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ORIGINAL ARTICLE

The effect of increased body mass index values on surgical outcomes after radical resection for low rectal cancer

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Abstract

Purposes This study aimed to explore the effect of increased body mass index (BMI) values (overweight: BMI ≥ 25–30 kg/m^2; obese: BMI ≥ 30 kg/m^2) on surgical outcomes after radical resection for low rectal cancer (LRC).

Methods Patients with LRC who underwent radical surgery from January 2009 to December 2013 were included. The patients were divided into three groups according to their BMI values (control group: BMI < 25 kg/m^2; overweight group: BMI 25 to < 30 kg/m^2; obese group: BMI ≥ 30 kg/m^2). The patients' clinicopathological characteristics and survival data were collected and analyzed.

Results A total of 792 patients were enrolled in this study finally (control, $n = 624$; overweight, $n = 147$; obese, $n = 21$). The baseline characteristics of the three groups were similar. We found that an increased BMI was associated with a longer operative time ($P < 0.001$) and length of postoperative hospital stay ($P = 0.032$). Patients with increased BMI values had a significantly higher incidence of postoperative complications, including pulmonary infection ($P = 0.008$), anastomotic leakage ($P = 0.029$), allergy ($P = 0.017$) and incisional hernia ($P = 0.045$). The limited data showed that the pathological outcomes of the three groups did not differ to a statistically significant extent. A multivariate analysis showed that increased BMI was not associated with poorer OS or DFS.

Conclusion In LRC resection, an increased BMI was associated with a longer operative time, postoperative hospital stay, and an increased number of postoperative complications. However, it did not contribute to poorer pathological or survival outcomes.

Keywords Body mass index · Low rectal cancer · Surgical outcome · Complication · Survival

Introduction

Rectal cancer (RC) is one of the most common carcinomas and leading causes of death worldwide [1]. Low-lying RC (LRC) accounts for the majority of these cases [2]. Although multidisciplinary treatment has been applied for RC in the past decade, radical resection is still the best choice, especially for patients with locally advanced disease [3, 4]. Since total mesorectal excision (TME) became the golden standard for RC resection, the incidence of local recurrence has been greatly reduced; thus, the quality of surgery is very important for RC resection [5]. In comparison to upper-middle RC, the procedure for LRC can be more difficult, especially when performed via laparoscopic surgery, as the laparoscope can be more challenging to handle in the deep and narrow pelvic cavity [6, 7]. Although several different surgical approaches have been developed for LRC resection, it remains a challenge for surgeons, particularly for patients who wish to undergo sphincter-saving surgery [8].

Several factors, including an increased body mass index (BMI), can contribute to the technical difficulty of LRC operations [9, 10]. With improvements in quality of life, increasing people have developed overweight and obesity, especially in Asian countries, including China [11]. Some studies have reported that obesity can increase the incidence of colorectal cancer (CRC), which means that surgeons will

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face more obese patients [12]. A recent study reported that an increased BMI could affect the pathological outcomes of patients undergoing RC surgery [13]. Some previous studies have demonstrated that an increased BMI can lead to increased postoperative complications (including wound infection, pulmonary infection, and anastomotic leakage) and slower recovery [14]. Some other studies pointed out that obese patients had significantly poorer survival outcomes after CRC surgery in comparison to non-obese patients [15]. However, the results were not always consistent and some studies did not find any negative effect of obesity on the surgical outcomes after CRC surgery [16]. Thus, this remains a controversial issue that requires further investigation.

Although several studies have reported a relationship between the BMI and the surgical outcomes after CRC surgery, there were little specific data on LRC resection. We therefore conducted the present study to explore the effect of increased BMI values on the surgical outcomes after LRC resection. To the best of our knowledge, this large-scale study was the first to investigate the impact of increased BMI values on LRC resection.

Methods

Patients selection

The prospective colorectal cancer database of the Department of Gastrointestinal Surgery, West China Hospital, Sichuan University was retrospectively reviewed. RC patients who underwent surgery from January 2009 to December 2013 were enrolled in this study. The inclusion criteria were as follows: (1) confirmed diagnosis of RC by biopsy; (2) distance of the tumor from anal verge ≤ 5 cm; and (3) potentially radical surgery. The exclusion criteria were: (1) multiple tumors in the gastrointestinal tract; (2) tumors infiltrating the adjacent organs or synchronous metastatic disease; (3) a history of other malignant tumors; (4) local recurrence of RC; (5) transanal local excision or trans-sacrococcygeal excision; (6) emergency surgery; (7) American Society of Anesthesiologists (ASA) score > 3. This study was approved by the Ethics Committee of West China Hospital, Sichuan University.

Assessed parameters

The demographic information and clinicopathological characteristics of the patients were collected, including: body mass index (BMI), gender, age, ASA score, pretreatment carcinoembryonic antigen (CEA) level, previous abdominal surgery (PAS), neoadjuvant and adjuvant therapy, tumor size, distance of tumor from anal verge, tumor stage, surgical procedure, resection type, operative time, blood loss, time-to-first flatus, postoperative hospital stay, postoperative complication, reoperation, mortality, readmission, number of harvested lymph nodes (LNs), positive proximal resection margin (PRM), distal resection margin (DRM), circumferential resection margin (CRM) and survival outcome. The distance of the tumor from the anal verge was measured by hard straight colonoscopy. The tumor-node-metastasis (TNM) stage was assessed according to the American Joint Committee on Cancer TNM staging system, seventh edition.

Follow-up

All patients were followed up regularly at 3, 6, 12, 24, 36, 48, and 60 months after surgery. Contrast-enhanced CT of the abdomen and chest was performed every half-year, and colonoscopy was performed every year. Routine blood tests and tumor biomarker measurements were performed at each follow-up examination. Biopsy and PET-CT could be added when necessary.

Statistical analysis

Data were stored and updated in our institutional databases. Continuous variables were expressed as the median (range) or mean (standard deviation), and analyzed using a non-parametric Mann–Whitney *U* test or an independent-sample *t* test. Ranked data were also analyzed by a non-parametric test. Categorical variables were shown as a number and were analyzed using Chi-squared or Fisher's exact tests. A logistic-regression analysis was performed to identify the factors associated with postoperative complications. Kaplan–Meier survival curves were used to analyze the cancer-specific outcomes and Cox-regression was performed as a multivariable analysis. P values of < 0.05 were considered to indicate statistical significance. All statistical analyses were performed using the SPSS 22.0 software program.

Results

Patients characteristic

A total of 792 patients who met the study criteria were enrolled. The patients were divided into three groups according to their BMI values: the control group (BMI < 25 kg/m^2; $n = 624$), the overweight group (BMI 25–30 kg/m^2; $n = 147$), and the obese group (BMI ≥ 30 kg/m^2; $n = 21$). The patient characteristics are shown in Table 1. There were no significant differences among the three groups with regard to the type of resection ($P = 0.152$). Furthermore, no significant differences were observed among the groups with regard to the other baseline information.

Table 1 Patient characteristics according to the BMI level

Characteristics	Control (BMI < 25 kg/m^2) n = 624	Overweight (BMI 25 to < 30 kg/m^2) n = 147	Obese (BMI ≥ 30 kg/m^2) n = 21	P value
Gender				0.248
Male	363 (58.2%)	94 (63.9%)	10 (47.6%)	
Female	261 (41.8%)	53 (36.1%)	11 (52.3%)	
Age	59 (22–89)	59 (33–88)	61 (41–77)	0.768
ASA				0.673
1	25 (4.0%)	8 (5.4%)	1 (4.8%)	
2	476 (76.3%)	113 (76.9%)	15 (71.4%)	
3	123 (19.7%)	26 (17.7%)	5 (23.8%)	
CEA level				0.922
< 5	408 (66.8%)	100 (68.0%)	14 (70.0%)	
≥ 5	203 (33.2%)	47 (32.0%)	6 (30.0%)	
PAS	99 (15.9%)	25 (17.0%)	3 (14.3%)	0.921
NeoCRT	72 (11.5%)	17 (11.6%)	0 (0.0%)	0.291
Surgical procedure				0.358
Open	432 (69.2%)	93 (63.3%)	15 (71.4%)	
Laparoscopy	192 (30.8%)	54 (36.7%)	6 (28.6%)	
Resection type				0.152
LAR	349 (55.9%)	90 (61.2%)	8 (38.1%)	0.116
ISR	95 (15.2%)	12 (8.2%)	3 (14.3%)	0.063
LHR	22 (3.5%)	7 (4.8%)	1 (4.8%)	0.769
APR	158 (25.4%)	38 (25.8%)	9 (42.8%)	0.196
Diverting stoma	35 (7.9%)	7 (6.9%)	0	0.727
Distance to anal verge	3.0 (0.5–5.0)	4.0 (1.0–5.0)	4.0 (1.0–5.0)	0.161
Tumor size	4.0 (0.7–13)	3.5 (0.4–9)	4.0 (2.0–8.0)	0.059
Tumor stage				0.780
1	207 (33.2%)	46 (31.3%)	5 (23.8%)	
2	161 (25.8%)	38 (25.9%)	7 (33.3%)	
3	256 (41.0%)	63 (42.8%)	9 (42.9%)	
Adjuvant therapy	387 (62.0%)	97 (66.0%)	14 (66.7%)	0.627

BMI body mass index, *ASA* American Society of Anesthesiologists, *CEA* carcinoembryonic antigen, *PAS* previous abdominal surgery, *NeoCRT* neoadjuvant chemoradiotherapy, *LAR* low anterior resection, *ISR* intersphincteric resection, *LHR* low Hartmann resection, *APR* abdominoperineal resection

Intraoperative and postoperative outcomes

The Intraoperative and postoperative outcomes are shown in Table 2. Three cases in the control group required conversion from laparoscopy to open surgery because of technical difficulties. We found that an increased BMI was associated with a significantly longer operative time ($P < 0.001$) and postoperative hospital stay ($P = 0.032$). A total of 34 patients underwent reoperation within 1 month after surgery because of surgical complications, including: anastomotic leakage ($n = 23$), anastomotic bleeding ($n = 2$), obstruction ($n = 2$), hernia formation ($n = 2$), intra-abdominal bleeding ($n = 1$), intra-abdominal infection ($n = 1$), bowel rupture ($n = 1$), acute urinary retention ($n = 1$), and rectovaginal fistula ($n = 1$). Four patients died after surgery due to anastomotic leakage and severe infection. The causes of readmission in the 17 patients who were readmitted included: obstruction ($n = 3$), wound infection ($n = 3$), anastomotic leakage ($n = 3$), pulmonary infection ($n = 2$), rectovaginal fistula ($n = 2$), acute gastroenteritis ($n = 2$), urinary infection ($n = 1$), and anastomotic bleeding ($n = 1$). The three groups had similar rates of reoperation ($P = 0.356$), 30-day mortality ($P = 0.609$) and readmission ($P = 0.297$). Although there was no significant difference among the three groups in the total incidence of short-term complications ($P = 0.496$), we still observed that patients with increased BMI values had a significantly higher incidence of pulmonary infection ($P = 0.008$), anastomotic leakage ($P = 0.029$), and allergy ($P = 0.017$). In addition, the results demonstrated that patients with increased BMI values had a significantly greater incidence of long-term complication ($P = 0.034$) and incisional hernia ($P = 0.015$) (Table 2).

Table 2 The intraoperative and postoperative outcomes

Characteristics	Control (BMI < 25 kg/m^2) $n=624$	Overweight (BMI 25 to 30 kg/m^2) $n=147$	Obese (BMI ≥ 30 kg/m^2) $n=21$	*P* value
Operative time	145.0 (65–360)	160.0 (80–340)	177.5 (100–350)	< 0.001
Blood loss	30 (5–500)	30 (10–350)	25 (15–300)	0.445
Laparoscopy conversion	3 (1.6%)	0	0	1.000
Postoperative hospital days	9 (3–102)	10 (4–107)	10 (6–24)	0.032
Time-to-first flatus	4 (1–13)	4 (2–7)	4 (2–7)	0.860
Short-term complication (within 30 days)*	154 (24.7%)	43 (29.3%)	6 (28.6%)	0.496
Minor complication	125 (20.0%)	31 (21.1%)	5 (23.8%)	0.885
Major complication[a]	29 (4.6%)	12 (8.2%)	1 (4.8%)	0.227
Grade 3	23 (3.7%)	8 (5.4%)	1 (4.8%)	0.443
Grade 4	1 (0.1%)	3 (2.0%)	0	0.031
Grade 5	4 (0.6%)	1 (0.7%)	0	1.000
Wound infection	47 (7.5%)	13 (8.8%)	2 (9.5%)	0.733
Pulmonary infection	19 (3.0%)	12 (8.2%)	2 (9.5%)	0.008
Cardiovascular complications	5 (0.8%)	2 (1.4%)	0	0.693
Anastomotic leakage	19 (4.3%)	11 (10.8%)	1 (9.1%)	0.029
Anastomotic bleeding	8 (1.8%)	0	0	0.460
Urinary retention	26 (4.2%)	2 (1.4%)	0	0.230
Urinary infection	3 (0.5%)	3 (2.0%)	0	0.221
Intra-abdominal infection	9 (1.4%)	2 (1.4%)	0	1.000
Intra-abdominal bleeding	3 (0.5%)	1 (0.7%)	0	0.613
Gastrointestinal dysfunction	16 (2.6%)	6 (4.1%)	1 (4.8%)	0.348
Obstruction	7 (1.1%)	0	0	0.459
Rectovaginal fistula	3 (0.5%)	1 (0.7%)	0	0.586
Stoma complications	2 (0.9%)	0	0	1.000
Perianal infection	3 (0.5%)	2 (1.4%)	0	0.345
DVT	1 (0.1%)	0	1 (4.8%)	0.085
Hernia information	1 (0.1%)	1 (0.7%)	0	0.384
Allergy	2 (0.3%)	3 (2.0%)	1 (4.8%)	0.017
Others	12 (1.9%)	3 (2.0%)	0	1.000
Reoperation	24 (3.8%)	9 (6.1%)	1 (4.8%)	0.356
30-day mortality	3 (0.5%)	1 (0.7%)	0	0.609
Readmission (within 30 days)	12 (1.9%)	4 (2.7%)	1 (4.8%)	0.297
Long-term complication (beyond 30 days)*	31 (5.0%)	15 (10.2%)	2 (9.5%)	0.034
Obstruction	7 (1.1%)	3 (2.0%)	0	0.552
Incision hernia	5 (0.8%)	2 (1.4%)	2 (9.5%)	0.015
Stoma complications	5 (0.8%)	5 (3.4%)	0	0.066
Anastomotic complication	3 (0.5%)	2 (1.4%)	0	0.349
Rectovaginal fistula	3 (0.5%)	1 (0.7%)	0	0.586
Rectovesical fistula	2 (0.3%)	1 (0.7%)	0	0.513
Inguinal hernia	2 (0.3%)	1 (0.7%)	0	0.513
Perianal abscess	1 (0.1%)	0	0	1.000
Others	3 (0.5%)	1 (0.7%)	0	0.615

*One patient might have developed more than one complication. DVT, deep venous thrombosis. Bold typeface indicates statistical significant *P* values

[a]Major complications were defined as Clavien–Dindo grade ≥ 3 complications

Besides, the results of the linear regression analysis demonstrated that male gender, BMI, laparoscopic surgery, APR, and distance to the anal verge were factors that could affect the operative time while BMI, short-term complication and reoperation were associated with the length of postoperative hospital stay (Table 3).

Pathological outcomes

The pathological outcomes are shown in Table 4. There were no significant differences among the three groups with regard to the number of harvested LNs ($P=0.580$) or the rates of PRM, DRM, and CRM positivity ($P=0.867$, 0.853, and 0.287, respectively).

Table 3 The results of a linear regression analysis to identify factors affecting operative time and postoperative hospital stay

Variable	Coefficient	*P* value	95% CI
Operative time			
Male	11.200	0.003	3.830–18.570
BMI	3.898	< 0.001	2.816–4.981
Laparoscopy	17.710	< 0.001	9.951–25.470
APR	37.741	< 0.001	29.875–45.606
Distance to anal verge	− 3.995	0.003	− 6.647 to − 1.343
Postoperative hospital stay (days)			
BMI	0.180	0.014	0.037–0.324
Short-term complication	5.971	< 0.001	4.974–6.968
Reoperation	13.006	< 0.001	10.902–15.110

BMI body mass index, *APR* abdominoperineal resection, *CI* confidence interval

Survival outcomes

With a median follow-up time of 65 months, the local recurrence rates of the control, overweight and obese groups were 8.5%, 8.8%, 14.4%, respectively. Although we could observe an increasing trend with the BMI, the result was not statistically significant ($P=0.650$) (Table 4). Besides, the 5-year overall survival rates of the control, overweight and obese groups were 80.8%, 80.9% and 81.0%, respectively, while the 5-year disease-free survival rates were 71.3%, 69.4% and 66.6%, respectively. The Kaplan–Meier curves demonstrated that there were no differences among the three groups with regard to OS ($P=0.734$) or DFS ($P=0.801$) (Fig. 1). A multivariate analysis showed that high tumor stage, positive DRM and CRM could contribute to poorer DFS and OS. A lower pretreatment CEA level and APR procedure might predict a better OS. However, the results did not suggest that an increased BMI was associated with poorer OS or DFS (Table 5).

Discussion

In this study, we explored the effect of an increased BMI on the surgical outcomes after LRC resection. We found that an increased BMI could affect the duration of surgery and postoperative recovery. However, it was not associated with poorer pathological or survival outcomes.

In fact, there are several factors that can affect the duration of surgery, including tumor location and BMI [17]. LRC resection is more technically difficult than surgery for middle or upper RC, particularly in laparoscopic surgery, because

Table 4 The pathological outcomes of the three groups

Variable	Control (BMI < 25 kg/m^2) $n=624$	Overweight (BMI 25–30 kg/m^2) $n=147$	Obese (BMI ≥ 30 kg/m^2) $n=21$	*P* value
LN harvested	10 (0–41)	9 (1–31)	9.5 (0–22)	0.580
PRM				0.867
Not reported	133	35	5	
Positive	4	0	0	
Negative	487	12	16	
DRM				0.853
Not reported	133	35	5	
Positive	2	0	0	
Negative	489	112	16	
CRM				0.287
Not reported	528	118	18	
Positive (≤ 1 mm)	9	0	0	
Negative (> 1 mm)	87	29	3	
Local recurrence	53	13	3	0.650

LN lymph node, *PRM* proximal resection margin, *DRM* distal resection margin

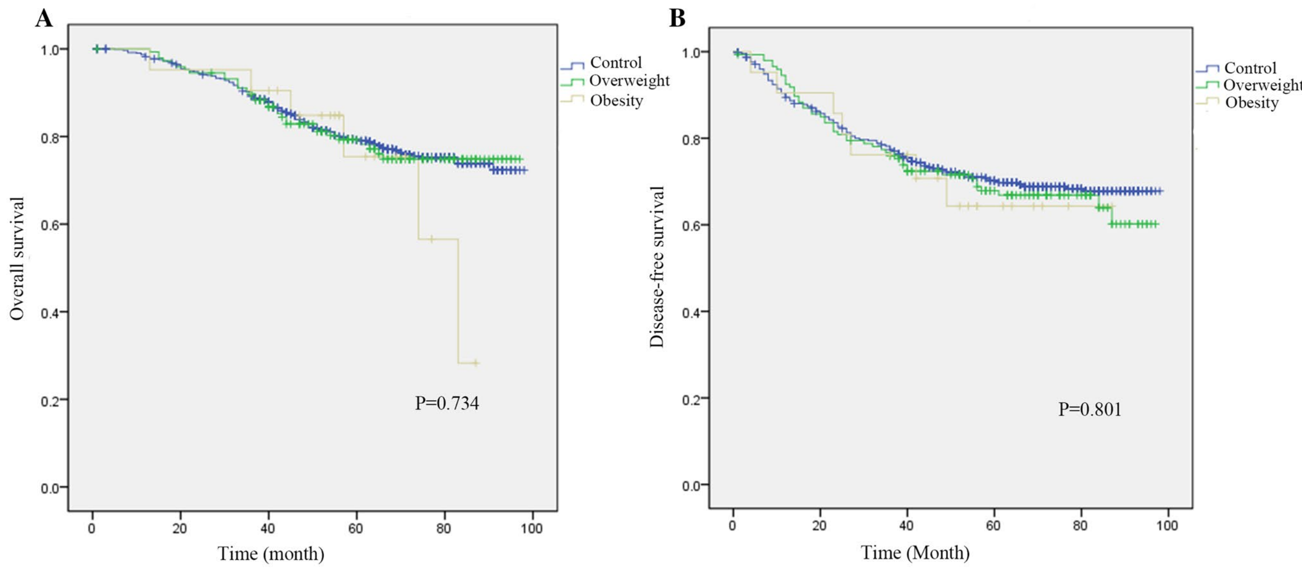

Fig. 1 Survival outcomes based on different BMI level; **A** *OS*, **B** DFS, *BMI* body mass index, *OS* overall survival, *DFS* disease-free survival

it is located deep in the pelvis [13]. Although the learning curve for laparoscopic techniques has been greatly improved in the past decades and some studies have reported a similar operative time to open surgery, this was not observed in the deep pelvis [18, 19]. The narrow space made it difficult to achieve sufficient exposure of the operative field to perform mobilization or ligation well [9]. In obese patients, the pelvic cavity can be further downsized, so the situation can be more complex [20]. In our study, there were no significant differences in the procedures chosen among the three groups, but we still observed that an increased BMI could increase the operative time. Our result was also supported by some previous studies [16]. We thought that the increased fat tissue could add to the time required for laparotomy or trocar insertion [21]. Some studies reported that an increased BMI could increase the risk of laparoscopic conversion and that surgeons tended to be less likely to perform laparoscopic surgery for obese patients [9, 22]. However, we did not find this outcome in our study and only 3 cases in the control group required conversion from laparoscopy. This might because all laparoscopic procedures were performed highly experienced and skillful surgeons. This could also demonstrate that our study had less selection bias.

Postoperative complications are an important issue in studies that explore the effect of an increased BMI on surgical outcomes. Supported by some previous studies, we found that patients with increased BMI values had a significantly higher incidence of postoperative complications, including anastomotic leakage, pulmonary infection and incisional hernia [23]. This might because the basal metabolism of overweight or obese patients was higher than that of the patients in the control group; thus, more time and energy were needed for recovery [24]. This might also be why the patients with increased BMI values had a higher incidence of anastomotic leakage. We thought that a longer duration of anesthesia would contribute to a higher incidence of pulmonary infection and that a higher amount of subcutaneous fat might be associated with a greater incidence of incisional hernia [25, 26]. Interestingly, our results differed from those of previous studies in that we did not observe a significant difference among the three groups with regard to the incidence of wound or abdominal infection [14]. We thought that this was related to improvement in the nursing level and the preventive use of antibiotics. In addition, some studies have reported that an increased BMI is associated with increased mortality after CRC surgery; however, we did not observe this outcome in our study [27]. We thought this was due to the control of surgical quality and timely intervention for severe complications, including anastomotic leakage.

Enhanced recovery programs have been widely used after CRC surgery and some studies have reported their effectiveness in reducing postoperative hospital stay [28]. In our center, the program has also been routinely applied in recent years. Even though, we still observed that patients with increased BMI values had a significantly longer length of postoperative hospital stay than patients in the control group. This result was also similar to some previous studies [23]. Thus, patients with high BMI values had a slower recovery. The higher incidence of postoperative complications might also contribute to this outcome.

It is still not clear whether an increased BMI is associated with worse survival outcomes because previous studies have shown inconsistent results [16, 22, 29]. In our study, we did not find a significant difference in the OS or DFS the groups.

Table 5 Univariate and multivariate analyses of factors associated with the survival outcomes

Variables	Overall survival				Disease-free survival			
	Univariate analysis		Multivariate analysis		Univariate analysis		Multivariate analysis	
	HR (95% CI)	*P* value	HR (95% CI)	*P* value	HR (95% CI)	*P* value	HR (95% CI)	*P* value
Gender: female/male	1.284 (0.945, 1.745)	0.110			1.352 (1.039, 1.759)	0.025	1.288 (0.550, 3.014)	0.560
Age ≥ 65 years	1.359 (1.003, 1.841)	0.048	1.841 (0.687, 4.932)	0.225	1.140 (0.875, 1.486)	0.332		
ASA score								
1,2/3	0.804 (0.540, 1.198)	0.284			0.735 (0.520, 1.039)	0.081		
CEA level	1.981 (1.487, 2.640)	< 0.001	2.907 (1.085, 7.790)	0.034	1.622 (1.265, 2.079)	< 0.001	1.795 (0.778, 4.142)	0.170
Neoadjuvant therapy	0.719 (0.409, 1.266)	0.253			0.727 (0.460, 1.149)	0.173		
BMI index								
Overweight	1.014 (0.691, 1.490)	0.942	0.310 (0.066, 1.446)	0.136	1.097 (0.799, 1.506)	0.569	0.895 (0.317, 2.529)	0.835
Obese	1.385 (0.612, 3.139)	0.435	0.000 (0.000, –)	0.984	1.162 (0.546, 2.472)	0.697	0.000 (0.000, –)	0.983
Sphincter-preserving /APR	1.779 (1.309, 2.417)	< 0.001	0.116 (0.036, 0.778)	0.023	1.483 (1.133, 1.943)	0.004	0.582 (0.199, 1.705)	0.324
Open/laparoscopy	1.173 (0.857, 1.607)	0.320			1.002 (0.762, 1.318)	0.989		
Short-term complication	1.109 (0.796, 1.545)	0.541			0.979 (0.732, 1.308)	0.884		
Long-term complication	0.813 (0.416, 1.591)	0.546			0.814 (0.455, 1.454)	0.487		
Tumor size ≥ 5 cm	1.413 (1.027, 1.945)	0.034	1.011 (0.389, 2.632)	0.981	1.271 (0.961, 1.682)	0.093		
Tumor stage								
I,II/III	4.725 (3.398, 6.572)	< 0.001	6.685 (2.130, 20.982)	0.001	3.841 (2.934, 5.029)	< 0.001	6.226 (2.425, 15.984)	< 0.001
Positive PRM	2.258 (0.315, 16.176)	0.418			1.317 (0.184, 9.406)	0.784		
Positive DRM	32.741 (7.730, 138.686)	< 0.001	109.593 (9.556, 1256.881)	< 0.001	14.929 (3.652, 61.033)	< 0.001	52.126 (5.383, 504.781)	0.001
Positive CRM	6.261 (2.264, 17.317)	< 0.001	8.976 (2.146, 37.536)	0.003	6.141 (2.434, 15.497)	< 0.001	4.533 (1.364, 15.068)	0.014
Adjuvant therapy	1.249 (0.909, 1.714)	0.170		–	1.261 (0.963, 1.651)	0.092		

Bold typeface indicates statistically significant P values

BMI body mass index, *ASA* American Society of Anesthesiologists, *CEA* carcinoembryonic antigen, *APR* abdominoperineal resection, *PRM* proximal resection margin, *DRM* distal resection margin, *CRM* circumferential resection margin, *HR* hazard ratio, *CI* confidence interval

There are several parameters that can be used to predict survival. Some studies have reported that if fewer that the retrieval of < 12 LNs could lead to poorer survival and an increased BMI could influence the number of LNs harvested in CRC surgery [30, 31]. In our study, similar numbers of LNs were harvested in the three groups and we thought that this might because all the surgeons follow the same principles for tumor resection and try their best to achieve R0 resection and retrieved as many LNs as possible even though surgery for LRC in patients with increased BMI values was more challenging. We also observed that the rates of PRM, DRM, and CRM positivity did not differ to a statistically significant extent among the three groups. However, we found that the median number of LNs in the three groups was less than 12 and that the 5-year survival outcomes were still similar to some previous studies [32]. Further studies should be conducted to explore whether the criteria regarding the number of LNs to be harvested should be changed for LRC.

Furthermore, the use of neoadjuvant and adjuvant therapy has greatly reduced local and distant recurrence [33]. In our study, neither neoadjuvant nor adjuvant therapy were associated with long-term survival. We thought that this might be because all of the treatments followed the recommendations of the NCCN guidelines.

The present study was associated with some limitations. Firstly, it was a retrospective study and the sample sizes of the overweight and obese groups were relatively small. Secondly, some of the pathological parameters were not applicable.

In conclusion, an increased BMI was associated with a longer operative time, longer postoperative hospital stay, and greater incidence of postoperative complications in patients undergoing LRC resection. However, a higher BMI did not contribute to poorer pathological or survival outcomes.

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Compliance with Ethical Standards

Conflict of interest The authors declare no conflicts of interest in association with the present study.

References

1. Nicholls J. Rectal cancer seen over 30 years. Colorectal Disease. 2014;16(9):659.
2. Rullier E, Denost Q, Vendrely V, Rullier A, Laurent C. Low rectal cancer: classification and standardization of surgery. Dis Colon Rectum. 2013;56(5):560–7.
3. Dietz DW. Multidisciplinary management of rectal cancer: the OSTRICH. J Gastrointest Surg. 2013;17(10):1863–8.
4. Allaix ME, Fichera A. Modern rectal cancer multidisciplinary treatment: the role of radiation and surgery. Ann Surg Oncol. 2013;20(9):2921–8.
5. de Chaisemartin C, Penna C, Goere D, Benoist S, Beauchet A, Julie C, et al. Presentation and prognosis of local recurrence after total mesorectal excision. Colorectal Dis. 2009;11(1):60–6.
6. Bebenek M, Pudelko M, Cisarz K, Balcerzak A, Tupikowski W, Wojciechowski L, et al. Therapeutic results in low-rectal cancer patients treated with abdominosacral resection are similar to those obtained by means of anterior resection in mid- and upper-rectal cancer cases. Eur J Surg Oncol. 2007;33(3):320–3.
7. Jeong SY, Park JW, Nam BH, Kim S, Kang SB, Lim SB, et al. Open versus laparoscopic surgery for mid-rectal or low-rectal cancer after neoadjuvant chemoradiotherapy (COREAN trial): survival outcomes of an open-label, non-inferiority, randomised controlled trial. Lancet Oncol. 2014;15(7):767–74.
8. Bordeianou L, Maguire LH, Alavi K, Sudan R, Wise PE, Kaiser AM. Sphincter-sparing surgery in patients with low-lying rectal cancer: techniques, oncologic outcomes, and functional results. J Gastrointest Surg. 2014;18(7):1358–72.
9. Denost Q, Quintane L, Buscail E, Martenot M, Laurent C, Rullier E. Short- and long-term impact of body mass index on laparoscopic rectal cancer surgery. Colorectal Dis. 2013;15(4):463–9.
10. Shukla PJ, Makino T, Trencheva K, Milsom JW. Challenges of improving outcomes of rectal cancer surgery in obese patients. J Am Coll Surg. 2011;212(1):130 **(author reply-1)**.
11. Wang K, Wang D, Pan L, Yu Y, Dong F, Li L, et al. Prevalence of obesity and related factors among Bouyei and Han peoples in Guizhou Province, Southwest China. PLoS One. 2015;10(6):e0129230.
12. Levi Z, Kark JD, Katz LH, Twig G, Derazne E, Tzur D, et al. Adolescent body mass index and risk of colon and rectal cancer in a cohort of 1.79 million Israeli men and women: a population-based study. Cancer. 2017;123(20):4022–30.
13. Fleshman J, Branda M, Sargent DJ, Boller AM, George V, Abbas M, et al. Effect of laparoscopic-assisted resection vs open resection of stage II or III rectal cancer on pathologic outcomes: the ACOSOG Z6051 randomized clinical trial. JAMA. 2015;314(13):1346–55.
14. Sun Y, Chi P. Impact of body mass index on surgical and oncological outcomes in laparoscopic total mesorectal excision for locally advanced rectal cancer after neoadjuvant 5-fluorouracil-based chemoradiotherapy. Gastroenterol Res Pract. 2017;2017:1509140.
15. Doleman B, Mills KT, Lim S, Zelhart MD, Gagliardi G. Body mass index and colorectal cancer prognosis: a systematic review and meta-analysis. Tech Coloproctol. 2016;20(8):517–35.
16. Kwak HD, Ju JK, Kang DW, Baek SJ, Kwak JM, Kim J, et al. Outcomes according to body mass index following laparoscopic surgery in patients with colorectal cancer. Gastroenterol Res Pract. 2018;14(2):134–9.
17. Ogiso S, Yamaguchi T, Hata H, Fukuda M, Ikai I, Yamato T, et al. Evaluation of factors affecting the difficulty of laparoscopic anterior resection for rectal cancer: “narrow pelvis” is not a contraindication. Surg Endosc. 2011;25(6):1907–12.
18. Keller DS, Park KJ, Augestad KM, Delaney CP. Integration of open and laparoscopic approaches for rectal cancer resection: oncologic and short-term outcomes. Surg Endosc. 2014;28(7):2129–36.
19. Wu QB, Deng XB, Zhang XB, Kong LH, Zhou ZG, Wang ZQ. Short-term and long-term outcomes of laparoscopic versus open surgery for low rectal cancer. J Laparoendosc Adv Surg Tech Part A. 2018;28(6):637–44.
20. Cakir H, Heus C, Verduin WM, Lak A, Doodeman HJ, Bemelman WA, et al. Visceral obesity, body mass index and risk of complications after colon cancer resection: a retrospective cohort study. Surgery. 2015;157(5):909–15.
21. Kawamata F, Homma S, Minagawa N, Kawamura H, Takahashi N, Taketomi A. Comparison of single-incision plus one additional port laparoscopy-assisted anterior resection with conventional laparoscopy-assisted anterior resection for rectal cancer. World J Surg. 2014;38(10):2716–23.
22. Jeong SH, Kim P, Yi SW, Kim YJ, Baeg MK, Yi JJ. Body mass index and gastrointestinal cancer mortality in Korean adults: a prospective cohort study. J Gastroenterol Hepatol. 2018;33(9):1582–9.
23. Bell S, Kong JC, Wale R, Staples M, Oliva K, Wilkins S, et al. The effect of increasing body mass index on laparoscopic surgery for colon and rectal cancer. Colorectal Dis. 2018;20(9):778–88.
24. Kuritzkes BA, Pappou EP, Kiran RP, Baser O, Fan L, Guo X, et al. Visceral fat area, not body mass index, predicts postoperative 30-day morbidity in patients undergoing colon resection for cancer. Int J Colorectal Dis. 2018;33(8):1019–28.
25. Hovaguimian F, Lysakowski C, Elia N, Tramer MR. Effect of intraoperative high inspired oxygen fraction on surgical site infection, postoperative nausea and vomiting, and pulmonary function: systematic review and meta-analysis of randomized controlled trials. Anesthesiology. 2013;119(2):303–16.
26. Nakayama M, Yoshimatsu K, Yokomizo H, Yano Y, Okayama S, Satake M, et al. Incidence and risk factors for incisional hernia

after open surgery for colorectal cancer. Hepato-gastroenterology. 2014;61(133):1220–3.
27. Kroenke CH, Neugebauer R, Meyerhardt J, Prado CM, Weltzien E, Kwan ML, et al. Analysis of body mass index and mortality in patients with colorectal cancer using causal diagrams. JAMA Oncol. 2016;2(9):1137–45.
28. Greco M, Capretti G, Beretta L, Gemma M, Pecorelli N, Braga M. Enhanced recovery program in colorectal surgery: a meta-analysis of randomized controlled trials. World J Surg. 2014;38(6):1531–41.
29. Sun Y, Xu Z, Lin H, Lu X, Huang Y, Huang S, et al. Impact of body mass index on treatment outcome of neoadjuvant chemoradiotherapy in locally advanced rectal cancer. Eur J Surg Oncol. 2017;43(10):1828–34.
30. Nir S, Greenberg R, Shacham-Shmueli E, White I, Schneebaum S, Avital S. Number of retrieved lymph nodes and survival in node-negative patients undergoing laparoscopic colorectal surgery for cancer. Tech Coloproctol. 2010;14(2):147–52.
31. Kuo YH, Lee KF, Chin CC, Huang WS, Yeh CH, Wang JY. Does body mass index impact the number of LNs harvested and influence long-term survival rate in patients with stage III colon cancer? Int J Colorectal Dis. 2012;27(12):1625–35.
32. Akagi Y, Adachi Y, Kinugasa T, Oka Y, Mizobe T, Shirouzu K. Lymph node evaluation and survival in colorectal cancer: review of population-based, prospective studies. Anticancer Res. 2013;33(7):2839–47.
33. Brenner H, Kloor M, Pox CP. Colorectal cancer. Lancet. 2014;383(9927):1490–502.