# Posterior mesorectal thickness as a predictor of increased operative time in rectal cancer surgery: a retrospective cohort study

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## Abstract

**Background** In rectal cancer surgery, larger mesorectal fat area has been shown to correlate with increased intraoperative difficulty. Prior studies were mostly in Asian populations with average body mass indices (BMIs) less than 25 kg/m$^2$. This study aimed to define the relationship between radiological variables on pelvic magnetic resonance imaging (MRI) and intraoperative difficulty in a North American population.

**Methods** This is a single-center retrospective cohort study analyzing all patients who underwent low anterior resection (LAR) or transanal total mesorectal excision (TaTME) for stage I–III rectal adenocarcinoma from January 2015 until December 2019. Eleven pelvic magnetic resonance imaging measures were defined a priori according to previous literature and measured in each of the included patients. Operative time in minutes and intraoperative blood loss in milliliters were utilized as the primary indicators of intraoperative difficulty.

**Results** Eighty-three patients (39.8% female, mean age: 62.4 ± 11.6 years) met inclusion criteria. The mean BMI of included patients was 29.4 ± 6.2 kg/m$^2$. Mean operative times were 227.2 ± 65.1 min and 340.6 ± 78.7 min for LARs and TaTMEs, respectively. On multivariable analysis including patient, tumor, and MRI factors, increasing posterior mesorectal thickness was significantly associated with increased operative time ($p = 0.04$). Every 1 cm increase in posterior mesorectal thickness correlated with a 26 min and 6 s increase in operative time. None of the MRI measurements correlated strongly with BMI.

**Conclusion** As the number of obese rectal cancer patients continues to expand, strategies aimed at optimizing their surgical management are paramount. While increasing BMI is an important preoperative risk factor, the present study identifies posterior mesorectal thickness on MRI as a reliable and easily measurable parameter to help predict operative difficulty. Ultimately, this may in turn serve as an indicator of which patients would benefit most from pre-operative resources aimed at optimizing operative conditions and postoperative recovery.

**Keywords** Rectal cancer · Colorectal Surgery · Body Mass Index · Obesity · Mesorectal Fat · Magnetic Resonance Imaging

The obesity epidemic is a well-known phenomenon in Western society [1]. While obesity is classically associated with cardiovascular disease and insulin resistance, there is also significant evidence supporting an increased risk of colorectal cancer with increasing BMI [2]. Specifically, a body mass index over 30 kg/m$^2$ is associated with a 10–60% increased risk of developing colorectal cancer [3, 4]. As such, patients requiring operative intervention for colorectal cancer have increasingly large BMIs.

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The pathophysiological consequences of obesity are complex and pervasive in the perioperative setting [5, 6]. Intraoperatively, obesity is associated with increased operative time and blood loss [7, 8]. Postoperatively, obesity is associated with higher rates of anastomotic leak, surgical site infection (SSI), urinary tract infection (UTI), wound dehiscence, sepsis, and venous thromboembolism (VTE) [9–12]. Obesity in the setting of surgery for rectal cancer, in particular, carries unique challenges, along with the aforementioned perioperative consequences [12]. Elevated BMI has been associated with difficult total mesorectal excision (TME) in laparoscopic surgery, a key oncological principle to the surgical management of rectal cancer [13, 14].

Obesity has been shown to correlate with increased visceral adiposity bulk and increased mesorectal fat area (MFA) [15, 16]. MFA has been previously identified as a predictor of a difficult TME [8]. In open, laparoscopic, and robotic surgery, larger MFA has correlated with increased operative time and increased intraoperative blood loss [8, 17]. Moreover, MFA, along with other mesorectal radiological measures such as mesorectal-to-pelvis ratio (MPR), have been associated with increased length of stay (LOS) in hospital and postoperative morbidity [8, 18]. However, two of these prior studies were in Asian populations with average BMIs of less than 25 kg/m², one of which evaluated robotic surgery, thus lacking generalizability to the North American population [8, 18]. A European study by Escal et al. also failed to evaluate a cohort representative of the North American population, as over 80% of the included patients had a BMI of less than 30 kg/m² [17].

As such, there is currently a paucity of data describing the relationship between mesorectal radiological measures, intraoperative, and postoperative complications in laparoscopic surgery for rectal cancer in North America. The aim of the present retrospective study is to define the relationship between radiological variables on pelvic magnetic resonance imaging (MRI) and intraoperative difficulty. We hypothesize that findings will be similar to previous study demonstrating increasing operative difficulty with increasing MFA. Furthermore, the derivation of an intuitive and easily measurable radiological parameter to identify patients at the greatest risk will be explored in the present study. Ultimately, these associations and measures may help identify patients that are at higher risk of perioperative complication and thus would benefit most from preoperative medical optimization programs.

## Materials and methods

### Patient selection

The electronic medical records (EMRs) of three minimally invasive colorectal surgeons were searched from January 2015 to December 2019 for patients undergoing elective laparoscopic low anterior resection (LAR) or transanal total mesorectal excision (TaTME) for American Joint Committee on Cancer (AJCC) stage I–III rectal adenocarcinoma. Patients with staging investigations consistent with stage IV disease, patients with prior pelvic colorectal surgery, and patients undergoing palliative resection were excluded. All included patients were over the age of 18, had preoperative staging investigations consistent with stage AJCC I–III rectal adenocarcinoma, and underwent elective, curative laparoscopic surgery. Hamilton Integrated Research Ethics Board approval was obtained for this retrospective study and the need to obtain informed consent was waived. This retrospective cohort study was reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines.

### Surgical technique

All of the included patients underwent laparoscopic tumor-specific TME, defined as complete excision of the visceral mesorectal tissue to a level at least 2 cm distal to the tumor, by one of the three surgeons at St. Joseph's Healthcare, Hamilton, Ontario, Canada [19]. Choice of surgical approach was dictated by tumor characteristics (i.e., tumor location with respect to anal sphincter complex) and patient characteristics (i.e., comorbidities, preoperative continence, preference, etc.). Care was taken to achieve a high ligation of the inferior mesenteric artery and adequate proximal (> 5 cm) and distal (R0 resection) margins during the course of all operations. Patients with locally advanced disease (i.e., threatened CRM, high-risk stage II disease, stage III disease) and/or a low primary tumor requiring downsizing for attempted sphincter-preserving approach were sent for neoadjuvant therapy. The majority of patients sent for neoadjuvant therapy underwent long course chemoradiotherapy as per local radiation oncologist protocols. No patients underwent total neoadjuvant therapy and all patients underwent surgery between six and 12 weeks following completion of neoadjuvant therapy.

### Outcomes assessed

The primary objective of this study was to determine the relationship between preoperative rectal MRI measurements (i.e., MFA, rectal area, mesorectal package area (MPA), bony pelvis area (BPA), lateral mesorectal span (L-MR), anterior–posterior mesorectal span (AP-MR), interspinous distance (IS), AP bony pelvis span (AP-BP), anterior mesorectal thickness (MT), posterior MT) and intraoperative difficulty. Operative time in minutes was utilized as the primary indicator of intraoperative difficulty as in previous studies [8, 20].

Secondary objectives included determining the relationships between BMI and intraoperative difficulty (operative time, intraoperative blood loss, intraoperative anastomotic revision/repair, and nodal harvest) and BMI and preoperative MRI measurements.

Tertiary objectives were aimed at elucidating rates of 30-day mortality and postoperative length of stay (LOS) in days, as well as long-term oncologic outcomes (i.e., overall survival, disease-free survival, local recurrence, distal recurrence). Overall 30-day postoperative morbidity included anastomotic leak, postoperative ileus, high output stoma, superficial surgical site infection (sSSI), intraabdominal abscess, postoperative hemorrhage, wound dehiscence, atelectasis, pneumonia, deep vein thrombosis (DVT), pulmonary embolism (PE), myocardial infarction (MI), myocardial injury following non-cardiac surgery (MINS), urinary tract infection (UTI), acute urinary retention (AUR), acute kidney injury (AKI), reoperation, and readmission.

## Data collection

Two study personnel (T.M. and C.K.) as well as an experienced medical administrative assistant abstracted data onto a data collection manual designed a priori on password protected computers and firewall protected programs (RedCap©). Baseline patient characteristics (i.e., age, gender, smoking status, past medical history, past surgical history, medications, allergies) as well as adjuvant therapy information and surgical pathology reports were accessed through the EMRs of the individual surgeons. Preoperative MRIs, MRI radiologist reports, anesthesiologist reports, operative dictations, postoperative discharge summaries, and 30-day follow-up data were accessed through the hospital-based EMR at St. Joseph's Healthcare Hamilton. Intraoperative complications as well as type of anastomosis (i.e., colorectal, coloanal) and presence or absence of diversion (i.e., loop ileostomy) were extracted from surgical team operative dictations. Postoperative morbidity data were found in discharge summaries and if incomplete, in postoperative daily progress notes.

## Pelvic MRI measurements

MRI was performed using either a 1.5 T General Electric (450 W, software version 25) or a 3 T Phillips (Achieva, Software version 3.2.3.5) system. Large field-of-view (FOV) T2-weighted axial images with a slice thickness of 5 mm were downloaded from the PACS system and analyzed with National Institute of Health funded, publicly available software (3D Slicer©, Version 4.11; Bethesda, MD) [21]. A pelvic MRI measurement protocol on 3D Slicer© was developed by a Senior Scientific Research Officer at the Imaging Research Centre at St. Joseph's

Healthcare Hamilton. The protocol was reviewed by an expert radiologist. One study investigator (T.M.) and an independent radiologist (H.J.) were taught the protocol and subsequently completed the pelvic MRI measurements independently on the preoperative MRIs of all of the included patients.

Pelvic MRI measurements were determined using the preoperative MRI closest to the operative date. The MFA has previously been defined as the mesorectal fat at the level of the tip of the ischial spines, as such a single 5 mm slice that most clearly demonstrated the ischial spines was analyzed for each of the included patients [15]. The 11 measures captured in the protocol were divided into mesorectal measurements and pelvic measurements, which are described in Table 1. Linear measures were made using the "ruler" function on 3D Slicer©, which required two consecutive left-mouse clicks with a calibrated cursor at two separate points on the image (Figs. 1, 2, 3). The circumferences of the rectum, mesorectum, and bony pelvis were manually traced with a calibrated cursor to obtain their surface areas (Figs. 4, 5, 6). In areas where a T3 tumor transgressed the rectal wall, thus making muscularis propia difficult to visualize, the trace of the muscularis propia on either side of the tumor was continued along a line following the contour that connected the two visualized edges of the muscularis propia.

## Statistical analysis

Descriptive statistics were used to characterize the sample population. Continuous variables were described as means with standard deviations, while categorical variables were reported as numbers and percentages. Statistical significance was set at $p < 0.05$ and 95% confidence intervals were provided where applicable. One-way ANOVAs, Chi-squared, and Fisher exact tests were used where applicable. Linear regression was performed to estimate associations of MRI variables with operative time. Multivariable analysis of operative time with a multiple linear regression model after assessing for collinearity was then performed. MRI variables with a $p < 0.05$ on multivariable analysis with MRI variables were entered into a multivariable linear regression analysis of operative time with patient, tumor, and treatment characteristics which were also identified to have a statistically significant association with operative time on univariable linear regression. Variables demonstrating a significant association with main outcomes (i.e., operative time) were considered risk factors. Interobserver agreement for evaluation of pelvic MRI measurements were assessed using a Spearman's correlation test. Data were analyzed using Stata statistical software (StataCorp, version 15; College Station, TX).

**Table 1** Definitions of pelvic MRI measurements captured with the 3D Slicer © protocol

| | Definition |
| --- | --- |
| Mesorectal MRI Variable | |
| 1. L-MR | Linear distance from the most left-lateral aspect of the mesorectal fascia to the most right-lateral aspect of the mesorectal fascia |
| 2. AP-MR | Linear distance from the most anterior aspect of the mesorectal fascia to the most posterior aspect of the mesorectal fascia |
| 3. Anterior MT | Greatest linear distance from the most anterior aspect of the mesorectal fascia to the anterior facing muscularis propria of the rectum |
| 4. Posterior MT | Greatest linear distance from the most posterior aspect of the mesorectal fascia to the posterior facing muscularis propria of the rectum |
| 5. Rectal area | Area confined by the muscularis propria of the rectum |
| 6. MPA | Area confined by the mesorectal fascia |
| 7. MFA | Rectal area subtracted from the mesorectal package area |
| Pelvic MRI Variable | |
| 8. IS | Linear distance between the ischial spines |
| 9. AP-BP | Linear distance from the most posterior aspect of rectus abdominis or pubis symphysis (anatomy dependent) to the anterior surface of the coccyx |
| 10. BPA | Area confined by the coccyx and sacrospinous ligaments posteriorly, ileums bilaterally, and pubis bones or parietal peritoneum (anatomy dependent) anteriorly |
| 11. Extra-MPA | Mesorectal package area subtracted from the bony pelvis area |

*MRI* magnetic resonance imaging, *IS* interspinous distance, *AP-BP* anterior–posterior bony pelvis span, *L-MR* lateral mesorectal span, *AP-MR* anterior–posterior mesorectal span, *MT* mesorectal thickness, *MPA* mesorectal package area, *MFA* mesorectal fat area, *BPA* bony pelvis area, *Extra-MPA* extra-mesorectal fat area

*All measurements obtained from a single 5 mm axial slice at the level of the ischial spines

**Fig. 1** Interspinous distance (IS) and anterior–posterior bony pelvis span (AP-BP) as measured on 3D Slicer© (Version 4.11; Bethesda, MD)
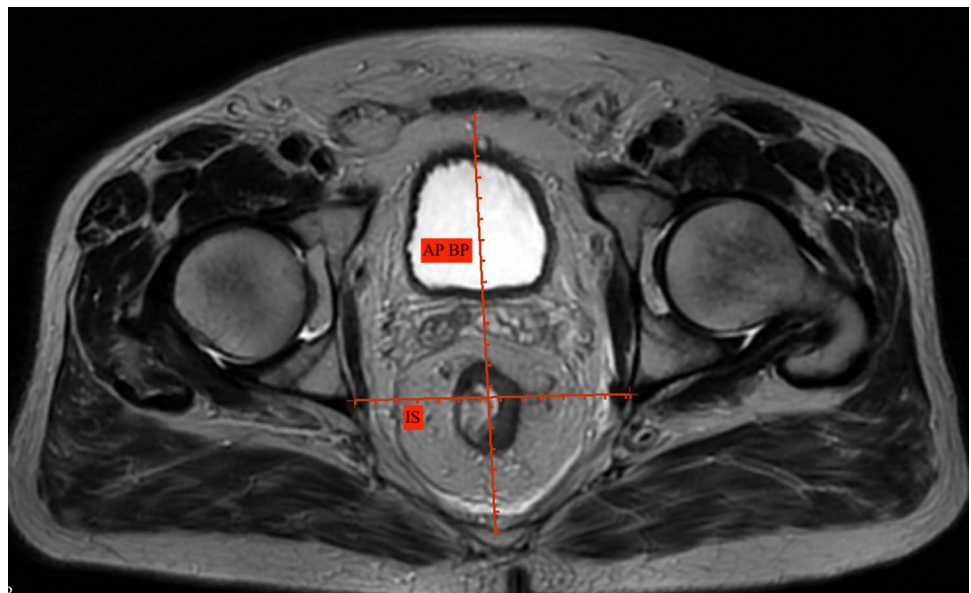


## Results

### Patient characteristics

In total, 144 patients were identified. Of these, 53 patients were subsequently excluded for not having undergone preoperative pelvic MRI. Additionally, five patients had preoperative MRIs that were not accessible by study personnel. Lastly, three patients were excluded for undergoing multivisceral resection (i.e., concomitant total abdominal hysterectomy, bilateral salpingo-oopherectomy, and rectal resection). As such, 83 consecutive patients (39.8% female, mean age: $62.4 \pm 11.6$ years) met inclusion criteria

**Fig. 2** Lateral mesorectal span (L-MR) and anterior–posterior mesorectal span (AP-MR) as measured on 3D Slicer© (Version 4.11; Bethesda, MD)
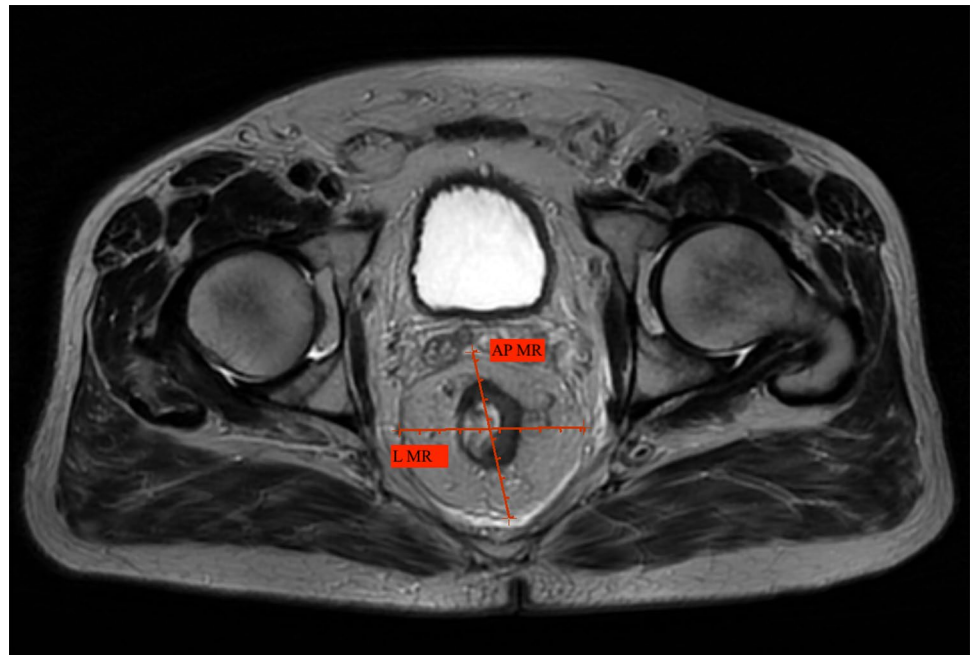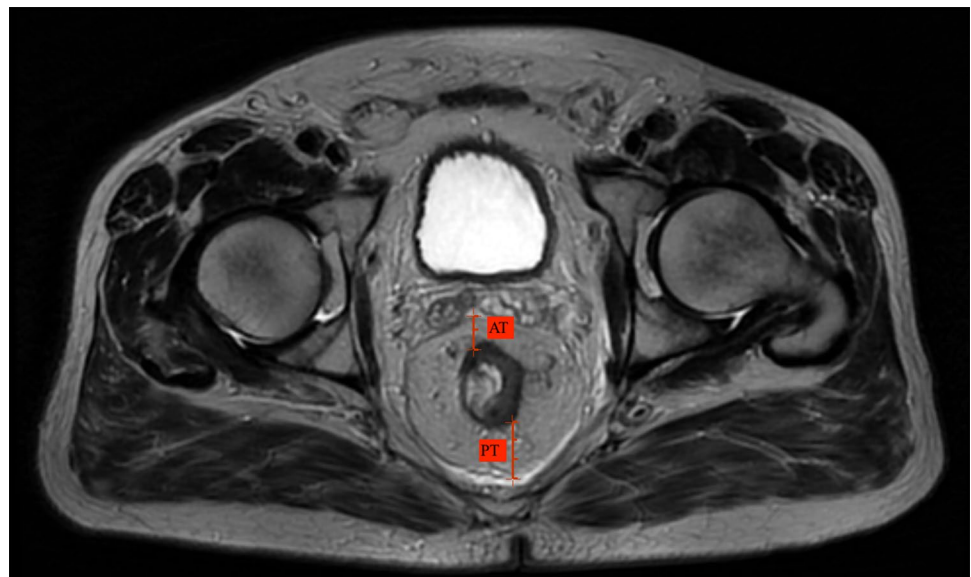


**Fig. 3** Anterior mesorectal thickness (MT) and posterior MT as measured on 3D Slicer© (Version 4.11; Bethesda, MD)



and were included in the final analysis. The mean BMI of included patients was $29.4 \pm 6.2$ kg/m$^2$, with 74.4% of patients having a BMI greater than 24.9 kg/m$^2$ and 43.9% of patients having a BMI of greater than 29.9 kg/m$^2$. The majority of patients (61.5%) had AJCC stage I or II disease. The majority of tumors were T2 or T3 (75.9%), were not threatening the circumferential resection margin (CRM) (84.0%), and had a mean distance of $9.5 \pm 4.0$ cm from the anal verge. Patients more commonly underwent LAR (69.9%) than TaTME (30.1%). Detailed patient, disease, and operative characteristics are reported in Table 2.

**Operative outcomes**

Table 3 presents detailed operative outcomes. Operative times were available for 80 (96.4%) patients. Mean operative times were $227.2 \pm 65.1$ min and $340.6 \pm 78.7$ min for LARs and TaTMEs, respectively. Operative time was not significantly different between the three surgeons ($p = 0.92$). Intraoperative blood loss was available for 68 (81.9%) patients. Mean blood loss was $148.1 \pm 82.0$ mL for patients undergoing LAR and $247.9 \pm 282.6$ mL for patients undergoing TaTME. Overall, 30-day postoperative morbidity was 45.8%,

**Fig. 4** Rectal area as measured on 3D Slicer© (Version 4.11; Bethesda, MD)



**Fig. 5** Mesorectal package area (MPA) as measured on 3D Slicer© (Version 4.11; Bethesda, MD)
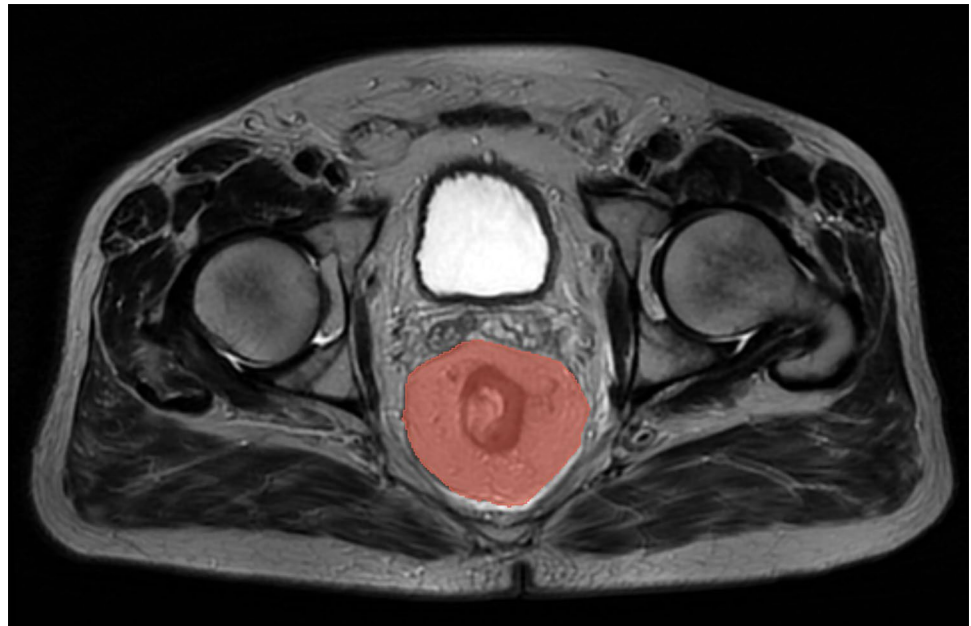


with the most common complications being postoperative ileus ($n = 18$, 21.7%), anastomotic leak ($n = 12$, 14.5%), and AUR ($n = 9$, 10.8%). There was no 30-day postoperative mortality. Median postoperative LOS following index surgery was 5 days (range: 2–63 days). Sixty-eight patients had pathology reports commenting on completeness of TME, 13 of which had incomplete TME (19.1%). TME completeness was not significantly associated with BMI nor any of the pelvic MRI measures. Oncologic outcomes beyond 30 days postoperatively included 3.4% mortality, 2.0% local recurrence, and 7.3% distant recurrence. Mean follow-up was 2.3 years.

## Factors associated with operative time

The associations between operative time in quartiles and patient characteristics, tumor characteristic, disease characteristics, intraoperative morbidity, and postoperative morbidity are presented in Table 4. Greater BMI was the only patient characteristic significantly associated with increasing operative time ($p = 0.03$). Shorter distance from the anal verge was the only tumor characteristic associated with increasing operative time ($p = 0.001$). Patients subjected to longer operative times were more likely to have undergone TaTME ($p < 0.001$). Increased

**Fig. 6** Bony pelvis area (BPA) as measured on 3D Slicer© (Version 4.11; Bethesda, MD)
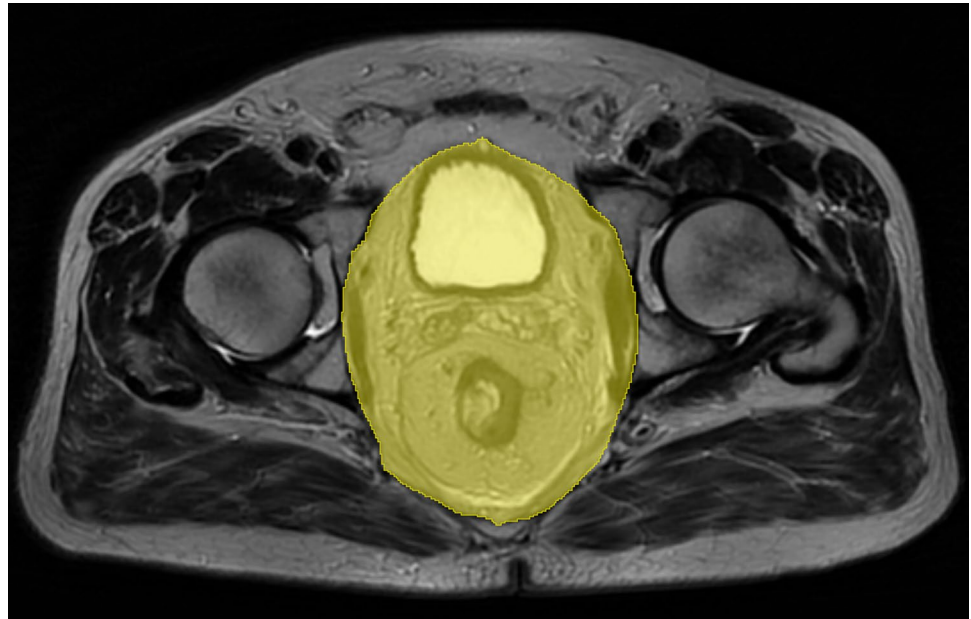


intraoperative blood loss ($p = 0.04$) was associated with significantly increased operative time. Postoperative morbidity was associated with longer operative time ($p < 0.001$).

## MRI characteristics

Mean mesorectal and pelvic MRI measures are reported in Table 5. None of the MRI measurements correlated strongly with BMI. AP-BP had the strongest positive correlation with BMI ($r = 0.47$) and L-MR had the strongest negative correlation with BMI ($r = -0.13$). Total MT ($r = 0.30$), anterior MT ($r = 0.27$), and posterior MT ($r = 0.19$) demonstrated weak positive correlations with increasing BMI. Interobserver variations in MRI measurements are summarized in Supplemental Table 1. The Spearman's correlation coefficients ranged from 0.74 to 0.99 ($p < 0.05$ for all measures).

## Operative times and MRI measurements

Univariable analysis of MRI mesorectal and pelvic measures demonstrated that larger AP-MR, posterior MT, Total MT, MPA, MFA, and AP-BP were significantly associated with increased operative time (Table 6). Upon removing collinear variables, multivariable analysis of MRI measures showed larger posterior MT and AP-BP were significantly associated with increased operative time (Table 6). On multivariable analysis including patient, tumor, and MRI factors, greater posterior MT remained significantly associated with increased operative time ($p = 0.04$). For every 1 mm increase in posterior MT, a 2 min and 6 s increase in operative time was noted (Table 7). Other factors significantly associated

with increased operative time on multivariable analysis included male gender ($p = 0.05$), greater BMI ($p = 0.04$), and shorter tumor distance from the anal verge ($p = 0.006$). Increased postoperative morbidity was both associated with significantly increased operative time ($p < 0.001$).

## Discussion

The obesity epidemic has a myriad of health-related consequences [22]. From a rectal cancer perspective, not only does obesity increase the risk of developing rectal cancer, but it also increases the technical difficulty of its surgical management [2, 20]. In an attempt to more accurately quantify the intraoperative difficulty associated with obesity in rectal cancer surgery, obesity has been correlated with MFA. Increasing MFA has been demonstrated to reflect increases in BMI, as well as predict increased operative time and intraoperative blood loss [8, 16, 17]. Nonetheless, there remains little data describing the relationship between mesorectal radiological measures and intraoperative complications in laparoscopic surgery for rectal cancer in North America. As such, the present study examined the relationship between 11 rectal MRI measurements and intraoperative difficulty, as measured by operative time and intraoperative blood loss, in a cohort of 83 patients who underwent laparoscopic LAR or TaTME between January 2015 and December 2019. Posterior mesorectal thickness was found to be a significant predictor of increased operative time ($p = 0.04$) and increased intraoperative blood loss ($p = 0.001$). A 1 cm increase in posterior mesorectal thickness was associated with a 26 min and 6 s increase in operative time and a 118.7 mL increase

**Table 2** Patient characteristics

| Characteristic | N (%)* N = 83 |
|---|---|
| Demographics | |
| Age, years (mean [SD]) | 62.4 (11.6) |
| Female | 33 (39.8) |
| BMI (mean [SD]) | 29.4 (6.2) |
| Smoker | 21 (25.3) |
| ASA | |
| II | 13 (15.7) |
| III | 59 (71.1) |
| IV | 9 (10.8) |
| Missing | 2 (2.4) |
| Pathologic T stage | |
| T0 | 13 (15.7) |
| T1 | 6 (7.2) |
| T2 | 34 (41.0) |
| T3 | 29 (34.9) |
| T4 | 1 (1.2) |
| Pathologic N stage | |
| N0 | 64 (77.1) |
| N1 | 15 (18.1) |
| N2 | 4 (4.8) |
| Pathological CRC stage | |
| 0 | 13 (15.7) |
| I | 32 (38.6) |
| IIa | 19 (22.9) |
| IIb/c | 0 |
| IIIa | 7 (8.4) |
| IIIb | 12 (14.5) |
| Tumor characteristics | |
| Distance from anal verge, cm (mean [SD]) | 9.5 (4.0) |
| Craniocaudal extent, cm (mean [SD]) | 3.9 (1.6) |
| Below anterior peritoneal reflection | 26/78 (33.3) |
| Mucinous | 4/69 (5.8) |
| Threatened CRM | 12/75 (16.0) |
| Operative characteristics | |
| LAR | 58 (69.9) |
| TaTME | 25 (30.1) |
| Diverting loop ileostomy | 68 (81.9) |
| Neoadjuvant therapy | 33 (39.8) |
| Adjuvant therapy | 30 (35.4) |

*N* number of patients, *SD* standard deviation, *BMI* body mass index (kg/m$^2$), *ASA* American Society of Anesthesiologist Score, *T* tumor, *N* nodal, *CRC* colorectal cancer, *cm* centimeters, *CRM* circumferential resection margin, *LAR* low anterior resection, *TaTME* transanal total mesorectal excision

*Values represent n (%) unless otherwise specified

**Table 3** Short-term and long-term operative outcomes

| Operative outcome | N (%)* N = 83 |
|---|---|
| Intraoperative | |
| Operative time, mins (mean [SD]) | 262.6 (87.0) |
| LAR | 227.2 (65.1) |
| TaTME | 340.6 (78.7) |
| Blood loss, mL (mean [SD]) | 183.3 (184.5) |
| LAR | 148.1 (82.0) |
| TaTME | 247.9 (282.6) |
| Anastomotic defect** | 5 (6.0) |
| Rectal perforation | 1 (1.2) |
| Short-term Morbidity† | |
| Overall | 36 (43.4) |
| Anastomotic leak | 9 (10.8) |
| Ileus | 18 (21.7) |
| sSSI | 2 (2.4) |
| Intra-abdominal abscess | 3 (3.6) |
| Atelectasis | 3 (3.6) |
| Pneumonia | 2 (2.4) |
| DVT | 1 (1.2) |
| MINS | 3 (3.6) |
| UTI | 3 (3.6) |
| AUR | 9 (10.8) |
| AKI | 1 (1.2) |
| LOS (median [range]) | 5 (2–63) |
| Reoperation | 5 (6.0) |
| Readmission | 15 (18.1) |
| Time to readmission, days (median [range]) | 7 (1–30) |
| Long-term outcomes‡ | |
| Mortality | 3/81 (3.7) |
| Local recurrence | 1/80 (1.3) |
| Distant recurrence | 6/80 (7.5) |
| Time to recurrence, months (mean [SD]) | 15.2 (7.3) |

*N* number of patients; mins, minutes, *mL* milliliters, *SD* standard deviation, *sSSI* superficial surgical site infection, *DVT* deep vein thrombosis, *MINS* myocardial injury in non-cardiac surgery, *UTI* urinary tract infection, *AUR* acute urinary retention, *AKI* acute kidney injury, *LAR* low anterior resection, *TaTME* transanal total mesorectal excision; LOS, length of stay

*Values represent n (%) unless otherwise specified

**Anastomotic defect = positive intraoperative leak test or intraoperative recognition of a hole in the rectum prior to intraoperative leak test

†Within 30 days postoperatively

‡Greater than 30 days postoperatively

in intraoperative blood loss. Male gender ($p = 0.05$), greater BMI ($p = 0.04$), and shorter tumor distance from the anal verge ($p = 0.006$) were also associated with significantly increased operative time. Interestingly, BMI did not correlate strongly with any mesorectal or pelvic MRI measurements.

Posterior mesorectal thickness is a simple and intuitive measure that was defined as the linear distance from the most posterior aspect of the muscularis propria of the rectum

**Table 4** Association between patient characteristics, tumor characteristics, operative characteristics, intraoperative morbidity, and postoperative morbidity and operative time

| | OR Time (Quartiles)* | | | | Total | P-Value |
|---|---|---|---|---|---|---|
| | 1st | 2nd | 3rd | 4th | | |
| | N = 20 | N = 20 | N = 20 | N = 20 | N = 80 | |
| OR time [mins] (SD) | 162.0 (33.2) | 226.4 (15.1) | 283.1 (22.9) | 379.1 (53.8) | 262.6 (87.0) | |
| Patient Characteristics** | | | | | | |
| Male | 10 (50.0) | 9 (45.0) | 14 (70.0) | 15 (75.0) | 48 (60.0) | 0.15 |
| Age (SD) | 60.5 (12.1) | 66.6 (10.1) | 61.6 (12.1) | 60.4 (12.5) | 62.3 (11.8) | 0.30 |
| BMI (SD) | 27.6 (4.5) | 27.3 (5.5) | 32.0 (7.7) | 31.1 (5.6) | 29.5 (6.2) | 0.03 |
| Neoadjuvant therapy | 4 (20.0) | 7 (35.0) | 9 (45.0) | 12 (60.0) | 32 (40.0) | 0.09 |
| Tumor Characteristics** | | | | | | |
| T3/4 | 7 (35.0) | 10 (50.0) | 10 (50.0) | 9 (45.0) | 36 (45.0) | 0.76 |
| Distance from Anal Verge [cm] (SD) | 12.4 (3.6) | 10.1 (5.6) | 8.7 (2.8) | 7.3 (2.2) | 9.5 (4.1) | 0.001 |
| Craniocaudal extent [cm] (SD) | 3.5 (1.2) | 4.5 (1.3) | 3.6 (1.5) | 3.9 (2.1) | 3.9 (1.6) | 0.21 |
| Threatened CRM | 2/15 (13.3) | 5/19 (26.3) | 1/18 (5.6) | 4/20 (20.0) | 12/72 (16.7) | 0.38 |
| Operative Characteristics** | | | | | | |
| LAR | 19 (95.0) | 18 (90.0) | 13 (65.0) | 5 (25.0) | 55 (68.8) | < 0.001 |
| TaTME | 1 (5.0) | 2 (10.0) | 7 (35.0) | 15 (75.0) | 25 (31.2) | < 0.001 |
| Intraoperative Morbidity** | | | | | | |
| Blood loss [mL] (SD) | 117.5 (59.9) | 185.3 (80.6) | 134.5 (89.1) | 278.9 (307.9) | 185.3 (185.2) | 0.04 |
| Anastomotic defect† | 0 | 0 | 2 (10.0) | 3 (15.0) | 5 (6.3) | 0.16 |
| Postoperative Morbidity** | | | | | | |
| Overall | 6 (30.0) | 3 (15.0) | 11 (55.0) | 15 (75.0) | 35 (43.8) | < 0.001 |
| LOS [d] (SD) | 4.0 (1.5) | 8.4 (13.6) | 8.0 (4.9) | 10.1 (13.1) | 7.6 (9.8) | 0.25 |

*OR* operating room, *N/n* number of patients, *SD* standard deviation; mins, minutes, *BMI* body mass index, *MRI* magnetic resonance imaging, *IS* interspinous distance, *AP-BP* anterior–posterior bony pelvis span, *L-MR* lateral mesorectal span, *AP-MR* anterior–posterior mesorectal span, *MT* mesorectal thickness, *MPA* mesorectal package area, *MFA* mesorectal fat area, *BPA* bony pelvis area, *Extra-MPA* extra-mesorectal fat area, *ant.* anterior; post., posterior, *LAR* low anterior resection, *TaTME* transanal total mesorectal excision; cm, centimeters, *CRM* circumferential resection margin, *mL* milliliters, *LOS* length of stay, *d* days

*Quartiles: Q1 = 115-204 min; Q2 = 210-249 min; Q3 = 253-314 min; Q4 = 315-510 min

**Values represent n (%) unless otherwise specified

***Measurements in mm and mm$^2$ unless otherwise specified

†Anastomotic defect = positive intraoperative leak test or intraoperative recognition of a hole in the rectum prior to intraoperative leak test

to the most posterior aspect of the mesorectal fascia. Previous studies have demonstrated higher rates of intraoperative and postoperative morbidity with increasing MFA and decreasing bony pelvis measures, but none have measured posterior mesorectal thickness [8, 17, 23]. The majority of the mesorectal fat is distributed posterior to the rectum; therefore, perhaps, the measurement of posterior mesorectal thickness more accurately encompasses mesorectal bulk [24]. Intraoperatively, the posterior mesorectal fascial plane is often the first to be incised [25]. Greater posterior mesorectal thickness may increase the amount of time and dissection required to identify the correct anatomical plane, as well as increase the difficulty of maintaining adequate retraction anteriorly for visualization of the deep pelvic planes [26]. As the procedure advances caudally, careful dissection of the posterior plane is of the utmost importance as breaching

the mesorectal fascia anteriorly can increase the risk of local recurrence and breaching the presacral fascia posteriorly can damage sacral nerves as well as the presacral plexus [27]. Disruption of the presacral plane in particular may lead to intraoperative bleeding [28]. Altogether, a larger posterior mesorectum potentially increases the technical difficulty associated with these aspects of a TME given the significant association with increased operative time and intraoperative blood loss in the present study. In contrast to previously developed pelvimetric scores to predict intraoperative difficulty, posterior mesorectal thickness is a single measure easily obtainable on any MRI or computed tomography (CT) software [17, 29]. Therefore, consideration to highlighting this value on preoperative MRI or CT reports may help surgeons better predict operative difficulty and plan operations accordingly.

**Table 5** Overall MRI measurement characteristics

| MRI Characteristic | Mean (SD) N=83 |
|---|---|
| Mesorectal Measures | |
| L-MR* | 79.1 (8.1) |
| AP-MR* | 61.5 (12.2) |
| Ant. MT* | 13.3 (5.3) |
| Post. MT* | 18.1 (7.3) |
| Total MT* | 29.2 (9.1) |
| MPA† | 5270.2 (2243.6) |
| MFA† | 3552.3 (1674.0) |
| Pelvic measures | |
| IS* | 107.7 (12.9) |
| AP-BP* | 145.9 (18.3) |
| BPA† | 20,679.3 (7519.3) |
| Extra-MPA† | 15,409.1 (5912.3) |

*MRI* magnetic resonance imaging, *IS* interspinous distance, *AP-BP* anterior–posterior bony pelvis span, *L-MR* lateral mesorectal span, *AP-MR* anterior–posterior mesorectal span, *MT* mesorectal thickness, *MPA* mesorectal package area, *MFA* mesorectal fat area, *BPA* bony pelvis area, *Extra-MPA* extra-mesorectal fat area, *ant.* anterior; *post.*, posterior

*Measurements in mm

†Measurements in mm$^2$

Considering the impact of posterior mesorectal thickness on operative time and intraoperative blood loss, it may also have the potential to be an important modifiable risk factor in rectal cancer patients. Current pre-habilitation programs for colorectal cancer patients are aimed at optimizing patients' functional and nutritional statuses in the weeks prior to surgery [30, 31]. While these are important factors, younger obese colorectal patients may derive greater benefit from pre-habilitation strategies geared toward weight loss and decreasing visceral adiposity [10]. For example, a four-week course of a very low energy diet (VLED) with Optifast© significantly decreased mesorectal fat volume on MRI in a cohort of bariatric surgery patients [32]. Employing pre-operative VLEDs in obese rectal cancer patients could have the same benefit, thus decreasing posterior mesorectal thickness, and potentially improving intraoperative and postoperative outcomes. The current study in this area is underway (NCT0437930; ACTRN12615000941561). Moreover, posterior mesorectal thickness may be an important variable to consider during the preoperative planning phase. If demonstrated on preoperative MRI, extensive posterior mesorectal thickness could prompt consideration for booking a longer operative time or relying on advanced laparoscopic techniques, such as robotic-assisted surgery. Robotic-assisted TME is less likely to be impacted by difficult pelvic anatomy and allows more degrees of freedom during dissection within the confines of a narrow bony pelvis [33, 34].

**Table 6** Univariable and multivariable analyses of the association between MRI characteristics and operative time [mins] for low anterior resections and transanal total mesorectal excision

| | Univariable | | | Multivariable | | |
|---|---|---|---|---|---|---|
| | OR Time | | | OR Time | | |
| | Coefficient | 95% CIs | P-Value | Coefficient | 95% CIs | P-Value |
| Mesorectal measures | | | | | | |
| L-MR [mm] | − 1.23* | − 3.62 to 1.16 | 0.31 | − 2.16* | − 4.83 to 0.52 | 0.11 |
| AP-MR [mm] | 2.49* | 1.00 to 3.98 | 0.001 | 0.12* | − 3.48 to 3.72 | 0.95 |
| Ant. MT [mm] | 0.81* | − 3.02 to 4.65 | 0.67 | – | – | – |
| Post. MT [mm] | 4.88* | 2.47 to 7.28 | <0.001 | 5.09* | 0.59 to 9.59 | 0.03 |
| Total MT [mm] | 3.38* | 1.40 to 5.36 | 0.001 | − 1.93* | − 6.98 to 3.12 | 0.45 |
| MPA [mm$^2$] | 1.06† | 0.18 to 1.93 | 0.02 | 1.32** | − 3.01 to 5.66 | 0.55 |
| MFA [mm$^2$] | 1.58† | 0.40 to 2.75 | 0.009 | − 0.75** | − 5.38 to 3.87 | 0.75 |
| Pelvic measures | | | | | | |
| AP-BP [mm] | 1.67* | 0.65 to 2.70 | 0.002 | 1.56* | 0.01 to 3.12 | 0.05 |
| IS [mm] | − 0.61* | − 2.12 to 0.91 | 0.43 | − 0.44* | − 2.05 to 1.18 | 0.59 |
| BPA [mm$^2$] | 0.24† | − 0.05 to 0.52 | 0.10 | 0.003** | − 0.75 to 0.75 | 0.99 |
| Extra-MPA [mm$^2$] | 0.21† | − 0.16 to 0.58 | 0.26 | – | – | – |

*OR* operating room, *CI* confidence intervals, *MRI* magnetic resonance imaging, *IS* interspinous distance, *AP-BP* anterior–posterior bony pelvis span, *L-MR* lateral mesorectal span, *AP-MR* anterior–posterior mesorectal span, *MT* mesorectal thickness, *MPA* mesorectal package area, *MFA* mesorectal fat area, *BPA* bony pelvis area, *Extra-MPA* extra-mesorectal fat area, *ant.* anterior; *post.*, posterior, *mm* millimeter, *mins* minutes

*Variation in operative time in minutes for every 1 mm increase in MRI measure

†Variation in operative time in minutes for every 100mm$^2$ increase in MRI measure

**Table 7** Multivariable analyses of the association of patient demographic, tumor, disease, and MRI characteristics [mm] with operative time [mins] for low anterior resections and transanal total mesorectal excision

| Characteristic | OR Time | | |
|---|---|---|---|
| | Coefficient | 95% CIs | *P*-Value |
| Post. MT [mm]* | 2.61 | 0.08 to 5.14 | 0.04 |
| Age, years | 0.60 | − 0.88 to 2.07 | 0.42 |
| Male | 35.83 | 0.03 to 71.63 | 0.05 |
| BMI | 3.07 | 0.20 to 5.95 | 0.04 |
| Neoadjuvant therapy | 14.15 | − 26.70 to 55.01 | 0.49 |
| Distance from anal verge, cm | − 6.35 | − 10.82 to − 1.89 | 0.006 |
| Preoperative T stage 3/4 | − 10.40 | − 49.03 to 28.22 | 0.59 |

*OR* operating room, *MT* mesorectal thickness, *post.* posterior, *cm* centimeter, *BMI* body mass index, *CI* confidence interval, *mm* millimeter, *mins* minutes, *T* tumor

*Variation in operative time in minutes for every 1 mm increase in posterior mesorectal thickness

Increasing anterior bony pelvis span, defined as the linear distance from the most posterior aspect of the symphysis pubis anteriorly to the most anterior aspect of the coccyx posteriorly, also correlated significantly with increased operative time ($p = 0.05$). This is somewhat counterintuitive given the assumption that a larger bony pelvis structure provides increased operative domain and thus decreased technical difficulty. However, previous study has more consistently highlighted increasing pelvic width, not anterior–posterior span, as an indicator of decreased intraoperative difficulty [35, 36]. Moreover, anterior–posterior pelvis span demonstrated the strongest correlation with BMI ($r = 0.47$) and thus may be reflective of the association between increasing operative time and increasing BMI [7, 8, 37].

This study has several limitations. First, there were only 83 patients that met inclusion criteria. This limited statistical power and thus other significant predictors of increased operative time may not have been identified. For example, in a previous study including 98 patients, MFA was identified as a significant predictor of operative time, but in the present study, this was not found ($p = 0.75$) [8]. Moreover, the low number of included patients limited the number of postoperative complications observed ($n = 46$) and precluded adequately powered statistical analysis aimed at determining the relationship between mesorectal and pelvic MRI measures and postoperative outcomes. Second, missing data from surgeon and institutional EMRs further limited statistical analysis. For example, intraoperative blood loss was only recorded for 81.9% of included patients. Furthermore, pre-neoadjuvant therapy MRIs were analyzed for patients in which post-neoadjuvant therapy MRIs were not available. While there are no data to suggest significant changes in

mesorectal measures due to neoadjuvant radiotherapy, it may have introduced heterogeneity to the population of analyzed MRIs [38]. Third, the single-center, retrospective nature of the present study increases the risk of bias of the observed results and decreases generalizability. However, patient demographics and treatment outcomes align with previously reported North American data and offer reassurance as to the generalizability of the observed results [39, 40]. Nonetheless, there remain multiple possible confounders that are important to consider when interpreting the results of the present study, such as nuanced operative techniques (e.g., splenic flexure mobilization, type of anastomosis) and patient variables (e.g., BMI, gender, prior pelvic operations, or radiation). Fourth, including patients undergoing LARs and TaTMEs introduced heterogeneity into the study population and may have slightly decreased the applicability of the effect estimate derived from our data. Despite TaTMEs having significantly longer operative times than LARs, there are no current data suggesting that mesorectal measures differ between patients undergoing LAR and TaTME. Fifth, 3D Slicer© is not a standard component of the MRI workstation and thus its use limits generalizability of some of the MRI measurements. Nonetheless, the mesorectal measurement that correlated best with operative difficulty, posterior mesorectal thickness, is a simple linear measurement that can be completed with the standard "ruler" function available on standard Picture and Archiving Communication Systems (PACS). Lastly, total operative time was used as a surrogate measure for intraoperative difficulty. Previous studies have suggested that pelvic dissection times are a more accurate reflection of the impact of mesorectal bulk in rectal cancer surgery; however, these data were not available through the St. Joseph's Healthcare Hamilton EMR [8]. Nonetheless, major factors influencing total operative time, such as multivisceral resections and conversion to open procedure, were excluded from the present study.

As the number of obese rectal cancer patients continues to expand, strategies aimed at optimizing the surgical management of this challenging patient population are paramount. Identifying which patients will present operative difficulty is the first step in optimizing management. While greater BMI is an important preoperative risk factor, the present study identifies posterior mesorectal thickness on MRI as a reliable and easily measurable parameter to predict whether patients may benefit from perioperative interventions to improve operative conditions. Specifically, this study suggests that male patients with low rectal tumors, elevated BMI, and large posterior mesorectums pose heightened intraoperative difficulty as measured by operative time. These patients should be considered for enhanced laparoscopic approaches (e.g., robotic-assisted surgery), preoperative VLED, or be booked for longer operative duration with high-level assistance in the operating room. Future

work should aim to validate these findings prospectively as well as identify the impact of decreasing mesorectal bulk through pre-habilitation interventions such as VLED.

## Declarations

**Disclosures** Dr. Eskicioglu, Dr. Hong, Dr. Doumouras, Dr. Amin, Dr. Cadeddu, Dr. Rebello, Dr. Noseworthy, Mr. Kruse, Dr. Ramji, and Dr. McKechnie do not have proprietary or commercial interest in any product mentioned or concept discussed in this article to report.

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