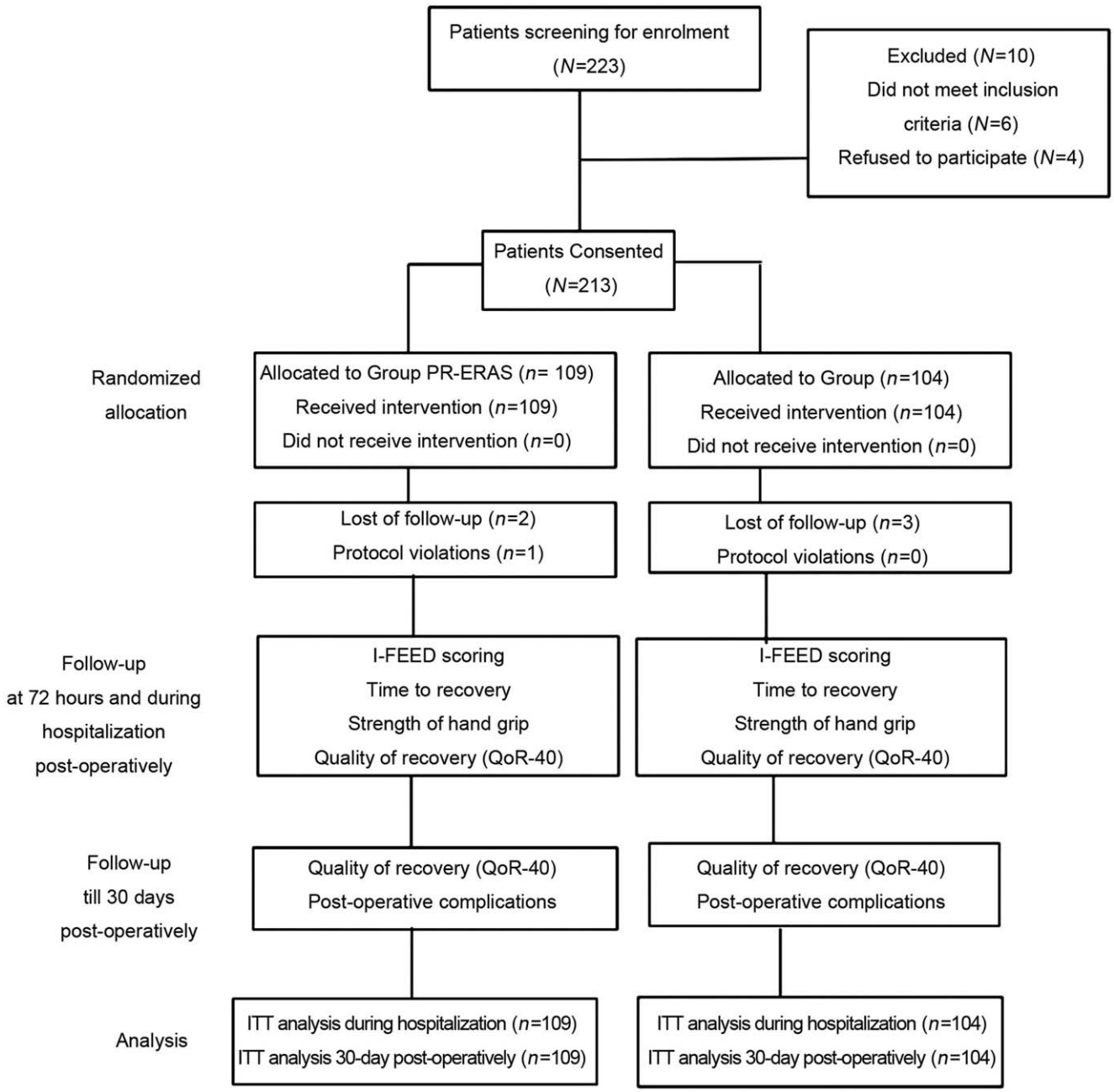

Figure 1: Study flow diagram. ERAS: Enhanced recovery after surgery; ITT: intent-to-treat; PR-ERAS: Enhanced recovery after surgery based on pre-operative rehabilitation; S-ERAS: Standardized enhanced recovery after surgery.

and 62.5 h (IQR: 43–73.4) in the PR-ERAS and S-ERAS groups, respectively ($P = 0.061$).

Discussion

The results of this study demonstrated that the additional preoperative rehabilitation exercise might be another benevolent factor for early recovery of the GI function after colorectal surgeries in the context of the standardized enhanced recovery protocol. Other possible confounding factors, such as the use of peri-operative opioids and neostigmine (it was used as a reversal for muscle relaxant but also might be a detrimental factor for post-operative nausea) and anesthesia time, were also found to be comparable between the two groups.[26] Although no statistical difference was found in the I-FEED scores between the two groups, the percentage of early "normal" recovery of the post-operative GI function was still clinically and statistically improved in patients who participated in the pre-operative rehabilitation program. I-FEED scoring is an emerging tool for the early measurement of the GI function after colorectal surgery; in contrast, "ileus" is usually diagnosed 3 days or 4 days after surgery.[9] Additional pre-operative rehabilitation exercise also did not adversely affect the 30-day recovery of the GI function after surgery, as the incidence of bowel-related complications was similar and low in both groups. Complications such as fall, myocardial ischemia, and

Table 2: Peri-operative characteristics of patients scheduled for elective colorectal surgeries ($n = 213$).

Pre-operative characteristics	PR-ERAS group ($n = 109$)	S-ERAS group ($n = 104$)	*P*
Age (year)	63.0 ± 2.8	62.8 ± 3.1	0.198
Male	65 (59.6)	53 (50.9)	0.345
Body mass index	22.3 ± 2.3	22.6 ± 2.4	0.216
NYHA Grade II-III	51 (46.8)	48 (46.2)	0.208
Pre-operative hemoglobin (g/L)	117 ± 28	118 ± 31	0.502
Pre-operative albumin (g/L)	39.5 ± 6.0	38.7 ± 6.0	0.410
Tumor			0.091
Malignant diseases	107 (98.2)	103 (99.0)	
Non-malignant diseases	2 (1.8)	1 (0.9)	
Minimally invasiveness			0.451
Laparoscopic surgery	109 (100)	104 (100)	
Open surgery	0	0	
ASA Grading			0.267
Grade I	6 (5.5)	9 (8.7)	
Grade II	45 (41.3)	43 (41.3)	
Grade III	58 (53.2)	52 (50.0)	
Types of surgery			0.941
Hemicolectomy	71 (65.1)	70 (67.3)	
Total colectomy	25 (22.9)	22 (21.2)	
Sigmoid resection	13 (11.9)	12 (11.5)	
Intra-operative characteristics			
Time of anesthesia (min)	223.4 ± 81.6	231 ± 90.4	0.109
Time of surgery (min)	192.7 ± 83.5	196.1 ± 89.4	0.101
Intra-operative cystalloid (mL)	596.4 ± 271.6	574.4 ± 303.7	0.267
Intra-operative colloid (mL)	485.0 ± 187.4	501.0 ± 204.6	0.361
Estimated blood loss (mL)	30 (10–50)	30 (10–50)	0.551
Intraoperative equianalgesic ratio to morphine	4.5 ± 1.6	4.3 ± 1.8	0.084
Transversus abdominis plane block	109 (100)	104 (100)	Non-applicable
Flumazenil for reversal (mg)	0.32 ± 0.13	0.35 ± 0.16	0.072
Neostigmine for reversal (mg)	1.60 ± 0.73	1.50 ± 0.80	0.185
Post-operative characteristics			
Patient controlled analgesia	106 (97.2)	101 (97.1)	0.964
Post-operative equianalgesic ratio to morphine	3.70 ± 1.62	3.90 ± 1.58	0.152

Data are presented as *n* (%), mean ± standard deviation or median (interquartile range). PR-ERAS: Enhanced recovery after surgery based on pre-operative rehabilitation; S-ERAS: Standardized enhanced recovery after surgery; NYHA: New York Heart Association; ASA: American Society of Anesthesiologists.

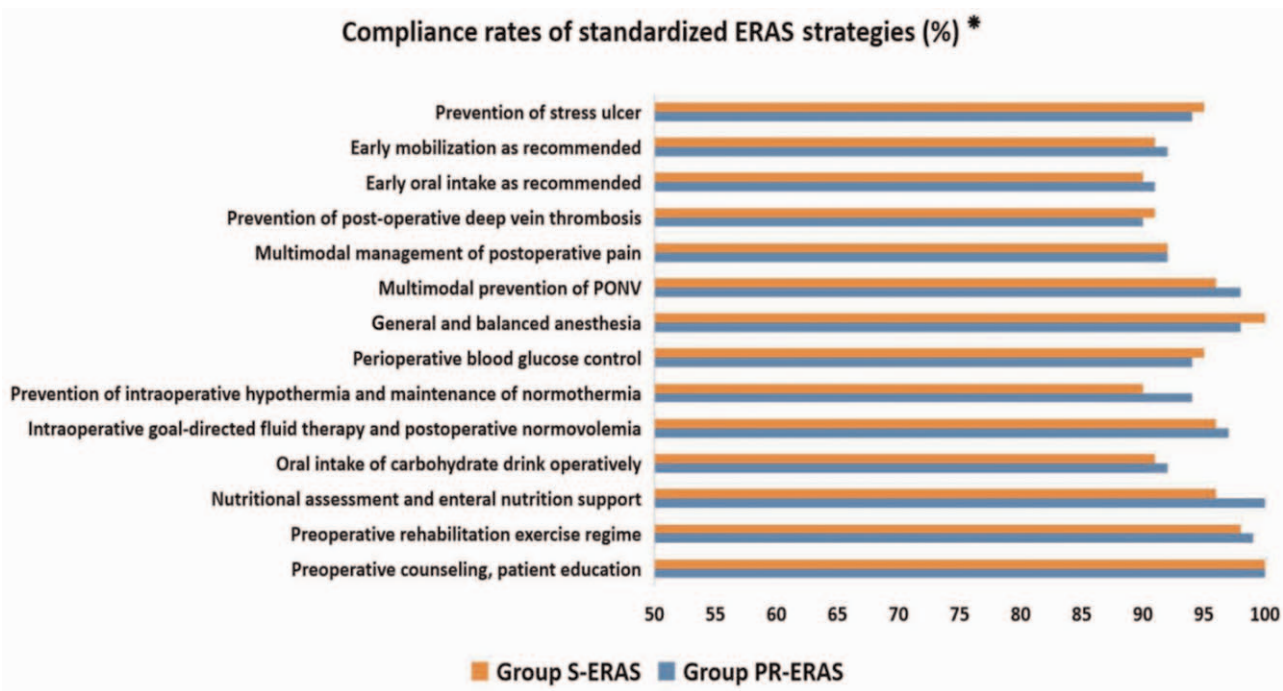

Figure 2: Compliance rates of standardized ERAS strategies. *No statistical difference was found between the two groups ($P > 0.050$). ERAS: Enhanced recovery after surgery; PR-ERAS: Enhanced recovery after surgery based on pre-operative rehabilitation; S-ERAS: Standardized enhanced recovery after surgery.

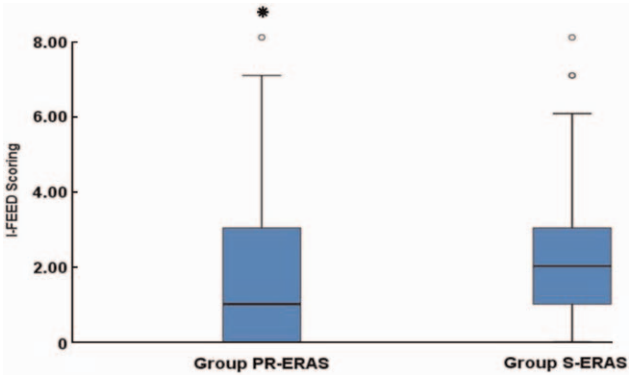

Figure 3: I-FEED scoring after colorectal surgery. *No statistical difference was found between the two groups ($P > 0.050$). ERAS: Enhanced recovery after surgery; PR-ERAS: Enhanced recovery after surgery based on pre-operative rehabilitation; QoR: Quality of recovery score; S-ERAS: Standardized enhanced recovery after surgery.

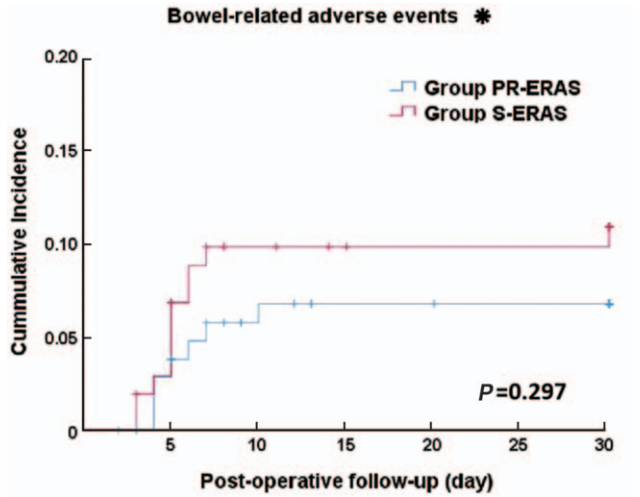

Figure 6: Bowel-related adverse events till 30-days post-operatively. *No statistical difference was found between the two groups ($P > 0.050$). ERAS: Enhanced recovery after surgery; PR-ERAS: Enhanced recovery after surgery based on pre-operative rehabilitation; S-ERAS: standardized enhanced recovery after surgery.

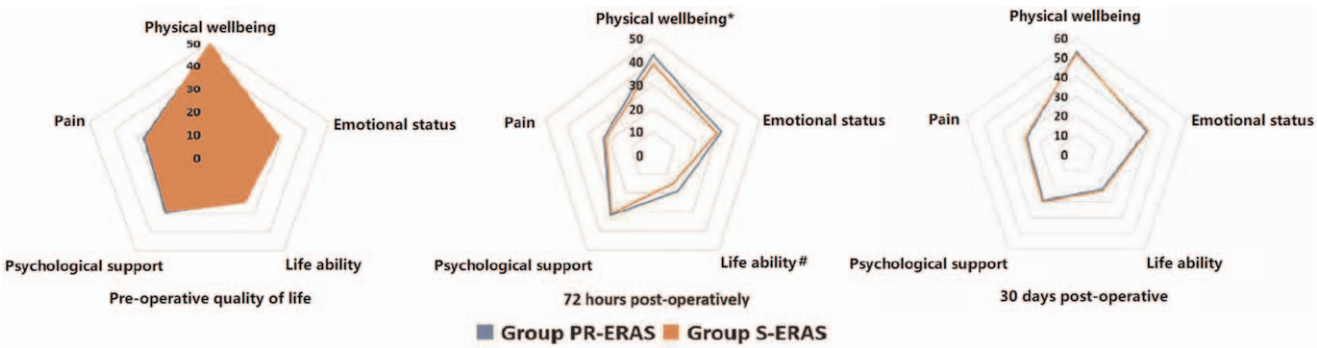

Figure 4: Pre-operative and post-operative quality of life (QOR-40). *Compared with group S-ERAS for physical well-being subscore ($P > 0.050$). # Compared with the group S-ERAS for life ability subscore ($P > 0.050$). PR-ERAS: Enhanced recovery after surgery based on pre-operative rehabilitation; QOR: Quality of recovery score; S-ERAS: Standardized enhanced recovery after surgery.

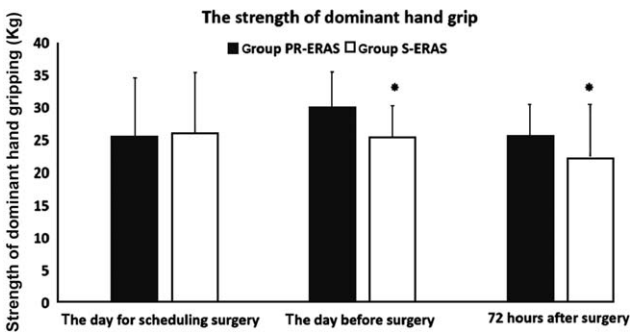

Figure 5: The strength of dominant hand grip. *Compared with the group PR-ERAS ($P < 0.050$). PR-ERAS: Enhanced recovery after surgery based on pre-operative rehabilitation; S-ERAS: Standardized enhanced recovery after surgery.

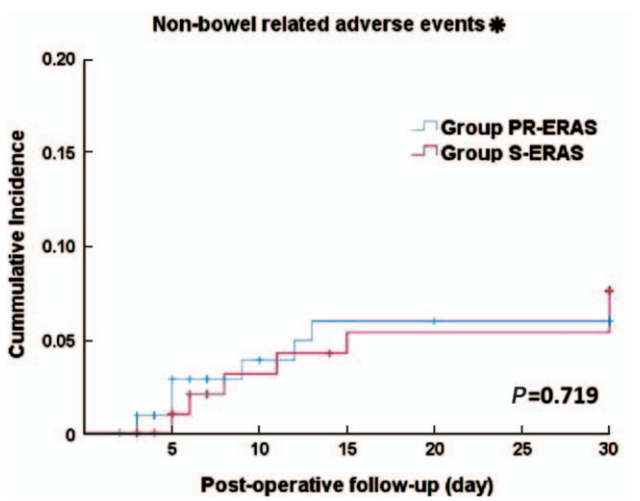

Figure 7: Non-bowel-related adverse events till 30-days post-operatively. *No statistical difference was found between the two groups ($P > 0.050$). ERAS: Enhanced recovery after surgery; PR-ERAS: Enhanced recovery after surgery based on pre-operative rehabilitation; S-ERAS: Standardized enhanced recovery after surgery.

injury were not reported in patients following the pre-rehabilitation protocol, suggesting that it is a safe and feasible approach for improving the function of the GI function after colorectal surgery.

The accelerated and early recovery of the GI function after surgery with our protocol could be explained by several reasons. Prolonged bed rest before surgery increases the risk of ileus development in patients after surgery. The rehabilitation exercise in this study was designed by combining dynamic exercise (such as shoulder abduction and ankle movement), isometric exercise (breathing exercise and hands squeeze), and resistance exercise (quads contraction and relaxation, abdominal curl, and lumbar movement) of mild intensity, all of which might have played a role in pre-conditioning the mesenteric flow to surgical stress; therefore, it may reduce the risk of impaired anastomotic blood supply and promote subsequent healing after surgery.[27,28] Pre-operative exercise has been shown to improve the cardiorespiratory function, which is also a beneficial factor for recovery of the GI function.[29] However, the incidence of 30-day bowel-related complications was similar in the two groups, which suggests that the perioperative standardized enhanced recovery protocol exerted a protective pre-conditioning effect and that a 2-week pre-operative exercise might not be effective for long-term improvement of the GI function after colorectal surgery.

Another prominent finding of this study was that the preoperative rehabilitation improved the early life of quality as the results of self-evaluated questionnaire (QOR-40) revealed. The QOR-40 is commonly used to evaluate patients' surgical recovery in five dimensions 72 h after surgery; two domains (life ability and physical well-being) were markedly improved in patients in the pre-operative rehabilitation group. These two domains mainly calibrate patients' appetite, sleep, the ability of combing, teeth brushing, and willingness to communicate.[23] These results further affirmed the role of pre-operative rehabilitation in accelerating early recovery of the GI function and functional performance in patients after surgery. Evidence also indicates that the physical activity benefits patients with chronic and surgical conditions by preserving the declining cognitive functions, facilitating wound healing, and improving the muscular performance of extremities.[29-31] Poor grip recovery may be related to a high risk of post-operative complications within 30 days of discharge after cardiac surgery.[32,33] Maintenance of the strength of hand grip by exercise also benefits patients by helping them resume their daily activity such as sitting, eating, and walking with aid after surgery, as demonstrated by the improved time to recovery and patients' quality of life in the present study. Caution must be exercised to prevent exercise-related injury and complications, especially in elderly and weak patients.[22,34] A more specific and potent rehabilitation program is yet to be designed to reduce long-term complications in these patients. In addition to pre-rehabilitation exercise, clinicians should strive to promote patients' compliance by using other modalities, such as pre-operative counseling, multimodal analgesia with less opioid use, and improved nutrition status to promote recovery after colorectal surgery.[35,36,37]

This study has some limitations. First, it did not quantify the change in mesenteric flow in the peri-operative period through radiological examination (Doppler and magnetic resonance imaging), and the serum or blood markers of colon inflammation were also not measured. Second, the strength of other core muscles, such as respiratory and abdominal muscles, was not investigated; the correlation of the strength of these muscles with the recovery of quality of life remains unknown. Third, tumor grading and pre-operative chemotherapy, which were potentially confounding factors for the effectiveness of this program, were not evaluated. Minimally invasive surgeries were performed in 99% of the surgical cohort in this study. Therefore, the effectiveness and safety of the prehabilitation-based enhance recovery protocol in open colorectal surgery in terms of type, duration, and intensity are yet to be assessed.

In sum, the pre-operative rehabilitation recovery protocol helped accelerate early recovery of the GI function after colorectal surgery. It also helped in improving the patients' early quality of life and functional muscle strength after surgery compared with the standardized enhanced recovery protocol. Designing and exploration of an optimal rehabilitation recovery protocol for improving patients' short-term and long-term recovery after colorectal surgery is warranted.

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Conflicts of interest

None.

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