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Study on sufficient blood vessel ligation and bowel mobilization in laparoscopic surgery for ascending colon cancer

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Abstract: Although well established, laparoscopic surgery for ascending colon cancer is a difficult procedure due to the presence of many blood vessels requiring treatment and the need for sufficient mobilization to extract the right colon through a small laparotomy. This is the first study to investigate the adequacy of vascular ligation and bowel mobilization for laparoscopic resection of ascending colon cancer and extracorporeal reconstruction. This retrospective study included 103 consecutive patients who underwent laparoscopic colectomy for ascending colon cancer from 2015 to 2022 at the Center Hospital of the National Center for Global Health and Medicine. We analyzed correlations between clinicopathological factors and vessels ligation or the mobilization range. The strongest factor correlated with vascular ligation was the distance from the Bauhin valve to the distal edge of the tumor (Length B). These lengths were significantly longer in the vascular ligated group (the right colic artery (RCA): 81 mm; the accessory right colic vein (ARCV): 85 mm; right branch of the middle colic artery (MCA-rt): 106.5 mm) than in the nonligated group (50 mm, 43 mm, 50 mm, $p < 0.01$). Mobilization range was not correlated with tumor location or size. According to the result, we developed practical indicators to assist during laparoscopic surgery: *i*) To omit the RCA ligation, Length B should be shorter than approximately 5 cm; *ii*) If Length B exceeds approximately 8 cm, both the RCA and ARCV should be ligated; and *iii*) If Length B exceeds approximately 10 cm, the MCA-rt should be ligated.

***Keywords*:** right hemicolectomy, extracorporeal anastomosis, complete mesocolic excision

1. Introduction

Currently, colon cancer surgery is generally performed laparoscopically in Japan (*1*). Since 2022, the number of robot-assisted laparoscopic surgeries for colorectal cancer has increased following approval under the National Health Insurance (*2*). We have since performed both laparoscopic and robotic surgeries, but primarily laparoscopic surgery for ascending colon cancer from 2015 to 2022.

We perform laparoscopic colon cancer resections using the complete mesocolic excision and central vascular ligation (CME–CVL) technique (*3-7*). Although well established, laparoscopic CME–CVL of the right colon is a difficult procedure due to the many blood vessels requiring treatment, including the ileocolic artery/vein (ICA/V), right colic artery (RCA), accessory right colic vein (ARCV), and right branch of the middle colic artery (MCA-rt), all of which exhibit considerable anatomical variations (*8,9*). Identification of the gastrocolic trunk of Henle and its tributaries requires detailed anatomical knowledge and meticulous dissection to vessel injury. Bleeding in this area can be difficult to control and may require conversion to an open procedure. After vascular ligation, the right colon is mobilized and extracted through a small laparotomy in the umbilicus. The specimen is then excised and anastomosed extracorporeally. In this process, tension on the mesocolon during extraction can cause bleeding, particularly from the mesocolon and the gastrocolic trunk of Henle. Moreover, the bowel must be sufficiently pulled out to allow extracorporeal reconstruction.

The number of vascular ligations and mobilization range in laparoscopic colectomy for ascending colon cancer can vary depending on whether it is near the Bauhin valve or the hepatic flexure. While these should be minimized to facilitate laparoscopic manipulation, they must be sufficient to permit extracorporeal resection and reconstruction. This is a major concern when performing laparoscopic surgery, but to our knowledge, no studies have examined this issue. This is the first study to investigate extent of vascular ligation and bowel mobilization for laparoscopic resection and extracorporeal reconstruction of ascending colon cancer and to establish practical intraoperative indicators.

2. Patients and Methods

2.1. Patients

This was a retrospective study including all consecutive patients who underwent laparoscopic colectomy for ascending colon cancer with D2 or D3 lymph node dissection and extracorporeal reconstruction from January 2015 to December 2022 at the Center Hospital of the National Center for Global Health and Medicine. We obtained data from medical records retrospectively.

2.2. Ethics declarations

This procedure was in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki declaration and its amendments or comparable ethical standards. The ethical review committee of the National Center for Global Health and Medicine approved the study protocol (NCGM-S-004511-01).

Study participation was announced on the website of the hospital, and patients could know they were included in the study, such that reluctant patients could reach the researcher to express their refusal.

2.3. Surgical technique

All surgical procedures were performed laparoscopically, using either standard right hemicolectomy or ileocecal resection with the CME–CVL technique (*3*). With five-port placement, a medial-to-lateral approach was used to dissect the right colon. First, the mesentery of the terminal ileum near the ileocolic vessels was incised sharply. Through this window, the mesenteric fascia of the ascending colon was separated from the retroperitoneum, identifying the duodenum and pancreas. Second, the ileocolic vessels were ligated at their origins with hemostatic clips, as they commonly include the ICA, RCA, MCA, and ARCV for identification (Figure 1). Using a lateral approach, mobilization of the distal ileum and right hemi-colon was performed. Mobilization began at the ileocecal region and continued to either the hepatic flexure (H-Fx) or mid-transverse colon (Mid-T), along with omentum dissection. The surgeons chose to use between the medial-to-lateral approach and the lateral-to-medial approach, therefore, in some cases, procedures were performed in reverse order. Following mobilization, extracorporeal tumor resection and reconstruction were performed. The midline umbilical incision was extended to approximately 4 cm, and the specimen including the tumor was extracted. In most cases, functional end-to-end ileocolic anastomosis using a linear stapler was performed. In some cases, end-to-side anastomosis using a circular stapler was performed.

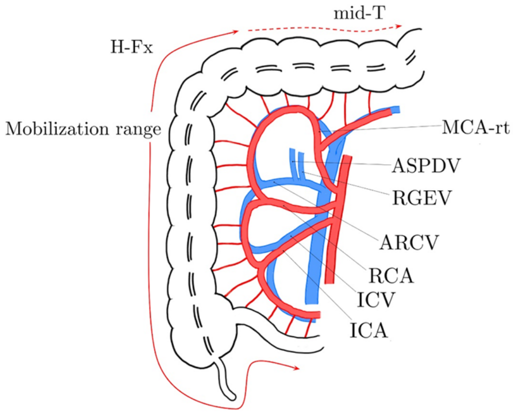

Figure 1. Common vascular anatomy of ascending colon. Range of mobilization: Mid-T: toward middle of transverse colon, H-Fx: toward hepatic flexure. MCA-rt: Right branch of middle colic artery; RGEV: Right gastroepiploic vein; ASPDV: Anterior superior pancreaticoduodenal vein; ARCV: Accessary right colic vein; RCA: Right colic artery; ICA/ICV: Ileocolic artery/Ileocolic vein.

According to Japanese colorectal cancer guidelines (*10*), the bowel was resected approximately 10 cm from the tumor, as lymph node spread rarely extends beyond this point.

2.4. Tissue measurements

Specimens were stretched and pinned on boards and fixed in formalin immediately after the operation. Pathologists and surgeons measured tissues on formalin-fixed specimens (Figure 2). They measured the distances from the Bauhin valve to the tumor (Length A), to the distal edge of the tumor (Length B), the distal margin of the specimen (Length C), and the tumor size along the intestinal axis (Length D).

2.5. Outcomes

Primary endpoints were the ligation of three arteries and mobilization range. Secondary endpoints were blood loss, operation time, postoperative complications and hospital stay.

2.6. Statistical analysis

Clinicopathological factors, including measured lengths, were compared between the ligated and nonligated groups of each vessel. Similarly, factors were compared between two groups with different mobilization ranges (H-Fx *vs*. Mid-T).

In the subset of 67 cases with RCA, we analyzed the correlation between vascular ligation and short-term outcomes, including operative time, blood loss, postoperative complications (Clavien–Dindo Grade II or higher), and postoperative hospital stay, to evaluate surgical safety.

Categorical and continuous variables were analyzed

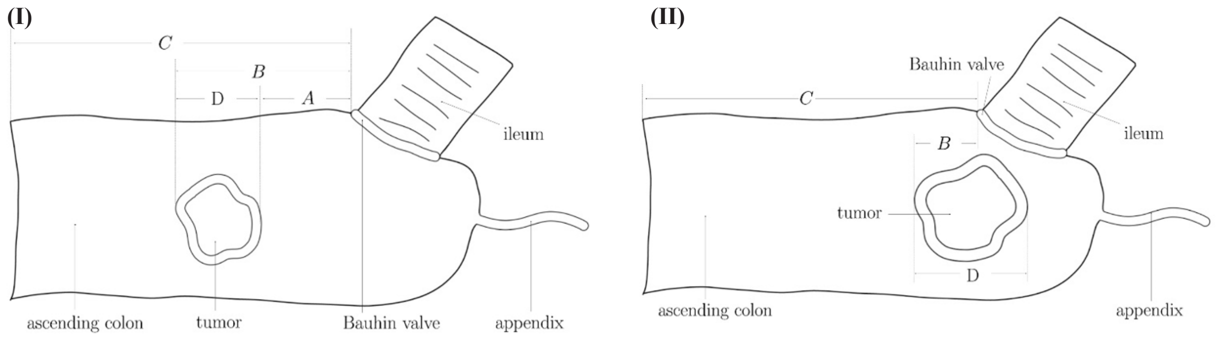

Figure 2. Measurement of formalin-fixed specimen. (I) when the tumor was located on the distal side of Bauhin valve; **(II)** when proximal edge of the tumor was on the cecal side of Bauhin valve. Length A: the distance from Bauhin valve to tumor; Length B: the distance from Bauhin valve to distal edge of tumor; Length C: the distance from Bauhin valve to distal margin of the specimen; Length D: tumor diameter along intestinal axis.

using Fisher's exact test and the Mann–Whitney *U* test, respectively. A *p*-value < 0.05 was considered statistically significant. All analyses were performed using JMP-Pro 15.1.0 from SAS (Cary, NC, U.S.A.).

3. Results

This study included 103 cases. Table 1 shows clinical characteristics of the patients. Median body mass index (BMI) was 22.6 kg/m^2, with three cases having a BMI > 30 kg/m^2, and the maximum recorded BMI was 33.3 kg/m^2. Anastomosis methods used were functional end-to-end anastomosis (FEEA) in 72 cases, end-to-side stapled anastomosis in 29 cases, and hand-sewn end-to-end anastomosis in two cases. Comparison among subgroups is summarized in Supplemental Table S1 (*https://www.globalhealthmedicine.com/site/supplementaldata.html?ID=108*).

Regarding surgical findings, feeding arteries of the tumors, which were ligated during lymph node dissection, included the ICA, RCA, and MCA-rt in 71, 18, and 5 cases, respectively. The ICA and RCA, ICA and MCA-rt, and RCA and MCA-rt were the feeding arteries in six, three, and three cases, respectively. The RCA was identified in 67 cases (65.0%), of which 46 (68.7%) were ligated. The ARCV and MCA-rt were ligated in 53 (51.5%) and 26 cases (25.2%), respectively. In one case, the MCA was ligated at its root, which was classified in the right-branch ligated group. The range of colon mobilization was to the H-Fx and Mid-T in 38 (36.9%) and 65 cases (63.1%), respectively. No case required conversion to laparotomy, and all procedures were completed laparoscopically. No serious complications, such as fatalities or reoperation, occurred during or after surgery. However, five and two cases had Clavien–Dindo Grade II and IIIa complications, respectively.

Table 1 shows the pathological findings as well. The median tumor diameter along the intestinal axis (Length D) was 30 mm. The median of Length A and Length B was 30 and 61 mm, respectively. Length B was equal to Length A + D when the tumor was located on the anal side of the Bauhin valve, but when the proximal edge of the tumor was on the cecal side of the Bauhin valve, Length A was recorded as 0 and Length B was shorter than Length A + D. The median distance from the Bauhin valve to distal margin of the specimen (Length C) was 160 mm (Figure 2).

Table 2 shows the analysis results regarding right colic vessel ligation. The strongest factor correlated with vascular ligation was Length B. For each of the three vessels, values of Length B were significantly longer in the ligated group (RCA: 81 mm, ARCV: 85 mm, and MCA-rt: 106.5 mm) compared with the nonligated group (RCA: 50 mm, ARCV: 43 mm, and MCA-rt: 50 mm; $p < 0.01$). Accordingly, Length C was significantly longer in the ligated group than in the nonligated group for each vessel (RCA: 200 *vs.* 135 mm, $p < 0.01$; ARCV: 200 *vs.* 135 mm, $p < 0.01$; MCA-rt: 205 *vs.* 150 mm, $p < 0.01$). Length A was also significantly correlated with ARCV and MCA-rt ligation (ARCV: 45 *vs.* 20 mm, $p < 0.01$; MCA-rt: 75 *vs.* 20 mm, $p < 0.01$). Length D correlated only with the RCA ligation (37.5 *vs.* 30.0 mm; $p = 0.05$).

Operative time was significantly longer in the RCA- and ARCV-ligated groups (227 and 233 minutes, respectively) compared to nonligated groups (195 minutes; $p = 0.03$, 207.5 minutes; $p = 0.04$, respectively). Intraoperative blood loss was significantly greater in the MCA-ligated group (72.5 mL) than in the nonligated group (36 mL; $p = 0.03$).

Although body size factors were generally not strongly correlated with vascular ligation, the ARCV-ligated group had a significantly higher BMI (23.3 kg/m^2) than the nonligated group (22.1 kg/m^2, $p = 0.02$). The BMI of the MCA-rt-ligated group (23.6 kg/m^2) also tended to be higher than that of the nonligated group (22.5 kg/m^2, $p = 0.06$).

Table 3 presents analysis of the mobilization range. No correlation was found between tumor location or size and mobilization range. However, Length C was significantly longer in the group with mobilization to the Mid-T colon compared with the H-Fx group (170 *vs.* 138 mm, $p < 0.01$). Operative time was also significantly

Table 1. Patient characteristics

Characteristic	Value
Age (year)	74 (43–91)
Gender (*n*)	Male: 57 Female: 46
Body height (cm)	160 (136–181)
Body weight (kg)	56.3 (35.0–93.5)
BMI (kg/m/m)	22.6 (15.9–33.3)
Surgical procedure (*n*)	Ileo-cecal resection: 36, Right hemicolectomy: 67
Lymph node dissection (*n*)	D2: 16 D3: 87
Anastomosis method (*n*)	FEEA: 72 End-to-side stapled anastomosis: 29 Hand-sewn end-to-end anastomosis: 2
Tumor feeding artery (*n*)	ICA: 69 RCA: 17 MCA-rt: 5 ICA + RCA: 6 ICA + MCA-rt: 3 RCA + MCA-rt: 3
RCA ligation: yes / no (*n*)	46 (68.7%) / 21 (31.3%)
ARCV ligation: yes / no (*n*)	53 (51.5%) / 50 (48.5%)
MCA-rt ligation: yes / no (*n*)	26 (25.2%) / 77 (74.8%)
Range of mobilization (*n*)	H-Fx: 38 (36.9%) Mid-T: 65 (63.1%)
Operating time (min)	225 (112–394)
Blood loss (mL)	40 (0–590)
Postoperative complications (> C–D Grade II**) (*n*)	7 (6.8%) (Grade II: 5, Grade IIIa: 2)
Postoperative hospital stay (days)	8 (5–46)
Tumor depth (*n*)	M: 3, SM: 24, MP: 13, SS: 48, SE: 14, SI: 1
Lymph node metastasis (*n*)	Positive: 39 Negative: 64
Length A (mm): Bauhin valve to tumor	30 (0–180)
Length B (mm): Bauhin valve to the distal edge of the tumor	61 (12–212)
Length C (mm): Bauhin valve to distal margin of the specimen	160 (35–290)
Length D (mm): Tumor size along the intestinal axis	30 (0–130)

103 cases were included. Medians are indicated with range in parentheses unless otherwise indicated. *RCA existed in 67 cases. **Postoperative complications classified Clavien-Dindo Grade or more serious were counted. FEEA: functional end-to-end anastomosis. ICA: ileocolic artery. RCA: right colic artery. ARCV: accessory right colic vein. MCA-rt: right branch of the middle colic artery. H-Fx: hepatic flexure. Mid-T: middle of transverse colon. C-D: Clavien-Dindo. Tumor depth: M: mucosa, SM: submucosa, MP: muscularis propria, SS; subserosa, SE: serosa exposed, SI: serosal invasion.

Table 2. Analysis of operative parameters according to right-colic vessels ligation

Outcome	RCA ligation			ARCV ligation			MCA-rt ligation		
	Yes (n = 46)	No (n = 21)	p vaule	Yes (n = 53)	No (n = 50)	p vaule	Yes (n = 26)	No (n = 77)	p vaule
Length A (mm): Bauhin valve to tumor	45 (0–86.3)	30 (0–37.5)	0.06	45 (13–85)	20 (0–30)	< 0.01*	75 (22.5–112.5)	20 (0–47.5)	0.06
Length B (mm): Bauhin valve to distal edge of the tumor	81 (53–130)	50 (37.5–68.5)	< 0.01*	85 (57.5–130)	43 (30–63.5)	< 0.01*	106.5 (64.5–143.8)	50 (35–80)	< 0.01*
Length C (mm): Bauhin valve to distal margin of the specimen	200 (143.8–230)	135 (115–157.5)	< 0.01*	200 (152.2–225.0)	135 (115–160)	< 0.01*	205 (165–205)	150 (120.0–182.5)	< 0.01*
Length D (mm): Tumor size along the intestinal axis	37.5 (25–50)	30 (17.5–40.0)	0.05*	32 (22–50)	30 (17.5–45.0)	0.20	30 (18–50.3)	30 (20–45)	0.05*
Operation time (min)	227 (204.3–250.8)	195 (166–232.5)	0.03*	233 (199–254)	207.5 (174.5–242)	0.04*	233.5 (199.5–265.75)	222 (186.5–243.5)	0.03*
Blood loss (mL)	54 (17.3–125.5)	30 (9.5–81.5)	0.26	60 (16.5–146.5)	34.5 (10.5–72.0)	0.05	72.5 (37.5–123)	36 (11.5–102.0)	0.26
Postoperative complications frequency (> C–D GradeII) (% (n))	10.9% (5)	0% (0)	0.17	9.4% (5)	4.0% (2)	0.44	11.5% (3)	5.2% (4)	0.17
Postoperative hospital stay (days)	9 (8–12)	9 (8–11)	0.84	9 (8–11)	8 (7-9.25)	0.07	8 (8–11)	8 (7–10)	0.84
Body height (cm)	155.6 (149.5–164.6)	160 (152.3–171.3)	0.15	157.5 (151.1–164.9)	162.2 (153.3–168.1)	0.08	161 (151.29–164.9)	159.5 (153.0–167.25)	0.15
Body weight (kg)	55.8 (50.4–62.8)	55 (50.6–62.9)	0.99	56.3 (50.4–67.2)	56.7 (49.3–63.9)	0.46	58.1 (49.7–71.9)	56 (50.25–64.75)	0.99
BMI (kg/m/m)	22.6 (20.4–24.2)	21.4 (19.5–24.3)	0.21	23.3 (20.7–24.9)	22.1 (19.3–23.9)	0.02*	23.6 (20.3–27.0)	22.5 (19.7–24.0)	0.21

Values are medians indicated with interquartile range in parentheses. Postoperative complications are indicated with its frequency and count in parentheses. *p value < 0.05 was considered significant. RCA: right colic artery. ARCV: accessory right colic vein. MCA-rt: right branch of middle colic artery. C–D: Clavien-Dindo.

Table 3. Analysis of operative parameters according to mobilization range

Outcome	Range of mobilization		
	H-Fx (n = 38)	Mid-T (n = 65)	p vaule
Length A (mm): Bauhin valve to tumor	25 (0–45)	35 (0–70)	0.25
Length B (mm): Bauhin valve to distal edge of the tumor	50 (35.0–82.5)	75 (36.5–107.5)	0.12
Length C (mm): Bauhin valve to distal margin of the specimen	138 (118.8–166.3)	170 (135–215)	< 0.01*
Length D (mm): Tumor size along the intestinal axis	29 (15.3–46.3)	30 (22–46)	0.48
Anastomosis methods (%)	FEEA 94.7%, E-to-S 5.3%	FEEA 55.4%, E-to-S 41.5%, hand 3.1%	< 0.01*
Operation time (min)	194.5 (167.0–222.8)	233 (202.5–256.0)	< 0.01*
Blood loss (mL)	37 (14.3–61.3)	60 (14.5-148.5)	0.10
Postoperative complications frequency (> C–D GradeII) (% (n))	7.9% (3)	6.2% (4)	0.71
Postoperative hospital stay (days)	8 (7–10)	9 (7.5–11.0)	0.33
Body height (cm)	157 (151.0–170.5)	161 (153.1–165.6)	0.76
Body weight (kg)	56.3 (48.4–65.3)	56.3 (51.1–65.7)	0.72
BMI (kg/m/m)	22.1 (19.5–24.2)	22.6 (20.0–24.3)	0.65

Values are medians indicated with interquartile range in parentheses unless otherwise indicated. Postoperative complications are indicated with its frequency and count in parentheses. *p value < 0.05 was considered significant. Range of mobilization; Mid-T: toward middle of transverse colon, H-Fx: toward hepatic flexure. FEEA: functional end-to-end anastomosis. E-to-S: end-to-side stapled anastomosis. Hand: hand-sewn end-to-end anastomosis. C–D: Clavien-Dindo.

longer in the Mid-T colon group than in the H-Fx group (233.0 *vs.* 194.5 min, $p < 0.01$). FEEA was significantly more frequent in the H-Fx group (n = 36; 97.7%) than in the Mid-T group (n = 36; 55.4%, $p < 0.01$). Factors related to body size were not correlated with mobilization range.

Table 4 shows evaluation of vascular treatment and surgical safety. Vascular ligation was performed in the following order: ICA/V, RCA, ARCV, and MCA-rt. The ICA/V was ligated in all cases. RCA was present in 67 cases, and this analysis was restricted to these cases. Operative time was significantly longer when the RCA (227 *vs.* 195 min, $p = 0.03$) or ARCV (228.0 *vs.* 202.5 min, $p = 0.03$) was ligated. Although ligation of the RCA or ARCV did not affect blood loss, MCA-rt ligation tended to increase the amount of bleeding (72.5 *vs.* 35.0 mL, $p = 0.08$). While ARCV or MCA-rt ligation did not affect the frequency of postoperative complications, all five postoperative complication cases occurred in the RCA-ligated group ($p = 0.17$). However, the ligation of these vessels did not impact postoperative hospital stay.

4. Discussion

This is the first study to investigate sufficient vascular ligation and bowel mobilization for laparoscopic resection and extracorporeal reconstruction of ascending colon cancer. We searched PubMed by June 2025 using the phrases "ascending colon cancer", "laparoscopic surgery", "vascular ligation", and "mobilization", and no previous research on this issue was found.

Right-sided colon resection can be performed using several approaches, with the two main approaches being the medial-to-lateral approach and the lateral-to-medial approaches. However, the conventional medial-to-lateral approach in laparoscopic right colectomy has been standardized (*11-13*). Due to anatomical complexity and vascular variation, dissection and vascular ligation around the duodenum and pancreas make it difficult to safely proceed (*14-16*). In our cohort, choice of the approach was left to the discretion of the surgeon based on intraoperative findings.

As expected, our analysis showed a correlation between the vascular ligation and Length A and B. Notably, Length C was significantly longer in the vascular ligated group. Surprisingly, only minimal correlation was found with tumor size or patient body size. Surgeons may be able to predict the need for vascular ligation based primarily on tumor location, focusing on distance from the Bauhin valve to the tumor and to the distal edge of the tumor, regardless of body size. Additionally, we conducted multivariate analyses (data not shown); neither Lengths A and B nor BMI were found to be statistically significant factors.

From the results of these analyses, we propose the following practical intraoperative indicators for determining the necessity of vascular ligation: *i*) To omit the RCA ligation, the distance from the Bauhin valve to the distal edge of the tumor should be less than approximately 5 cm; *ii*) If this distance is greater than approximately 8 cm, both the RCA and ARCV should be ligated; *iii*) If the distance exceeds approximately 10 cm, the MCA-rt should be ligated.

Regarding mobilization range, contrary to expectations, no correlation was observed with tumor characteristics or body size. As expected, Length C and operative time were significantly longer in the mobilization range of the Mid-T group. Additionally, the range of bowel mobilization was correlated with the anastomosis technique ($p < 0.01$). This result was attributed to surgery timing. Before 2018, most cases involved mobilization toward the center of the transverse colon, using the end-to-side anastomosis technique. The first 40 cases were affected by this bias. Therefore, due

Table 4. Surgical safety according to extent of vascular ligation

Outcome	RCA ligation			ARCV ligation			MCA-rt ligation		
	Yes (n = 46)	No (n = 21)	p vaule	Yes (n = 41)	No (n = 26)	p vaule	Yes (n = 16)	No (n = 51)	p value
Operation time (min)	227 (204.3–250.8)	195 (166.0–232.5)	0.03*	228 (201.5–254.0)	202.5 (168.5–231.3)	0.03*	229 (199.8–262.5)	222 (188–242)	0.24
Blood loss (mL)	54 (17.3–125.5)	30 (9.5–81.5)	0.26	50 (14.5–134.5)	38 (19.3–94.0)	0.56	72.5 (52.0–136.5)	35 (12–104)	0.08
Postoperative complications frequency (> C–D GradeII) (% (n))	10.9% (5)	0% (0)	0.17	7.3% (3)	7.7% (2)	1.00	6.3% (1)	7.8% (4)	1.00
Postoperative hospital stay (days)	9 (8–12)	9 (8–11)	0.84	9 (8.0–11.5)	9 (8–12)	0.84	8 (8-11)	9 (8–12)	0.68

Values are medians indicated with interquartile range in parentheses unless otherwise indicated. Postoperative complications are indicated with its frequency and count in parentheses. *p value < 0.05 was considered significant. RCA: right colic artery. ARCV: accessory right colic vein. MCA-rt: right branch of middle colic artery. C–D: Clavien-Dindo.

to this historic influence, our study could not provide reliable indicators for the required mobilization range.

Postoperative complications of Clavien–Dindo Grade II or higher were observed in seven cases (6.7%). There were no reoperations or fatal complications. Two cases had Grade IIIa complications: one developed a subcutaneous abscess due to anastomotic leakage, which required drainage, and another required long tube insertion for small bowel obstruction. Five cases experienced Grade II complications: one case of anastomotic leakage was treated conservatively with antibiotics, two cases of urinary tract infection required antibiotics, and two cases required postoperative blood transfusion. Although no significant correlation was found between postoperative complications and vascular ligation or mobilization range, it is noteworthy that all complications were observed in the RCA-ligated group only.

In five of the 103 cases, additional vascular ligation or mobilization was required during extracorporeal specimen extraction (data shown in Supplemental Table S2, *https://www.globalhealthmedicine.com/site/supplementaldata.html?ID=108*). These cases are important examples of minimal need for procedures and are considered very important cases in this study. In two cases, the ARCV had to be ligated through a small laparotomy due to excessive tension. In these cases, of course, the ARCV were not ligated laparoscopically. In one of these cases, Lengths A, B, and C were 70, 88, and 210 mm, respectively — values greater than the median distances in our ARCV-ligated group, which were not aligned with our indicator *ii*) above, suggesting that ARCV should have been ligated laparoscopically in advance. In the other case, these distances were 0, 30, and 90 mm, respectively — within the expected range of the ARCV nonligated group and aligned with our indicator *ii*). Although this patient was thin with a BMI of 16 kg/m^2, the depth of the tumor was serosal invasion (SI); it invaded the retroperitoneum, and the retroperitoneal tissue was also resected along with the tumor, which may have affected the additional ligation of the ARCV, as it was necessary to remove a large tissue mass. This was the only case in our study with a tumor invading depth with SI, indicating that the case was influenced by factors that could not be captured by this limited analysis alone.

In two other cases, the ARCV or anterior superior pancreatico-duodenal vein (ASPDV) was damaged and caused bleeding during extracorporeal extraction, requiring additional laparoscopic manipulation to achieve hemostasis. In one case, the ARCV had not been ligated, and Length A (25 mm) and Length B (60 mm) were shorter than the median distances observed in our ARCV ligation group and aligned with our indicator *ii*). In this case, obesity may have contributed to the patient being at risk of damaging the ARCV, as body weight was 93.5 kg (the highest value in this study) and BMI was 31.2 kg/m^2. However, the ASPDV was damaged in another case, where the ARCV was ligated, the tumor depth was submucosa (SM), the size was 24 mm, and the BMI was 23.0 kg/m^2. Those parameters indicated that the patient had no obvious risk factor. This operation may have had some technical problems.

In one case, additional mobilization was required. Mobilization had been conducted toward the H-Fx, but it was insufficient to pull the intestine out of the abdomen at the time of pulling out the intestine through the small laparotomy. Length C was 108 mm, which was not longer than the median length of the group, considering the range of mobilization to the H-Fx. FEEA reconstruction was performed in this case, and the BMI was 24.1. Although not a significant factor in this analysis, the large tumor size of 70 mm may have influenced the insufficient mobilization range.

Based on these cases requiring additional procedures, there may be influences from factors that could not be derived from the analysis results of this study alone.

Currently, colectomy is performed using the da Vinci Xi robotic surgical system (Intuitive Surgical California, USA). In laparoscopic colectomy, intracorporeal anastomosis is technically more difficult than extracorporeal anastomosis, increasing the operative time (*17,18*). Although risk of intra-abdominal contamination with bowel content and tumor cells is a concern, intracorporeal anastomosis helps avoid traction of the bowel and the mesentery through the small laparotomy for resection and reconstruction (*19*). In addition to traditional laparoscopy, this robotic system features a surgeon-guided, stable camera platform, providing superior 3D views, seven degrees of freedom instrumentation, tremor filtering, and individualized ergonomics. Because intracorporeal anastomosis is easier with robotic surgery (*20*) and requires less bowel mobilization, we usually choose this method for robotic colectomy. According to the lower necessity of mobilization to extract the colon or conduct the extracorporeal anastomosis, robotic surgery with intracorporeal anastomosis is expected to have different suggested lengths for each vessel ligation. In the future, we plan to analyze the vascular ligation and mobilization range required when performing intracorporeal anastomosis in robot-assisted surgery and compare the results with those of this study. To evaluate the necessity of mobilization, more detailed description like the distance from the distal margin might be required rather than the mobilization range as described in this study, because robotic surgery enables more customized minimum mobilization for each case.

This study has several limitations, including being a nonrandomized retrospective study and the small number of patients included from a single institution. Each ligation group had small cases, as the results should be read cautiously. Our retrospective study design limited the information we could obtain and analyze. The lengths of the specimens were all measured after formalin fixation. Specimens were known to shrink after removal and then after formalin fixation (*21*), so their lengths might have been different from the length on any preoperative or intraoperative measurement. This difference might make the study result difficult to utilize in clinical settings. Hopefully, future studies will show more clinically applicable indicators.

5. Conclusion

In this retrospective single-institute study, we explored sufficient blood vessel ligation and bowel mobilization in laparoscopic surgery for ascending colon cancer with extracorporeal anastomosis. As a result, the distance from the Bauhin valve to the distal edge of the tumor was identified as a strong factor for vascular ligation. The following indicators may be useful in determining whether vascular ligation is necessary: *i*) To omit the RCA ligation, the distance from the Bauhin valve to the distal edge of the tumor should be shorter than approximately 5 cm; *ii*) If the distance from the Bauhin valve to the distal edge of the tumor exceeds approximately 8 cm, both the RCA and ARCV should be ligated; and *iii*) If the distance from the Bauhin valve to the distal edge of the tumor exceeds approximately 10 cm, the MCA-rt should be ligated.

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