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ORIGINAL ARTICLE

Splenic flexure mobilization: does body topography matter?

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Abstract

Background Splenic flexure mobilization can be technically challenging, and its oncological benefits remain uncertain. This study aims to explore the relationship between patient and clinical characteristics and splenic flexure mobilization time as well as the implications of prolonged splenic flexure mobilization duration.

Methods This retrospective cohort study includes 105 patients who underwent laparoscopic distal colorectal cancer surgery between 2013 and 2018. The study analyzed patient characteristics, duration of surgical steps, and postoperative outcomes. Splenic flexure mobilization time was assessed using operation videos, and the impact of patient-related factors on splenic flexure mobilization complexity was examined.

Results The study identified significant correlations of higher body mass index (BMI) ($p=0.0086$), weight ($p=0.002$), and height ($p=0.043$) with longer splenic flexure mobilization time. Gender did not significantly influence splenic flexure mobilization duration. Splenic flexure mobilization time was correlated with the durations of other individual surgical steps (Step 1: medial-to-lateral dissection [$p=0.0013$], Step 2: pelvic dissection [$p=0.067$], Step 3: dissection of white line and mobilization of descending colon [$p=0.0088$], Step 5: stapling, resection, extraction of the specimen, and anastomosis [$p=0.04$]) and the overall operation time ($p<0.0001$). A 10-min cutoff point predicts the total operation time more efficiently than other potential thresholds.

Conclusion This research suggests that patient characteristics including BMI, weight, and height may serve as indicators for prolonged splenic flexure mobilization time in laparoscopic distal colorectal cancer surgery. Longer splenic flexure mobilization durations were correlated with extended durations of other surgical steps. A BMI-based approach to anticipate SFM duration may enhance preoperative planning, potentially aiding in surgical decision-making.

Trial registration E-10840098–772.02–61604 2.2.2019.

Keywords Sigmoid colon cancer · Rectal cancer · Splenic flexure · Laparoscopy

Introduction

Splenic flexure mobilization (SFM) is a commonly preferred maneuver when completing distal colectomies, in either open or minimally invasive surgeries. It requires the separation of the connections between the left side of the transverse colon and adjacent tissues, ligaments, and attachments. SFM may be critical for a good blood supply at the proximal remnant, particularly if high ligation of inferior mesenteric vessels is the case for oncological purposes. Accordingly, it is generally believed to be essential while performing low anterior resections (LAR) where a longer proximal remnant is necessary to obtain a tension-free anastomosis in the deep pelvis [1–3]. Since the decision for SFM seems to be a technical issue, but its oncological benefit has not been clarified, some have offered selective use of SFM because of

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the technical difficulty of this step and perceptive increases of intra- and postoperative risks [4, 5]. They propose SFM only when it is necessary, specifically if the anastomosis is in danger because of the tension. Accordingly, they reserve the implication of SFM only for low rectal tumors, where an anastomosis at the deep pelvis is needed. For sigmoidal or more proximal cancers, partial SFM may be considered with a tailored tension-free connection; rarely, it may not be needed and completely skipped [5–8]. The debate continues regarding which approach is more reasonable for routine practice. Despite these different perceptions regarding SFM, it is inevitable for distal colorectal cancer surgery, which surgeons may routinely or at least selectively perform in most patients with distal colorectal cancer.

Although several technical notes have been offered to ease SFM, it continues to be a challenging step at the time of laparoscopy [9–11]. In a survey, surgeons rated the difficulty of the key components of laparoscopic rectal operations, where the highest difficulty score was reported for SFM [12]. Moreover, the SFM time may differ from patient to patient, and factors affecting the difficulty and duration of SFM have not been well studied. Any presurgical measure indicating the potential complexity of SFM may help the surgeon develop a better planning of the surgery. As part of these pre-surgical markers, obesity was perceived as an augmenting risk in general surgery outcomes, since performing surgery on obese patients, especially for colorectal cancer, poses greater technical challenges [13]. Therefore, this study also aims to investigate the association between patients' body characteristics and SFM time in laparoscopic distal colorectal cancer surgery.

Method

Study design

This study is a single-center retrospective cohort study with the institutional review board approval from Medipol University Ethics Committee (E-10840098–772.02–61604). All surgeries were performed by the same board-certified colorectal surgeon. All patients provided written consent for the surgical procedures and for the collection and use of their data in clinical studies. The patients' demographic, anthropometric, and clinical data were extracted from our colorectal cancer database, which has been in use at the Department of Surgery since 2012. However, the assessment of and data extraction from the operation videotapes was prospectively completed after IRB approval of the study design.

Patients

Inclusion criteria included patients > 18 years old having elective laparoscopic anterior resection (AR) or low anterior resection (LAR) for histologically proven distal sigmoid or rectal cancer between 2013 and 2018.

The study excluded patients with open and robotic procedures as these procedures had not been video-recorded, abdominoperineal resections as they did not require SFM, ultra-LAR with coloanal handsewn anastomosis as duration of anastomosis for such cases could not be calculated, and patients having procedures for benign diseases, stage IV disease (which necessitated additional procedures for metastases), recurrent tumors, synchronous or metachronous tumors, emergent procedures (obstruction, bleeding), and cancers accompanying inflammatory bowel diseases. At our institution, complete SFM was a routine step for all cases with distally located cancers during the study period. Since it was impossible to calculate the periods of the operative steps in converted patients, conversion to open surgery was considered another exclusion criterion.

All patients had the same preoperative workup. Pelvic MRI was used for local staging of rectal tumors. Rigid sigmoidoscopy and/or imaging techniques were used to classify tumor location, and those located 0 to 6 cm, 5 to 12 cm, and 12 to 15 cm from the dentate line were defined as lower, mid, and upper rectal tumors, respectively, considering the distal border of the mass. Those above the peritoneal reflection or > 15 cm from the dentate line and at the border of the promontorium were considered distal sigmoid cancers. For complicated cases, management plans were finalized with the consultation of the institutional multidisciplinary oncology council. Neoadjuvant long course chemoradiotherapy consisted of 45 to 50.4 Gy irradiation and concomitant 5-flourouracil infusions of 225 mg/m^2/day. 5-Flourouracil infusions were applied for locally advanced (T3 or T4 or node-positive) low or mid-rectal tumors. The interval between chemoradiotherapy and surgery was between 8 and 11 weeks in most cases. The performance status of the patients was assessed by the American Society of Anesthesiologists (ASA) classification [14]. Patient comorbidities were collected, including hypertension and congestive heart disease, diabetes mellitus, chronic obstructive pulmonary disease, and chronic kidney disease.

Surgery

All patients received mechanical bowel preparation and venous thromboembolism prophylaxis. Intravenous 1.5 g cefuroxime axetil (Aksef IV, Nobel, Istanbul, Turkey) and 500 mg metronidazole (Flagyl IV, Eczacibasi, Istanbul, Turkey) were administered 30 min before surgery and repeated every 3 to 4 h. Total mesorectal excision was performed for mid- and low-rectal tumors. Upper rectal and distal sigmoid tumors were resected with partial mesorectal excision. Surgery aimed to cover a minimum of 2 cm of the distal margin, and if it was < 1 cm, it was defined as a positive distal margin. The type of surgery was categorized as AR if the anastomosis was above the peritoneal reflection and as LAR if the anastomosis was below the reflection. All procedures were performed or supervised by the same board-certified colorectal surgeon who has advanced laparoscopy experience.

The laparoscopic distal colorectal cancer operation technique consists of a stepwise approach. It includes a medial-to-lateral approach with high ligation of the inferior mesenteric artery and vein. It is followed by the dissection of the holy plain and mobilization of the rectum. It continues through the white line and Toldt's fascia lateral to descending colon up to the spleen. Then, the connections between the left side of the transverse colon and the adjacent tissues are separated, and the splenic flexure is completely mobilized. At this stage, phreno-colic, spleno-colic, and gastro-colic ligaments, omentum, and pancreato-mesocolic attachments are divided until the Treitz ligament, and the previously high-ligated inferior mesenteric vein is seen over the mobilized transverse colon and splenic flexure (Fig. 1). As previously described in a report from our institution, we routinely place a midline trocar between the umbilicus and xiphoid to ease SFM instead of the left upper quadrant, which is more commonly preferred at other institutions [2]. The camera is moved to this trocar before finishing the SFM to achieve an enhanced view towards the spleen during this maneuver. After completion of SFM, the camera returns to the umbilical trocar, and the rectal transection is performed with linear staplers, specimen samples are extracted through a Pfannenstiel incision, and a double-stapled anastomosis is carried out. After the air-leak test, a pelvic drain is routinely placed and removed on postoperative day 5 if no intra-abdominal complication occurs.

Postoperative follow-up

Intravenous antibiotics were not given postoperatively unless there were signs of an infection in patients' laboratory findings or daily examinations. Any intestinal discharge or a pelvic abscess originating from the anastomosis detected either radiologically or clinically, or any clinical evidence of enteric fluid, pus, or air in the drains was defined as an anastomotic leak. No routine abdominal imaging was performed unless there was clinical suspicion of complications. Computed tomography was performed if clinical signs or laboratory findings (e.g., fever, abdominal tenderness, prolonged ileus, elevated white blood cells) were observed. Postoperative complications were analyzed, considering the Clavien-Dindo scoring system. Perioperative mortality was defined as death occurring within 30 days of surgery or during the surgery-related hospitalization

Assessment of operation videos and surgical steps

A special data collection form was created to capture the durations of the procedural steps before the initiation of the study. An external reviewer, a surgeon (HA) from another institution, watched all the operation videos and prospectively recorded the duration of operative steps as minutes.

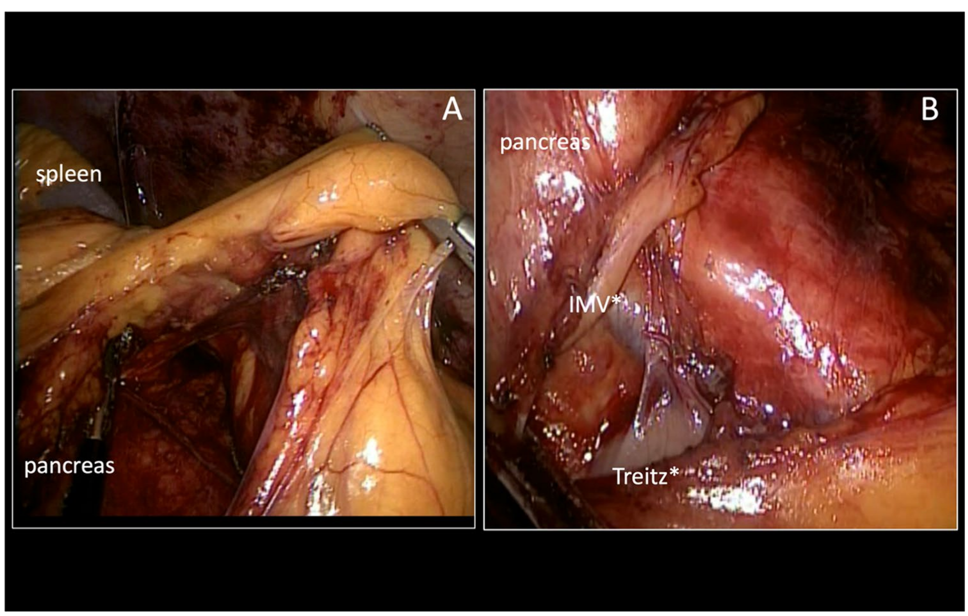

Fig. 1 The attachments and ligaments are dissected (**A**) until the Treitz ligament and previously ligated inferior mesenteric vein are seen above the mobilized colon (**B**)

The external reviewer was blinded to the patients' information, surgeon, operative details, postoperative courses, and complications. The operative steps were described as follows:

Step 1: medial-to-lateral dissection, including dividing the peritoneum, high ligations of the inferior mesenteric artery and vein, and dissection of the Toldt's fascia until the lateral white line is seen;

Step 2: pelvic dissection;

Step 3: dissection of the white line and mobilization of the left colon until the inferior border of the spleen;

Step 4: SFM (this period was easy to calculate since, as mentioned in our previous study, SFM was completed when the camera was moved to the midline trocar between the umbilicus and xiphoid, and after finishing this step, the camera was placed back to the umbilical trocar) [2];

Step 5: stapling, resection, extraction of the specimen, and anastomosis.

While calculating the durations of operative steps, only active operating time was counted in, and the intervals, including waiting periods where the camera was out of the abdomen for cleansing or breaks for the preparation of the devices, were measured and subtracted from the total time of the relevant step.

Finally, a significant cutoff SFM time was calculated to predict total operation time.

Statistical analysis

The primary outcome measure was SFM duration (Step-4) calculated from the operation videos, and the primary analysis objective was to assess the association of patient characteristics with SFM duration.

Categorical variables were presented as frequency and percentages, and the existence of an association between two categorical factors was assessed using the chi-square test. Continuous variables were expressed as mean and standard deviation or median and range as appropriate, and their distributions across the levels of a factor of interest were compared by Wilcoxon-Mann-Whitney or Kruskal-Wallis tests, which are the non-parametric counterparts of two-sample *t*-tests and one-way ANOVA, respectively. To describe the association between two continuous markers, Spearman's rank correlation coefficient was estimated. The sources of the variation in SFM time (primary analysis) were modeled through the linear regression framework. We investigated the association between SFM duration and BMI as both a continuous variable and a categorical variable of normal weight (BMI $\leq$ 25), overweight (BMI 25–30), and obese (BMI > 30) participants. We also investigated the multivariable associations of BMI, height, and weight with SFM duration in linear regression models.

All analyses were performed using SAS® Version 9.4 (Cary, NC, USA). *P*-values < 0.05 indicated statistical significance, and the *p*-values were not adjusted for multiple testing; therefore, the results must be considered in a hypothesis-generating context.

Results

Patient characteristics and operative measures

One hundred eighty-one patients were assessed for eligibility, and 76 patients (41.9%) were excluded: 17 patients (9.4%) because of missing data, and 59 patients (32.6%) because of the lack of surgical video materials, leaving 105 patients as the final analysis cohort. Of those, 62 (59%) patients were male, the median age (interquartile range [IQR]) was 63 (52–67) years, and the median BMI was 27 (17–46) kg/m². Forty-one (39%) and 64 (61%) patients underwent AR and LAR, respectively. Patient and disease characteristics were comparable between AR and LAR patients, except that neoadjuvant therapy and ileostomy rates were higher in the LAR group, and operation time was longer in the LAR patients, related to the longer pelvic dissection time (step 2) in these patients (Table 1).

Prediction and consequences of a longer SFM duration

SFM time was significantly positively rank-correlated with BMI ($p = 0.0086$), weight ($p = 0.002$), and height ($p = 0.043$). SFM duration was found to be rank-correlated with the other procedural steps (except step 2) as well as SFM duration and total operation time (Table 2). BMI categorization as normal weight, overweight, and obese was found to be associated with SFM duration as expected ($p < 0.0001$). However, no significant relationship was found between the male-to-female ratio and the duration of SFM ($p = 0.17$).

During the study period, no specific intraoperative complications related to SFM were observed, including inadvertent hollow organ injury or bleeding secondary to splenic capsular or mesenteric tears. A total of 39 complications (Clavien-Dindo grade 1 in 7, grade 2 in 27, and grade 3 in 5 cases) were observed in 20 (19%) patients. Five (4.8%) patients had anastomotic complications: two patients (1.9%) had pelvic abscesses without peritonitis and were treated by percutaneous drainage and intravenous antibiotics, and three patients (2.8%) experienced a free peritoneal leak and required reoperations. All were treated with diverting ileostomies and pelvic lavage. There were no Clavien-Dindo grade 4 or 5 (perioperative or 30-day mortality) complications. Lengthened SFM duration did not worsen perioperative measures.

Table 1 Demographics, clinical and surgical characteristics of the study patients

	$n = 105$
Gender	
Male	62 (59%)
Female	43 (41%)
Age (years, median, IQR)	63 (52–67)
BMI (kg/m^2, median, IQR)	27 (17–46)
Weight (kg, median, IQR)	72 (66–85)
Height (cm, median, IQR)	164 (157–173)
Comorbidity (any) (+)	40 (38%)
Hypertension and chronic heart disease	31 (30%)
Diabetes mellitus	15 (14%)
Chronic obstructive pulmonary disease	10 (10%)
Chronic kidney disease	1 (1%)
ASA score	
1	33 (31%)
2	65 (66%)
3	3 (3%)
Previous abdominal surgery (+)	17 (16%)
Neoadjuvant treatment (+)	63 (60%)
Intraoperative blood loss (ml, median, IQR)	50 (0–700)
Blood transfusion (+)	29 (26.7%)
Ileostomy (+)	53 (50%)
Operative time* (min, median, IQR)	102 (43–200)
Operation steps (min, median, IQR)	
Step 1	26 (10–69)
Step 2	21 (3–63)
Step 3	4 (2–17)
Step 4 (SFM time)	10 (3–32)
Step 5	5 (1–31)
Complications	
Clavien-Dindo 1–2	34 (32.4%)
Clavien-Dindo 3–5	5 (4.8%)
Anastomotic complications (+)	5 (4.8%)
Hospital stays (days, median, IQR)	6 (3–35)
Tumor size (cm, mean ± SD)	3.9 ± 1.9
pT stage	
0	13 (13%)
1	9 (8%)
2	13 (12%)
3	57 (54%)
4	13 (12%)
Number of harvested lymph nodes (n, IQR)	25 (18–33)
pN stage	
0	60 (57%)
1	32 (30%)
2	13 (12%)
Length of the specimen (cm, mean ± SD)	23.7 ± 6.3
Proximal margin (cm, mean ± SD)	12.4 ± 5
Distal margin (cm, mean ± SD)	5.9 ± 3.8
Positive distal margin (+)	4 (3.8%)

BMI body mass index, *ASA* American Society of Anesthesiologists, *SD* standard deviation, *SFM* splenic flexure mobilization

*Operative time includes active operating time with waiting periods

Table 2 Correlation between duration of SFM and other steps of the operation ($n = 105$)

Measures	Correlation coefficient (confidence interval, CI)*	p-value
Age	−0.03 (−0.22, 0.16)*	0.78
BMI (kg/m^2)	0.29 (0.07, 0.47) *	0.0086
Weight	0.31 (0.11, 0.47) *	0.002
Height	0.21 (−0.01, 0.41) *	0.043
Operation steps (min)		
Step 1	0.32 (0.12, 0.47)*	0.0013
Step 2	0.18 (−0.01, 0.36)*	0.067
Step 3	0.26 (0.07, 0.42) *	0.0088
Step 5	0.24 (0.01, 0.43)*	0.04
Operation time	0.48 (0.28, 0.59)*	< 0.0001

To propose a cutoff value of SFM time in predicting total operation time, we analyzed different potential SFM time cutoffs from 8 to 20 min and assessed the predictive ability through R-square measure and p-values in linear regression models. These models revealed that a 10-min cutoff point (that is SFM time < 10 vs ≥ 10 min) predicts the total operation time more efficiently than other potential thresholds with R^2 of 0.165 ($p < 0.0001$), while the other cutoff values have R^2 values < 0.15.

Discussion

Despite being a challenging step, SFM is at least selectively necessary while performing distal colorectal cancer surgery [15]. Therefore, in surgical planning it might be critical to consider the patient characteristics indicative of a difficult SFM and the perioperative outcomes and potential complications of a longer SFM duration. Being able to predict whether or not the patient needs a prolonged SFM before surgery could help with better surgical decisions and planning. Currently, a significant knowledge gap still exists in this field, as only very few studies have focused on this specific issue [16, 17]. Our data revealed that patient anthropometrics, especially higher weight and BMI, are associated with longer SFM durations. In a previous study by Kawai et al., body weight was found to be correlated with lengthened SFM in univariable analysis, but the study did not include BMI or height [18]. Although several other studies have shown that increased BMI is associated with difficult operation scores, lengthened operation time, and increased risk for conversion during laparoscopic rectal cancer surgery, they have not specifically investigated the correlation between SFM duration and BMI [18–20]. We have found that SFM duration was significantly correlated with BMI. This correlation was also obvious when BMI was categorized as normal weight, overweight, and obese; as expected, multivariable models have revealed that weight may be as important as BMI in predicting the SFM duration.

We further investigated a possible cutoff value to define what would be considered a prolonged SFM. Although subjective, an SFM cutoff value of ≥ 10 min to define the prolonged SFM resulted in the most significant association with BMI and total operation time in our study cohort. We recognize that there is no evidence regarding whether either SFM time or any of its possible cutoffs may be associated with any postoperative disease outcomes. Therefore, this definition of prolonged SFM as ≥ 10 min and its impact on surgical practice and postoperative disease outcome need to be confirmed in future prospective studies. If future studies show such a potential effect, then the surgeon may consider changing the surgery plan based on this information.

It has long been believed that male gender is a risk factor for difficult SFM [21]. However, the current study does not support this hypothesis and has not revealed any significant association between gender and SFM duration. In our opinion, further studies may better focus on novel measures or calculations that will be obtained from different instruments, such as CT and magnetic resonance imaging findings, to discover new tools for the prediction of lengthened SFM. There is still an absence of evidence regarding other structural abnormalities such as previous abdominal surgery or the actual location of splenic flexure to better explain the difficulty and duration of SFM time.

The current study has categorized the operation into sections, and the durations of the surgical intervals have been separately calculated from the operation videos. We have observed strong correlations between the durations of SFM and other steps, except for a borderline significance ($p = 0.067$) between the durations of SFM and step 2. This insignificance may be related to the fact that patients in the current analysis were treated with AR or LAR, which obviously necessitated different pelvic dissection periods. A positive correlation of SFM duration with the intervals of other steps is a significant finding as it indicates that if longer pre-SFM steps result in a difficult and time-consuming SFM, in turn, longer SFM leads to the increase in the intervals of other subsequent steps and total operation time.

This study has several strengths. First, the study design is unique since a blinded investigator from another institution assessed the operative videos and calculated different well-defined steps of the operation. Second, in this study, subtraction of waiting periods and gaps when the camera was out of the abdomen was performed on the total time of the relevant step. So, supportive intervals at the time of the operation, such as for warming the camera or periods for preparing the devices, have been removed so that more precise calculations of the operation times in each step can be obtained. The fact that the study included a single surgeon for the operations in a single center and a single blinded surgeon for the central review also strengthened the paper as the results were not affected by potential interoperator variation.

Our study also has several weaknesses, one of which is its retrospective nature, as we relied on the available data, leading to the exclusion of 76 patients from the initial 181 potentially eligible patients, limiting our final analysis cohort. This reduced reliability and generalizability of our findings may be particularly true for some patient-related measures, including comorbidities, and some postoperative outcomes, including complications as they are rare incidents. We also had to remove a limited number of conversion cases ($n = 3$), and the conversion decision may sometimes be due to a challenging SFM although it was not the case in this particular study, and the exclusion of these three cases was necessary for the current study as it was impossible to calculate the duration of each of the operative steps accurately in such conversion cases.

Conclusion

The current study has analyzed the possible risk factors for and consequences of lengthened SFM duration at the time of laparoscopic distal colorectal resections for cancer. Only BMI, height, and weight of the patients correlate with the SFM time. The findings suggest that a BMI-based approach to anticipate SFM duration may enhance preoperative planning, potentially aiding in surgical decision-making.

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Data availability No datasets were generated or analyzed during the current study.

Declarations

Conflict of interest The authors declare no competing interests. Drs. Caglar Kazim Pekuz, Dr. Huseyin Akyol, Ismail Gogenur, Mehmet Kocak, Mustafa Haksal, Mustafa Oncel, Naciye Cigdem Arslan, and Reza Shahhosseini have no conflicts of interest or financial ties to disclose.

Ethical approval and Informed Consent All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. This article does not contain any studies with animals performed by any of the authors.

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