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Factors affecting difficulty of laparoscopic surgery for left-sided colon cancer

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Abstract
Background Laparoscopic colon resection for left-sided colon cancer is being performed with increasing frequency worldwide. The purpose of this study is to evaluate the influence of patient- and procedure-related factors on difficulty of laparoscopic surgery for left-sided colon cancer.
Methods Two hundred sixty consecutive patients underwent laparoscopic surgery for left-sided colon cancer from July 2005 to December 2008. Gender, body mass index (BMI), tumor location, tumor size, previous abdominal surgery, tumor depth, tumor stage, splenic flexure mobilization, type of anastomosis, and site of arterial division were analyzed as potential variables that affect difficulty of laparoscopic surgery. Dependent variables were operative time, intraoperative blood loss, intra- and postoperative complications, and proximal and distal tumor margin. Univariate and multivariate analyses were performed to determine predictive significance of variables.
Results Multivariate analysis showed that male gender ($P = 0.0183$) and splenic flexure mobilization ($P < 0.0001$) were independently predictive of longer operative time. Splenic flexure mobilization was related to greater intraoperative blood loss ($P = 0.0006$), intraoperative complications ($P = 0.0111$, odds ratio: 7.22), and wider distal tumor margin ($P = 0.0048$).
Conclusions Male gender and splenic flexure mobilization were independent predictors of difficulty of laparoscopic surgery for left-sided colon cancer. In contrast, our findings also showed that BMI, tumor location, previous abdominal surgery, tumor stage, type of anastomosis, and site of arterial division did not have an adverse impact on difficulty of laparoscopic surgery for left-sided colon cancer in our clinical setting. Our data support the safety of performing laparoscopic surgery for left-sided colon cancer in well-selected patients by well-experienced surgical teams.

Keywords Laparoscopic surgery · Left-sided colon cancer · Splenic flexure mobilization · Body mass index · Difficulty

Laparoscopic colorectal surgery is being performed with increasing frequency worldwide. In particular, left colon resection for left-sided colon cancer is one of the most frequent procedures performed in laparoscopic colorectal surgery [1–4]. Several factors are thought to influence the technical difficulty of laparoscopic surgery [5, 6]. These include patient-related factors such as gender, obesity, and tumor stage, and procedure-related factors such as vascular dissection and anastomosis. There is increased demand for laparoscopic surgery, because laparoscopy has been shown to decrease the rate of postoperative complications [7], without compromising long-term oncological outcomes [1–4]. Therefore, better understanding of the factors associated with difficulty of laparoscopic surgery is important for surgeons to develop strategies for reducing operative time and conversion to open surgery and for improving patient outcome, especially among those who are learning these operations for proper case selection.

The purpose of this study is to evaluate the impact of patient- and procedure-related factors on the technical

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difficulty of laparoscopic surgery for left-sided colon cancer at our cancer institution.

Materials and methods

Patient selection

From July 2005 to December 2008, 260 consecutive patients underwent laparoscopic colectomy for left-sided colon cancer (splenic flexure to sigmoid, excluding the transverse colon and rectum). The basic indications for laparoscopic surgery in our institution include no evidence of bulky tumor, no evidence of invasion to adjacent organs, no evidence of ileus, no evidence of lymph node metastasis in the root of inferior mesenteric artery or para-aorta, and no evidence of synchronous resectable liver metastasis. Under these conditions, 142 patients underwent open colectomy for left-sided colon cancer during the same period (laparoscopy ratio: 65%). Tumor location was in the descending colon in 24 patients and sigmoid colon in 118. Reasons for open approach in these patients were bulky tumor in 16 patients, suspected invasion to adjacent organs in 28 patients, ileus in 23 patients, suspected lymph node metastasis in the root of inferior mesenteric artery or para-aorta in 19 patients, synchronous liver resection in 24 patients, synchronous cancer resection in 6 patients, no consent for laparoscopy in 7 patients, previous colorectal cancer resection in 6 patients, and surgeon's discretion in 13 patients. Data were prospectively collected for age, gender, body mass index (BMI), tumor size, tumor staging, duration of operation, amount of blood loss, conversion to open surgery, and postoperative data including pathology, hospital stay, and 30-day morbidity and mortality. Intraoperative complications such as bowel injury, bleeding, and anastomotic problems were recorded. Bowel injury and anastomotic problems required further surgical procedures. Bleeding was recorded as a complication when additional treatment such as blood transfusion or conversion to open surgery was needed, or the amount of bleeding reached more than 500 ml from the same source.

Dependent and independent variables

The outcomes of interest were operative time, intraoperative blood loss, intraoperative and postoperative complications, and width of proximal and distal tumor margin. Operative time, intraoperative blood loss, and proximal and distal tumor margin were evaluated as continuous variables. Ten independent clinical variables were analyzed. Characteristics evaluated as categorical variables included gender, BMI (<25 kg/m^2 and ≥ 25 kg/m^2), tumor location (descending and sigmoid colon), tumor depth (T0/T1/T2 and T3/T4), tumor stage (0/I/II and III/IV), type of anastomosis [FEEA (functional end-to-end anastomosis) and DST (double stapling technique anastomosis)], site of arterial division [inferior mesenteric artery and superior rectal artery (preservation of left colic artery) and left colic/sigmoidal artery (preservation of superior rectal artery)], splenic flexure mobilization, and previous abdominal surgery. BMI of 25.0 kg/m^2 was selected as the cutoff point, in accordance with the definition of obesity proposed by the Steering Committee of the Regional Office for the Western Pacific Region of the World Health Organization (WHO), the International Association for the Study of Obesity and the International Obesity Task Force (WPRO criteria) [8], and the Japan Society for the Study of Obesity [9]. Characteristics evaluated as continuous variables included tumor size.

Surgical procedure

A five-port technique was employed: a 10-mm port below the navel, 5-mm ports on the upper right and left abdominal quadrants, and 12-mm ports on the lower right and left quadrants, as we reported previously [10, 11]. Medial-to-lateral retroperitoneal dissection of the mesocolon and early division of the artery were performed, which preserved the inferior mesenteric plexus and superior hypogastric plexus. Arterial division was proximal (at the origin of the inferior mesenteric artery or after the origin of the left colic artery) or distal (preserving the superior rectal artery), as appropriate for the disease. We used an ENDOPATH Endo-Cutter or Echelon60 (Ethicon Endo-Surgery, Cincinnati, OH, USA) for the distal colon transection for DST. Full splenic flexure mobilization was performed for tension-free anastomosis in the case of lesions located in the descending colon or sigmoid–descending junction, or in the case of lack of redundancy of the sigmoid colon in the intraoperative period. The specimen was extracted through the left quadrant port or the camera port, which was extended to about 4 cm, and the anastomosis was formed extracorporeally by FEEA or intracorporeally by DST. All operations were performed under the supervision of a well-experienced board-certified laparoscopic colorectal surgeon (H.K.).

Statistical analysis

Analysis was performed using the Fisher exact test, χ^2 test, Mann–Whitney U test, Kruskal–Wallis test, or Spearman's rank correlation coefficient when appropriate. After univariate analysis, variables with P value <0.20 were selected for multivariate analysis. Multivariate analysis was performed using a multiple linear regression model with a stepwise (forward selection/backward elimination) method.

Intraoperative and postoperative complications were evaluated using multivariate logistic regression analysis. Statistical analysis was performed by using JMP6.0 software (SAS Institute Inc., Cary, NC, USA) and $P \leq 0.05$ was considered to be significant.

Results

The patient and tumor characteristics of the 260 patients included in the study are summarized in Table 1. Mean age was 64 years (range 28–89 years), and 128 (49%) patients were male. Mean BMI was 22.5 kg/m^2 (range 14.3–33.3 kg/m^2). Mean BMI in 142 patients who underwent open colectomy for left-sided colon cancer during the same period was 21.6 kg/m^2 (range 12.4–31.4 kg/m^2). BMI was significantly higher in laparoscopy group than in open group ($P = 0.0234$). Tumor location was in the descending colon in 29 patients and sigmoid colon in 231. The percentage of descending colon cancer was higher in open group than in laparoscopy group (17% versus 11%), but the difference was not statistically significant ($P = 0.1229$). Ninety (35%) patients had history of previous abdominal surgery.

Intraoperative outcomes are summarized in Table 2. Mean operative time was 194 min (range 95–405 min), and mean blood loss was 18 ml (range 0–740 ml). Splenic flexure mobilization was performed in 42 (16%) patients: 29 with descending colon cancer and 13 with sigmoid colon cancer. There were two cases of conversion to open surgery. The reason for conversion was bulky tumor in one case and bleeding in the other. Intraoperative complications were observed in nine patients (3.5%). There were two bleeding episodes, five anastomotic problems, one marginal artery injury, and one rectal injury.

Postoperative outcomes are summarized in Table 3. No positive proximal resection margins were identified, but one positive distal resection margin was identified. There were no hospital deaths or 30-day mortality. The overall morbidity rate was 6.9%. The most common complications were wound infections. There was no anastomotic leakage.

Correlations between operative time or intraoperative blood loss and clinical factors are summarized in Table 4. Univariate analysis showed that gender, tumor location,

Table 1 Patient and tumor characteristics

Gender (male/female)	128/132
Age, years, mean (range)	64 (28–89)
Body mass index (<25 kg/m^2/≥25 kg/m^2)	208/52
Tumor location (descending/sigmoid)	29/231
Tumor size, mm, mean (range)	32 (5–100)
Previous abdominal surgery	90 (34.6%)
Pathologic T stage	
T0	10 (3.8%)
T1	67 (25.8%)
T2	48 (18.5%)
T3	102 (39.2%)
T4	33 (12.7%)
Pathologic N stage	
N0	157 (60.4%)
N1	83 (31.9%)
N2	20 (7.7%)
Tumor stage	
0	9 (3.5%)
I	89 (34.2%)
II	58 (22.3%)
III	90 (34.6%)
IV	14 (5.4%)

Table 2 Intraoperative outcomes

Operative time, min, mean (range)	194 (95–405)
Estimated blood loss, ml, mean (range)	18 (0–740)
Splenic flexure mobilization	42 (16.2%)
Type of anastomosis (DST/FEEA)	204/56
Site of arterial division (IMA/SRA/LCA or SA)	161/35/64
Conversion to open surgery	2 (0.8%)
Intraoperative complications	9 (3.5%)
Bleeding	2
Anastomotic problems	5
Injury of marginal artery	1
Rectal injury	1

DST double stapling technique, *FEEA* functional end-to-end anastomosis, *IMA* inferior mesenteric artery, *SRA* superior rectal artery, *LCA* left colic artery, *SA* sigmoidal artery

Table 3 Postoperative outcomes

Number of harvested lymph nodes, mean (range)	15.3 (4–36)
Proximal tumor margin, mm, mean (range)	89 (30–600)
Distal tumor margin, mm, mean (range)	89 (20–230)
Invasion proximal margin	0 (0%)
Invasion distal margin	1 (0.4%)
Mortality	0 (0%)
Morbidity	18 (6.9%)
Wound infection	11
Anastomotic bleeding	2
Enterocolitis	2
Ileus	2
Intra-abdominal bleeding	1
Pneumonia	1
Decubitus	1
Postoperative hospital stay, days, mean (range)	11 (6–37)

Table 4 Correlations between operative time or blood loss and clinical factors

Independent variable	*P* value for operative time	*P* value for blood loss
Gender	0.0257	0.0002
Body mass index (<25 vs. ≥25 kg/m^2)	0.3143	0.0176
Tumor location	<0.0001	0.0583
Tumor size	0.2944	0.8942
Previous abdominal surgery	0.5100	0.3053
Tumor depth (T0/T1/T2 vs. T3/T4)	0.8095	0.1789
Tumor stage (0/I/II vs. III/IV)	0.7005	0.1648
Splenic flexure mobilization	<0.0001	0.0229
Type of anastomosis	0.0225	0.6472
Site of arterial division	0.0024	0.0502

Table 5 Stepwise linear regression analysis for operative time and blood loss

		Estimate	*P* value
Operative time	Gender	11.9	0.0183
	Splenic flexure mobilization	51.6	<0.0001
Blood loss	Splenic flexure mobilization	35.65	0.0006

splenic flexure mobilization, type of anastomosis, and site of arterial division were significantly associated with operative time; gender, BMI, and splenic flexure mobilization were significantly associated with intraoperative blood loss. Stepwise linear regression analysis showed that the optimal model to predict operative time included gender and splenic flexure mobilization; and the optimal model to predict intraoperative blood loss included splenic flexure mobilization (Table 5). A formula to predict operative time was as follows: operative time (min) = 180 + 12 in case of male + 52 in case of splenic flexure mobilization.

Results of multivariate analysis for intra- and postoperative complications, and proximal and distal tumor margin, are summarized in Table 6. Predictors for intraoperative complications were splenic flexure mobilization ($P = 0.0111$, odds ratio: 7.22, 95% confidence interval: 1.57–33.3). Splenic flexure mobilization was a predictor for distal tumor margin ($P = 0.0048$). There were no predictors for postoperative complications and proximal tumor margin.

Discussion

Use of laparoscopy for major colonic resection is growing. A recent, large multi-institutional database from the American College of Surgeon's National Surgical Quality Improvement Program has shown that laparoscopy decreases the rate of postoperative complications compared with open surgery [7]. It can be concluded that laparoscopy should be offered to all patients who require colon surgery and who lack contraindications to laparoscopic surgery. Therefore, it is anticipated that there will be increased demand for laparoscopic colon resection in the future, with many surgeons entering this field.

Laparoscopic resection for left-sided colon cancer is one of the most frequent procedures in laparoscopic colorectal surgery. Previous studies have reported that factors such as gender, BMI, and tumor stage are associated with conversion of laparoscopic to open surgery [5, 12]. In the present study, we excluded cases of transverse colon and rectal cancer. With regard to rectal cancer, recent studies have reported that tumor distance from the anal verge and pelvic diameter are associated with difficulty of laparoscopic rectal surgery [13, 14]. These parameters are unique for rectal cancer, and should be evaluated separately from colon cancer. With regard to transverse colon cancer, procedures such as the extent of retroperitoneal dissection and lymph node dissection of middle colic vessels are quite different from those for left-sided colon cancer. Thus, by excluding transverse colon and rectal cancer, we could

Table 6 Multivariate analysis for other factors

Dependent variable	Predictive factor	*P* value	Odds ratio	95% CI
Intraoperative complications	Splenic flexure mobilization	0.0111	7.22	1.57–33.3
Postoperative complications	No parameter			
Proximal tumor margin	No parameter			
Distal tumor margin	Splenic flexure mobilization	0.0048		

analyze more accurately the factors that affect difficulty of laparoscopic surgery for left-sided colon cancer.

In the present study, splenic flexure mobilization was significantly associated with longer operative time. More importantly, splenic flexure mobilization was significantly associated with greater intraoperative blood loss and intraoperative complications. Intuitively, laparoscopic splenic flexure mobilization is thought to be a difficult procedure [15]. This may be because of the requirement for extensive retroperitoneal dissection without injury of the mesentery and retroperitoneal structures such as the left ureter or pancreas, and the risk of splenic injury. The present data showed objectively that laparoscopic splenic flexure mobilization had the impact of 52 min on operative time in multiple regression equation for experienced laparoscopic colorectal surgeons. In terms of intraoperative complications, four occurred in patients with splenic flexure mobilization: bleeding near the pancreas in two cases, and injury of marginal artery and anastomotic problems (incomplete donuts and re-anastomosis) in one case each. One patient who experienced arterial bleeding was converted to open surgery. However, splenic flexure mobilization was not associated with postoperative complications and was associated with wider distal tumor margin. These results suggest that laparoscopic splenic flexure mobilization is difficult and time-consuming, but it can be performed without increasing postoperative morbidity and conferring any oncological disadvantage, with great expertise and dealing effectively with intraoperative complications. However, increased intraoperative complications suggest that laparoscopic surgery for left-sided colon cancer with splenic flexure mobilization may be best reserved for more experienced surgeons.

The present study showed that male gender was significantly associated with longer operative time. Previous studies have reported that men had higher BMI and greater abdominal visceral fat deposits [6], and higher risk of metabolic syndrome than women in the Japanese population [16]. It is notable that BMI $\geq$ 25 kg/m^2 was not significantly associated with operative time, intraoperative blood loss or postoperative complications in the present study. Previous studies have shown that higher BMI is significantly associated with conversion to open surgery in laparoscopic colectomy [5, 12]. On the other hand, our result is consistent with previous study, which has shown that BMI is not associated with operative time or postoperative complication rates in laparoscopic left colectomy [17], but a BMI of 30.0 kg/m^2 was used as the cutoff point. However, BMI is $\geq$ 30 kg/m^2 in no more than 2–3% of the Japanese population, in contrast to 10–20% for Europe and the USA [9]. In fact, there were only four (1.5%) patients in laparoscopy group and one (0.7%) patient in open group with BMI $\geq$ 30 kg/m^2 in our study. It was difficult to evaluate the impact of BMI $\geq$ 30 kg/m^2 on difficulty of laparoscopic surgery for left-sided colon cancer in the standard Japanese population. However, accumulating evidence has suggested that the relationship between BMI and body fat deposits differs between ethnic populations, and Asian populations have high level of abdominal fat at lower BMI relative to Caucasians [8]. Generally, for the same BMI, percentage body fat in Asians was 3–5% higher compared with in Caucasians [18]. These higher body fat deposits at low BMI levels in Asians can be partly explained by differences in trunk-to-leg ratio, physical activity, and diet [18]. Therefore, universal BMI cutoff points are not appropriate for comparisons between different ethnic groups, and BMI $\geq$ 25 kg/m^2 has been validated as a population-specific definition of obesity in the Japanese population [8, 9].

In the present study, splenic flexure mobilization was performed in all descending colon cancers and 13 (5.6%) sigmoid colon cancers. The reasons for using splenic flexure mobilization for sigmoid colon cancer were that the tumor was located near the sigmoid–descending junction in ten cases, proximal multiple diverticular disease in two cases, and for tension-free anastomosis in one case. The necessity of splenic flexure mobilization for sigmoid colon cancer may differ between Western and Asian countries, which may be associated with length of sigmoid colon and relative quantity of mesenteric fat [17, 19, 20]. Furthermore, splenic flexure mobilization could be omitted in patients with long sigmoid colon by preserving the superior rectal artery to save blood supply to the distal sigmoid colon. The present data showed that selective splenic flexure mobilization for sigmoid colon cancer could be safely performed without conferring any oncological disadvantage.

A limitation of this study was that it was performed within a single specialized institution. The impact of BMI, splenic flexure mobilization, type of anastomosis, and site of arterial division on surgical outcomes might be modified significantly according to surgeon experience. However, supervision of all operations by a single experienced surgeon in a single surgical team can avoid the risk of bias within the early phase of the learning curve, or the inter-center variability of a multicenter trial. Second, our study was consecutive but retrospective, and therefore potentially biased. In particular, our study could not evaluate the impact of bulky tumor, invasion to adjacent organs, and para-aortic lymph node metastasis on difficulty of laparoscopic surgery for left-sided colon cancer because of our institutional criteria for laparoscopic surgery. However, we believe that this study reflects actual predictive factors that affect difficulty of laparoscopic surgery for left-sided colon cancer in our clinical setting.

In conclusion, male gender and splenic flexure mobilization were associated with longer operative time for

laparoscopic surgery for left-sided colon cancer. In addition, splenic flexure mobilization was associated with greater intraoperative blood loss and complications. In contrast, variables such as BMI, tumor location, previous abdominal surgery, tumor stage, type of anastomosis, and site of arterial division did not affect difficulty of laparoscopic surgery for left-sided colon cancer. Our data supports the safety of performing laparoscopic surgery for left-sided colon cancer in well-selected patients by well-experienced surgical teams.

Disclosures Authors Takashi Akiyoshi, Hiroya Kuroyanagi, Masatoshi Oya, Masashi Ueno, Yoshiya Fujimoto, Tsuyoshi Konishi, and Toshiharu Yamaguchi have no conflicts of interest or financial ties to disclose.

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