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Comparison of Outcomes between Obese and Non-Obese Patients in a Colorectal Enhanced Recovery After Surgery (ERAS) Program: A Single-Center Cohort Study

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Keywords

Obesity · Enhanced Recovery After Surgery · Colorectal surgery

Abstract

Introduction: Obese patients are considered at increased risk of postoperative adverse events after colorectal surgery. ***Objective:*** The objective of the present study was to compare postoperative outcomes between obese and non-obese patients undergoing elective colorectal surgery in an Enhanced Recovery After Surgery (ERAS) program. ***Methods:*** A retrospective analysis of a prospective cohort including patients who underwent elective colorectal surgery and were included in an ERAS protocol between February 2014 and December 2017 at Geneva University Hospital, Geneva, Switzerland, was performed. Postoperative outcomes of obese and non-obese patients were compared. ***Results:*** Data of 460 patients were analyzed, including 374 (81%) non-obese and 86 (19%) obese patients. Overall, there was no difference in postoperative outcomes between the 2 groups. Among patients undergoing oncologic surgery, obese subjects had a significantly higher rate of conversion to laparotomy (11.9 vs. 2.1%, $p = 0.01$) and longer time until return of bowel function (2.38 vs. 1.98 days, $p = 0.03$), without increased morbidity or longer length of stay. ***Conclusion:*** Obese and non-obese patients had similar postoperative outcomes after elective colorectal surgery with ERAS management. ERAS can potentially reduce the increased morbidity usually observed in obese patients following elective colorectal surgery.

Introduction

Obesity has reached epidemic proportions in numerous countries across the world [1]. According to the World Health Organization global data, 39% of adult men and women were overweight, as defined by a Body Mass Index (BMI) of ≥25 kg/m^2; 11% of men and 15% of women were obese (BMI ≥ 30) in 2014 [2]. These figures are even more alarming in western countries such as the USA, which present an overall prevalence of obesity of 39.8% in its adult population [3]. Excess weight and excess body fat result in numerous obesity-related comorbidities, which notably affect the cardiovascular, metabolic, musculoskeletal, and respiratory systems [4, 5].

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Furthermore, obese patients have a higher incidence of postoperative adverse events such as thromboembolic disease, pneumonia, and myocardial infarction [6, 7]. Some authors, however, argue that obese patients can have similar or paradoxically better postoperative outcomes than non-obese patients and suggest the existence of an obesity-related protective factor [8–10]. In the field of colorectal surgery, several studies have shown increased rates of surgical site infections, fascial dehiscence, stomal complications, and even anastomotic leaks in patients with BMI ≥ 30 [11–14]. Other authors found worse outcomes after colorectal surgery in patients with BMI < 30 but increased visceral fat volume and pleaded for a new definition of obesity in this context [15–17]. Sarcopenia has also been correlated with visceral obesity and poorer outcomes after abdominal surgery [18, 19]. Enhanced Recovery After Surgery (ERAS) programs have been shown to decrease morbidity, shorten length of hospital stay (LOS), and diminish costs in both obese and non-obese patients in various surgical fields, including colorectal surgery [20–24]. The objective of the present study was to compare the postoperative outcomes between obese and non-obese patients enrolled in a colorectal surgery ERAS program. Our hypothesis was that obese patients undergoing colorectal surgery would have similar outcomes when compared with non-obese patients in this setting.

Methods

Study Design and Setting

This study was a single-center, retrospective analysis of a prospective cohort of patients who underwent colorectal surgery with ERAS management between February 2014 and December 2017 at Geneva University Hospital, Geneva, Switzerland.

Participants

The inclusion criteria in the study were age ≥18 years, elective colon and/or rectum resection, and enrollment in the ERAS program. The exclusion criteria were emergency colorectal surgery and ineligibility for the ERAS program, which included dementia, inability to speak and understand French or English, combined surgical procedures, and intraoperative chemotherapy.

The ERAS Protocol

All patients were given detailed explanations and instructions about the ERAS program preoperatively. Their Nutrition Risk Screening (NRS) score was assessed, and oral nutritional supplements were prescribed if their score was ≥3. Complete blood count, basic metabolic panel, coagulation studies, and nutritional parameters including albumin, prealbumin, and iron studies were also performed. Any organ dysfunction and/or deficiency was addressed and, if possible, treated accordingly before surgery.

A minimally invasive approach was systematically favored for the surgical procedure. No mechanical bowel preparation was given for colonic resection, while a mechanical bowel preparation was given to patients planned for low rectal resection. Patients drank a liquid carbohydrate load 3 hours before surgery. Multimodal pain management was provided by the anesthesia team favoring an intravenous lidocaine protocol. A single dose of prophylactic antibiotics was given in the hour preceding incision. During the procedure, goal-directed fluid therapy principles were used and special attention was given to normothermia maintenance. Intra-abdominal drainage was avoided whenever possible.

If present, nasogastric tubes were removed at the end of the procedure. Patients received clear liquids and were actively mobilized as soon as they were awake. Opioid-sparing analgesic and antiemetic regimens were systematically provided.

Collected Data and Outcomes

Baseline characteristics such as age, gender, and BMI were collected. Clinical data included comorbidities, NRS score, American Society of Anesthesiology (ASA) score, preoperative laboratory values, presence of malignancy, and types of procedures and approaches (laparoscopic or open). Laparoscopic procedures which required conversion to laparotomy were counted as open procedures.

The primary outcome was postoperative morbidity, as defined by the Dindo and Clavien classification [25], with a distinction between severe (grade ≥ III) and non-severe (grade < III) complications. Secondary outcomes were operation duration, LOS, number of conversions to laparotomy, total opioid consumption, time to return of bowel function, and utilization of intraoperative drainage. Readmissions and complications were tracked until December 2018, to ensure a minimum follow-up of 1 year after surgery for all patients.

Assessment of Visceral Fat Volume and Skeletal Muscle Mass

Several studies have shown suboptimal correlation between BMI and other body compartment indicators influencing postoperative outcomes such as visceral fat volume (VFA) and skeletal muscle mass (SMA) [15–19]. Since categorizing patients according to BMI alone could lead to potential bias, preoperative computed tomography (CT) of all patients were reviewed to calculate VFA and SMA. These 2 surrogate markers have been shown to correlate well with visceral fat volume and skeletal muscle mass, respectively [15, 26–29]. VFA and SMA were measured with a standardized CT reading technique on a single axial slice at the L3 vertebra level using the widely available OsiriX software (Pixmeo, Geneva, Switzerland). VFA was calculated using semi-automated tissue demarcation with Hounsfield units between −150 and −50 to isolate visceral adipose tissue, as described in previous studies [28, 30, 31]. SMA was calculated using the same technique with Hounsfield units between −30 and +150 to isolate skeletal muscle [28, 31, 32]. Integrated software computation was used to determine the area of selected surfaces. Visceral obesity was defined by VFA > 100 cm^2 and sarcopenia by SMA < 110 cm^2 [15, 28, 31].

Statistical Analysis

Data were analyzed by dividing patients into a cohort with and without obesity (BMI ≥ 30 and <30, respectively). The cohort of patients with obesity was further divided into 2 groups with severe and non-severe obesity (BMI ≥ 35 and 30–34.9, respectively). Sub-

Table 1. Baseline and preoperative clinical characteristics

	Total cohort			Cohort of obese patients		
	BMI < 30 (*n* = 374)	BMI ≥ 30 (*n* = 86)	*p* value	BMI 30–34.9 (*n* = 66)	BMI ≥ 35 (*n* = 20)	*p* value
Age (mean ± SD), years	63.5 (14.3)	63.1 (14.1)	0.881[a]	64.4 (14.6)	59.1 (11.6)	0.077[a]
Gender, female:male	194:180	36:50	0.119[b]	25:41	11:9	0.202[b]
BMI (mean ± SD), kg/m^2	24.4 (3.28)	33.5 (3.4)	<0.001[a]	31.9 (1.44)	38.8 (2.55)	<0.001[a]
Smoker, *n* (%)	163 (43.6)	41 (47.7)	0.548[b]	34	7	0.214[b]
Coronary artery disease, *n* (%)	64 (17.11)	24 (27.9)	**0.032**[b]	24	0	**0.001**[b]
Diabetes mellitus type II, *n* (%)	37 (9.9)	17 (19.8)	**0.015**[b]	10	7	0.062
Hypertension, *n* (%)	43 (11. 5)	20 (23. 3)	**0.008**[b]	12	9	0.067
Chronic renal failure, *n* (%)	29 (7.8)	17 (19.8)	**0.002**[b]	15	2	0.338[b]
NRS score (mean ± SD)	1.66 (1.50)	0.74 (0.45)	0.841[a]	1.69 (1.43)	1.20 (1.03)	0.161[a]
ASA score (mean ± SD)	2.06 (0.46)	2.19 (0.45)	0.097[a]	2.18 (0.46)	2.20 (0.41)	0.936[a]
Need for preoperative oral supplements, *n* (%)	61 (16.3)	7 (8.1)	0.063[b]	7	0	0.193[b]
Albumin (mean ± SD), g/dL	41.7 (16.4)	40.4 (4.4)	0.889[a]	40.7 (4.5)	39.5 (4.2)	0.289[a]
Prealbumin (mean ± SD), mg/L	264.1 (71.8)	267.9 (56.0)	0.944[a]	268.0 (58.5)	267.7 (48.5)	0.857[a]
Hemoglobin (mean ± SD), g/L	134 (18.5)	136.4 (16.0)	0.418[a]	136.6 (16.8)	135.5 (13.3)	0.653[a]
Surgery for oncologic disease, *n* (%)	188 (50. 3)	43 (50)	0.999[b]	34	9	0.799[b]
Surgery for inflammatory bowel disease, *n* (%)	17 (4.5)	1 (1.2)	0.218[b]	1	0	0.999[b]
Crohn's disease, *n*	15	1	0.326[b]	1	0	0.999[b]
Ulcerative colitis, *n*	2	0	0.999[b]	0	0	NA
Surgery for other benign disease, *n* (%)	169 (45.2)	42 (48.8)	0.551[b]	31	11	0.613[b]
Endoscopically unresectable benign adenomas, *n*	30	8	0.667[b]	5	3	0.318[b]
Diverticular disease, *n*	123	33	0.377[b]	25	8	0.999[b]
Others, *n*	16	1	0.218[b]	1	0	0.999[b]

p values in bold indicate statistically significant result. SD, standard deviation; NRS, Nutrition Risk Screening; ASA, American Society of Anesthesiologists. [a] Mann-Whitney test. [b] Fisher's exact test.

group analysis was additionally performed by considering only patients undergoing colorectal resection for malignancy.

Correlation between BMI and VFA was assessed by comparing patients with and without obesity according to each definition (BMI ≥ 30 and VFA > 100 cm^2, respectively). Data were subsequently analyzed by dividing patients according to VFA (patients with and without visceral obesity) and SMA (patients with or without sarcopenia) cut-offs mentioned above. Results obtained through BMI, VFA, and SMA stratifications were compared to detect varying statistically significant differences between groups of patients.

All statistical analyses were performed using the PASW software (IBM Corporation, Armonk, NY, USA). Primary and secondary outcomes were compared between groups and subgroups using 2-tailed Mann-Whitney and Fisher's exact tests where appropriate. A p value ≤ 0.05 was considered statistically significant.

Ethical and Quality Considerations

Since this retrospective study was performed on an already existing and anonymized database, there was no need for institutional review board (IRB) approval according to local policies. The creation of the prospective database for research purposes had been previously approved by the IRB, and informed consent had been obtained from all patients at that time. The reporting of the trial was based on the guidelines of the Strengthening The Reporting of Observational Studies in Epidemiology (STROBE) [33] statement.

Results

A total of 460 patients were included in the analysis, including 374 patients (81%) with BMI < 30 and 86 (19%) patients with BMI ≥ 30. Among the latter group, 20 patients had a BMI of ≥35, representing 4% of the total cohort and 23% of the cohort of obese patients.

Demographic and clinical characteristics are reported in Table 1. Baseline variables were similar between groups, except prevalence of ischemic heart disease, hypertension, diabetes mellitus, and chronic kidney failure, which were significantly more prevalent in obese patients. There were no significant differences in these parameters between patients with severe and non-severe obesity. Surgeries for diverticular disease included both elective sigmoidectomies and Hartmann's reversals. Other surgeries for benign disease included colon resections for recurrent volvulus, Ogilvie's syndrome, and stricture due to chronic ischemia.

Among patients with BMI < 30, 57 (15.2%) had visceral obesity (VFA > 100 cm^2) and 24 (6.4%) had sarco-

Table 2. Surgical approaches and types of intervention

	Total cohort			Cohort of obese patients		
	BMI < 30 (*n* = 374)	BMI ≥ 30 (*n* = 86)	*p* value[a]	BMI 30–34.9 (*n* = 66)	BMI ≥ 35 (*n* = 20)	*p* value[a]
Approach, *n* (%)						
Laparoscopy	311 (83.2)	69 (80.2)	0.529	54 (81.8)	15 (75)	0.529
Laparotomy (including conversions to laparotomy)	63 (16.8)	17 (19.8)	0.529	12 (18.2)	5 (25)	0.999
Type of colorectal procedure, *n* (%)						
Left hemicolectomy	20 (5.3)	4 (4.7)	0.999	4 (6.1)	0	0.569
Right hemicolectomy	78 (20.9)	22 (25.6)	0.384	16 (24.2)	6 (30)	0.575
Sigmoidectomy	144 (38.6)	39 (45.3)	0.272	29 (43.9)	10 (50)	0.798
High anterior resection	2 (0.5)	1 (1.1)	0.463	0	1 (5)	0.233
Low anterior resection	51 (13.6)	8 (9.3)	0.483	7 (10.6)	1 (5)	0.675
Hartmann's colostomy reversal	50 (13.4)	9 (10.5)	0.592	7 (10.6)	2 (10)	0.999
Abdominoperineal amputation	11 (2.9)	3 (3.5)	0.732	3 (4.5)	0	0.999
Ileocaecal resection	4 (1.1)	0	0.999	0	0	NA
Transverse colectomy	7 (1.9)	0	0.357	0	0	NA
Transanal resection	2 (0.5)	0	0.999	0	0	NA
Subtotal colectomy	2 (0.5)	0	0.999	0	0	NA
Total proctocolectomy	1 (0.3)	0	0.999	0	0	NA
Others	2 (0.5)	0	0.999	0	0	NA

[a] All *p* values calculated using Fisher's exact test.

penia (SMA < 110 cm^2). Among patients with BMI ≥ 30, 79 (91.9%) had visceral obesity and 5 (5.8%) had sarcopenia. All patients with BMI ≥ 35 had visceral obesity.

All surgeries were performed by board certified general surgeons. An attending surgeon specialized in colorectal surgery with at least 5 years of experience in this field was present during all cases, either as a primary surgeon or as a teaching assistant.

There was no difference between groups in terms of surgical approach (laparoscopic vs. open) and type of surgical procedures (Table 2). Overall, 82.6% of procedures (380/460) were successfully performed laparoscopically.

Primary and secondary outcomes obtained by BMI stratification can be seen in Table 3. The overall rate of conversion to laparotomy was 3.9% (18/460). There were no statistically significant differences between obese and non-obese patients in terms of primary and secondary outcomes. Both groups had similar rates of overall and severe complications, with obese patients showing non-significant trends toward longer operation duration (249.2 vs. 236.1 min, $p = 0.18$), higher rate of conversion to laparotomy (8 vs. 3.7%, $p = 0.12$), higher opioid consumption (24.7 vs. 21.5 mg, $p = 0.18$), faster diet progression to solid food (1.2 vs. 1.5 days, $p = 0.12$), and longer time until return of bowel function (2.2 vs. 2.0 days, $p = 0.14$). There were 7 anastomotic leaks among non-obese patients and none in the obese cohort (1.8 vs. 0%, $p = 0.36$). Wound dehiscence (1.1 vs. 1.2%, $p > 0.99$) and readmission rates (3.7 vs. 2.3%, $p = 0.75$) were similar in both groups. Reasons for readmission in the non-obese cohort were diarrhea or high-output ileostomy with dehydration ($n = 6$), anastomotic leak ($n = 2$), surgical site infection ($n = 2$), constipation ($n = 1$), ileus ($n = 1$), and central venous access chamber infection ($n = 1$). In the obese cohort, one readmission was due to pneumonia and one due to hematochezia. The subgroup analysis within the cohort of obese patients (BMI 30–34.9 vs. BMI ≥ 35) did not identify differences in terms of primary and secondary outcomes.

Data analysis by VFA stratification showed similar primary and secondary outcomes between patients with and without visceral obesity. There was no statistically significant difference compared with results obtained by BMI stratification. Among the 7 anastomotic leaks found in patients with BMI < 30, 4 patients had visceral obesity (2.9 vs. 0.9%, $p = 0.20$). Patients with visceral obesity showed non-significant trends toward longer operation duration (262.2 vs. 231.2 min, $p = 0.17$), higher rate of conversion to laparotomy (6.6 vs. 2.8%, $p = 0.07$), and higher opioid consumption (25.7 vs. 21.1 mg, $p = 0.14$).

Table 3. Primary and secondary outcomes

	Total cohort			Cohort of obese patients		
	BMI < 30 (*n* = 374)	BMI ≥ 30 (*n* = 86)	*p* value	BMI 30–34.9 (*n* = 66)	BMI ≥ 35 (*n* = 20)	*p* value
Operation time (mean ± SD), min	236.1 (85.4)	249.2 (85.4)	0.183[a]	249.1 (92.6)	249.8 (57.4)	0.617[a]
Conversion to laparotomy, *n* (%)	12 (3.7)	6 (8)	0.122[b]	3 (5.3)	3 (16.7)	0.145[b]
Intraoperative drain placement, *n* (%)	94 (25.1)	21 (24.4)	0.999[b]	14 (21.2)	7 (35)	0.241[b]
Postoperative days until first sips of water (mean ± SD), days	0.1 (0.4)	0.1 (0.3)	0.865[a]	0.1 (0.2)	0.1 (0.3)	0.795[a]
Postoperative days until clear liquid diet (mean ± SD), days	1.0 (0.5)	1.0 (0.4)	0.984[a]	1.0 (0.2)	1.0 (0.8)	0.617[a]
Postoperative days until solid food diet (mean ± SD), days	1.5 (1.2)	1.2 (0.6)	0.119[a]	1.2 (0.5)	1.2 (1.0)	0.569[a]
Postoperative days until first flatus (mean ± SD), days	2.0 (1.2)	2.2 (1.2)	0.136[a]	2.1 (1.2)	2.3 (1.0)	0.441[a]
Postoperative days until first stool (mean ± SD), days	3.1 (1.6)	3.1 (1.5)	0.841[a]	3.0 (1.5)	3.4 (1.3)	0.271[a]
Total opioid consumption (mean ± SD), mg	21.5 (32.2)	24.7 (29.8)	0.177[a]	24.9 (30.9)	23.8 (26.2)	0.726[a]
LOS (mean ± SD), days	8.2 (10.3)	7.0 (3.9)	0.294[a]	7.4 (4.3)	6.0 (2.3)	0.418[a]
Home discharge, *n* (%)	348 (93.0)	82 (95.3)	0.628[b]	64 (97)	18 (90)	0.229[b]
Nursing facility discharge, *n* (%)	26 (7.0)	4 (4.7)	0.628[b]	2 (3)	2 (10)	0.229[b]
Complications, *N* (%)	81 (21.7)	18 (20.9)	0.999[b]	16 (24.2)	2 (10)	0.221[b]
Grade I, *n*	24	6	0.999[b]	6	0	0.569[b]
Grade II, *n*	34	6	0.705[b]	6	0	0.061[b]
Grade IIIa, *n*	2	0	0.357[b]	0	0	0.999[b]
Grade IIIb, *n*	15	2	0.751[b]	1	1	0.413[b]
Grade IVa, *n*	6	4	0.406[b]	3	1	0.553[b]
Severe complications (grade ≥ III), *n* (%)	23 (6.1)	6 (7)	0.652[b]	4 (6.1)	2 (10)	0.329[b]
Complications requiring surgical intervention, *N* (%)	15 (4)	2 (2.3)	0.751[b]	1 (1.5)	1 (5)	0.413[b]
Anastomotic leak, *n*	7	0	0.357[b]	0	0	NA
Bleeding, *n*	3	0	0.999[b]	0	0	NA
Wound dehiscence, *n*	4	1	0.999[b]	1	0	0.999[b]
Upper extremity compartment syndrome, *n*	0	1	0.187[b]	0	1	0.233[b]
Internal hernia, *n*	1	0	0.999[b]	0	0	NA
Readmissions, *n* (%)	14 (3.7)	2 (2.3)	0.747[b]	2 (3)	0	0.999[b]
Readmission LOS, days, mean (SD)	9 (5.7)	5.5 (0.7)	0.472[a]	5.5 (0.7)	–	NA

SD, standard deviation; LOS, length of stay. [a] Mann-Whitney test. [b] Fisher's exact test.

Analyses performed when dividing patients according to SMA found comparable results for all primary and secondary outcomes, except for a significantly longer time until return of bowel function among sarcopenic patients (2.6 vs. 1.9 days, $p = 0.03$).

A total of 188 non-obese and 42 obese patients underwent colorectal resections for malignancy. Their postoperative outcomes obtained by BMI stratification are reported in Table 4. Conversion to laparotomy was significantly more frequent in obese patients undergoing oncologic surgery (11.9 vs. 2.1%, $p = 0.01$). Obese patients also had a delayed return of bowel function (2.38 vs. 1.98 days before first flatus, $p = 0.03$). There was no difference in the other outcomes. When performing analyses according to VFA, patients with visceral obesity who underwent oncologic resection had a higher rate of conversion to laparotomy (11.1 vs. 2.4%, $p = 0.02$) and similar results for all other primary and secondary outcomes. There was no difference between patients with and without sarcopenia undergoing oncologic resections for any outcome. Within the obese cohort, patients with BMI ≥ 35 and BMI 30–34.9 had similar outcomes, except for postoperative time until first bowel movement, which was significantly longer in patients with BMI ≥ 35 (3.89 vs. 2.7 days, $p = 0.03$).

Discussion

In this study, obese and non-obese patients had overall similar postoperative outcomes after colorectal surgery in the setting of an ERAS program. These results confirm that obese patients are good candidates for ERAS management and suggest that ERAS can potentially outweigh the poorer postoperative outcomes reported in obese patients undergoing colorectal procedures and reduce their morbidity to the level seen in non-obese patients.

Table 4. Primary and secondary outcomes for patients undergoing oncologic resections

	Total cohort			Cohort of obese patients		
	BMI < 30 (*n* = 188)	BMI ≥ 30 (*n* = 42)	*p* value	BMI 30–34.9 (*n* = 33)	BMI ≥ 35 (*n* = 9)	*p* value
Operation time (mean ± SD), min	247.8 (92.4)	260.4 (96.2)	0.596[a]	263.9 (101.3)	246.8 (78.8)	0.779[a]
Laparoscopic procedures, *n* (%)	157 (83.5)	30 (71.4)	0.081[b]	25 (75.8)	5 (55.6)	0.406[b]
Laparotomy procedures (including conversions), *n* (%)	31 (16.5)	12 (28.6)	0.081[b]	8 (24.2)	4 (44.4)	0.406[b]
Conversion to laparotomy, *n* (%)	4 (2.1)	5 (11.9)	**0.012**[b]	3 (9.1)	2 (22.2)	0.288[b]
Intraoperative drain placement, *n* (%)	68 (36.2)	14 (33.3)	0.859[b]	10 (30.3)	4 (44.4)	0.451[b]
Postoperative days until first sips of water (mean ± SD), days	0.1 (0.31)	0.1 (0.29)	0.976[a]	0.06 (0.24)	0.22 (0.44)	0.471[a]
Postoperative days until clear liquid diet (mean ± SD), days	1.03 (0.39)	1.1 (0.55)	0.603[a]	1.06 (0.24)	1.25 (1.16)	0.849[a]
Postoperative days until solid food diet (mean ± SD), days	1.53 (1.38)	1.28 (0.75)	0.429[a]	1.22 (0.49)	1.5 (1.41)	0.881[a]
Postoperative days until first flatus (mean ± SD), days	1.98 (1.3)	2.38 (1.18)	**0.032**[a]	2.27 (1.18)	2.78 (1.2)	0.238[a]
Postoperative days until first stool (mean ± SD), days	2.98 (1.79)	2.95 (1.4)	0.779[a]	2.7 (1.31)	3.89 (1.36)	**0.029**[a]
Total opioid consumption (mean ± SD), mg,	20.53 (37.21)	21.05 (27.37)	0.303[a]	20.9 (27.82)	21.74 (27.3)	0.728[a]
LOS (mean ± SD), days	8.91 (5.25)	7.92 (3.55)	0.834[a]	8.27 (4.13)	7.33 (2.4)	0.610[a]
Home discharge, *n* (%)	169 (94.9)	39 (92.9)	0.773[b]	32 (97)	7 (77.8)	0.111[b]
Nursing facility discharge, *n* (%)	19 (5.1)	3 (7.1)	0.773[b]	1 (3)	2 (22.2)	0.111[b]
Complications, *N* (%)	42 (22.3)	11 (26.2)	0.685[b]	10	1	0.403[b]
Grade I, *n*	19	5	0.780[b]	5	0	0.567[b]
Grade II, *n*	9	4	0.263[b]	3	1	0.999[b]
Grade IIIa, *n*	0	0	NA	0	0	NA
Grade IIIb, *n*	11	1	0.699[b]	1	0	0.999[b]
Grade IVa, *n*	3	1	0.556[b]	1	0	0.999[b]
Severe complications (grade ≥ III), *n* (%)	14 (7.4)	2 (4.8)	0.743[b]	2	0	0.999[b]
Complications requiring surgical intervention, *N* (%)	10 (5.3)	1 (2.4)	0.694[b]	1 (3)	0	0.999[b]
Anastomotic leak, *n*	5	0	0.588[b]	0	0	0.999[b]
Bleeding, *n*	2	0	0.999[b]	0	0	0.999[b]
Wound dehiscence, *n*	3	1	0.556[b]	1	0	0.999[b]
Readmissions, *n* (%)	8 (4.2)	2 (4.8)	0.999[b]	2 (6.1)	0	0.999[b]
Readmission LOS (mean ± SD), days	19 (7.4)	11.5 (2.12)	0.181[a]	11.5 (2.12)	–	NA

p values in bold indicate statistically significant result. SD, standard deviation; LOS, length of stay. [a] Mann-Whitney test. [b] Fisher's exact test.

Analyses performed according to presence or absence of visceral obesity and sarcopenia did not modify these findings, except for a slightly longer time until return of bowel function for sarcopenic patients. In this study, the correlation between visceral obesity and BMI ≥ 30 was particularly high (91.9%), and a relatively small number of patients with BMI < 30 had visceral obesity (57/374, 15.2%). The relatively low prevalence of obesity among patients in this study (18.7%) could have potentially masked the discrepancies found in other studies between high BMI and visceral obesity [15–17].

In terms of complications, there were interestingly no anastomotic leak and no intra-abdominal bleeding requiring surgical management in patients with BMI ≥ 30 versus 7/374 (1.8%) and 3/374 (0.8%), respectively, in patients with BMI < 30. This trend toward better outcomes for obese patients was, however, not statistically significant. Of note, patients with visceral obesity had more anastomotic leaks (4/136, 2.9%) than patients without visceral obesity (3/324, 0.9%), without reaching statistical significance ($p = 0.20$).

Patients with BMI 30–34.9 and BMI ≥ 35 had overall similar outcomes as well. However, the number of patients with BMI ≥ 35 was relatively low ($N = 20$) and could have masked a potential difference linked to the severity of obesity (insufficient power).

Patients with obesity showed a statistically significant delayed return of bowel movement (2.38 vs. 1.98 days, $p = 0.03$). This mean difference of 0.4 days (9.6 h) is, however, probably too small to have clinical significance on routine management of patients.

The overall trend toward higher rate of conversion to laparotomy in obese patients (8 vs. 3.7%, $p = 0.12$) was confirmed when considering oncologic resections only (11.9 vs. 2.1%, $p = 0.01$). A possible explanation is the more rigorous and extensive mesentery dissection necessary to ensure adequate lymph node harvest during oncologic colorectal resections, which can be challenging laparoscopically in obese patients due to excessive intra-abdominal fat. Of note, 5/6 (83.3%) conversions to laparotomy in obese patients happened during an oncologic resection versus only 4/12 (33.3%) in non-obese patients. These technical intraoperative difficulties might as well account for the delayed return of bowel function (2.38 vs. 1.98 days until first flatus, $p = 0.03$) seen after oncologic surgery in obese patients. The significantly higher rate of conversion to laparotomy and the delayed return of bowel function did not translate, however, into higher complication rates or longer LOS in the cohort of patients with obesity.

Surgical approach plays a key role in ERAS protocols [34]. Based on a review of randomized controlled trials, the American Society of Colon and Rectal Surgeons (ASCRS) strongly recommends using laparoscopic surgery in its clinical guidelines for ERAS after colorectal surgery [35]. Numerous studies have shown the advantages of minimally invasive colorectal surgery in obese patients [36, 37]. Thus, the high percentage of laparoscopic approaches most likely had an overall positive impact on the outcomes of obese patients in this study.

This study has limitations. Even though data analysis was performed on a prospective database, the study remains retrospective in nature. The relatively low percentage of patients with obesity in this study (86/460, 18.7%), especially patients with class II or III obesity (20/460, 4.3%), could have led to potential type 2 errors and missed potential differences between patients whose obesity was defined by BMI versus VFA, therefore limiting the statistical significance of these findings.

Conclusion

This study shows similar outcomes for obese and non-obese patients undergoing elective colorectal surgery in the context of an ERAS program. When considering oncologic resections only, patients with obesity show a higher rate of conversion to laparotomy and a delayed return of bowel function, without increased morbidity or delayed discharge. These results suggest that the potentially higher morbidity of colorectal surgery in obese patients can be significantly decreased, if not eliminated and brought to the same level as non-obese patients, when obese patients are managed according to an ERAS protocol. Larger, prospective studies are needed to confirm these results.

Statement of Ethics

Since this retrospective study was performed on an already existing and anonymized database whose creation was approved by the IRB, there was no need for further IRB approval according to local policies.

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