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Laparoscopic colorectal surgery for neoplasm. A large series by a single surgeon

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Abstract
Background The value and efficacy of laparoscopic colorectal surgery has been validated by large multicenter, randomized, controlled trials. However the results of a large series by a single surgeon in a single center have yet to be reported. We reviewed the short-term outcome of our series of laparoscopic colorectal procedures to better define the learning curve for acquiring these skills.
Methods Four hundred four patients with a colorectal neoplasm underwent laparoscopic surgery between August 1998 and December 2005. Surgery was performed under 8 to 10 cm H_2O CO_2 pneumoperitoneum. Type of operation, time of operation, and estimated blood loss were compared for each level of lymph node dissection, and the rate and reason for conversion to open procedures were determined. Time to passage of flatus, hospital stay, and postoperative complications were recorded. The learning curve for right hemicolectomy, sigmoidectomy, and low anterior resection was calculated.
Results Open conversion was required in 13 patients (3.2%). Uncontrollable bleeding occurred in four cases, and inability to divide the rectum because of adhesions or local invasion occurred in three. The time of operation for D3 level lymph node dissection was longer than for D2 in ileocecal resection, right hemicolectomy, and sigmoidectomy. Estimated blood loss was similar among the different types of operation. Blood loss of last 40 right hemicolectomies was less than in the first 40 cases, and the incidence of intraoperative complications in the first 40 sigmoidectomies was higher than subsequent cases. Time of operation, estimated blood loss, and number of complications did not change over time for low anterior resection.
Conclusion The large series performed by a single surgeon is consistent with large multicenter studies that have validated the superiority of laparoscopic colorectal surgery over conventional open procedures. The learning curve flattens out after about 40 cases of right hemicolectomy and sigmoidectomy.

Keywords Laparoscopic colorectal surgery · Open conversion · Complication · Short-term outcomes · Learning curve

Since the first report of laparoscopic colectomy by Jacobs et al. [1], laparoscopic resection has become standard care for both benign and malignant disease. Over the post decade, a number of problems such as port site recurrence [2–4] and prolonged time of operation among others have been managed successfully. The latest studies of laparoscopic colorectal resection show shorter hospital stay, fewer complications, and quicker return to normal life compared with open procedures [5–7]. The ultimate aim, however, is to achieve the same survival rate, and several long-term randomized controlled trials have been published worldwide [8–10]. Results consistently support the superiority of laparoscopic over open colectomy. Consequently, it is incumbent on each institution to review their own outcomes to confirm that they conform to established standards of care.

We initiated laparoscopic resection for colorectal cancer in August 1998 and have prospectively registered our results.

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In the present study, all complications during each operative procedure and the postoperative period were detailed and investigated. In addition, short-term results at our hospital, including complications and operative variables of each procedure, were investigated with particular attention to the period of learning that assured appropriate experience for safe performance of laparoscopic colorectal surgery.

Subjects and methods

Consecutive patients with a colorectal neoplasm who underwent laparoscopic colorectal surgery by a single surgeon (one of the authors, Dr. Y. Fukunaga) in our hospital since its introduction in August 1998 to December 2005 were identified from the prospective database. The protocol was approved by the ethical committee of our hospital. In the absence of specific contraindications to laparoscopy, patients were considered candidates for laparoscopic surgery when surgery was elective and there was no obstruction. Morbid obesity, prior major lower abdominal surgery, or tumor occupying most of the pelvic space were considered absolute contraindications. Advanced transverse colon cancers with lymph node metastases were also excluded. Advanced rectal cancers located below the peritoneal reflection were not treated laparoscopically when the anus could not be preserved and lateral lymph node dissection was required. Tumors confined to the mucosal layer underwent D1 lymph node dissection; tumors confined to the submucosal layer underwent D2 dissection; and D3 dissection was performed for invasion of the muscle layer. Level of lymph node dissection was based on 'General Rules for Clinical and Pathological Studies on Cancer of the Colon, Rectum and Anus' edited in 1998 by the Japanese Society for Cancer of the Colon and Rectum. According to this definition, D1 indicates lymph node dissection surrounding the marginal artery of the colon; D2 indicates lymph node dissection that includes tissues surrounding the intermediate feeding artery; and D3 indicates lymph node dissection extending to the root of the feeding artery.

Clinical parameters subjected to analysis included patient demographics, operative variables, and short-term outcome variables in all laparoscopic cases. Operative variables included type of operation, blood loss, time of operation, and conversion rate. Blood loss and time of operation were compared between procedures. Conversion to laparotomy was defined as unplanned incision. Short-term outcome variables included number of days until passage of flatus, postoperative length of stay, postoperative morbidity, and 30-day mortality. To determine our own learning curves, sequential changes in time of operation, blood loss, and conversion rate to open surgery, and postoperative complications for right hemicolectomy, sigmoidectomy, and low anterior resection for rectal cancer with at least D2 curative lymph node dissection were compared.

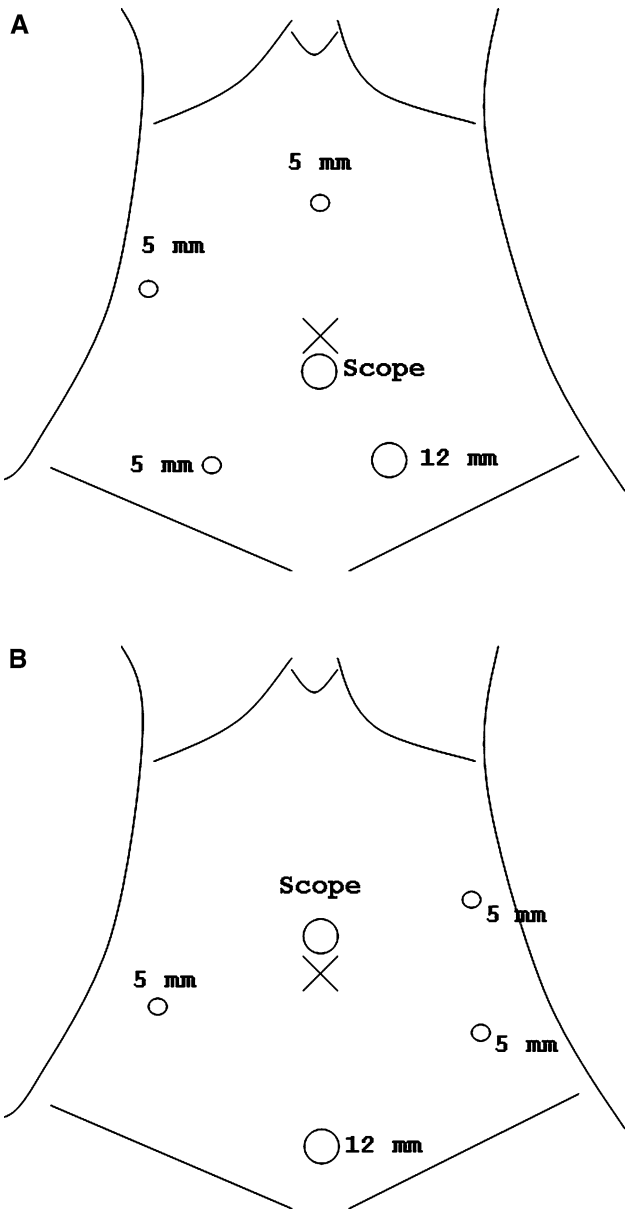

Fig. 1 Schematic drawings illustrating the placement of trocars in laparoscopic colorectal surgery. A: right-sided colectomy. B: left-sided colectomy and anterior resection

The statistical analysis was performed by using the chi-square test and Student's t-test and $p < 0.05$ was determined as a significant difference.

Operative technique

The patient was placed in the lithotomy position under general anesthesia and fixed in position to tolerate deep Trendelenburg position. Five ports were usually placed,

regardless of tumor location (Fig. 1). CO_2 pneumoperitoneum of 8–10 mmHg was maintained during the procedure. We routinely utilized the median approach for all procedures.

Right colectomy (D3 lymphadenectomy): The medial side of mesentery, just caudal to the ileocolic vessels, is pulled up by the first assistant and incised. The incision is carried to the anterior surface of the duodenum, and lymphadenectomy around the root of the ileocolic vessels is performed, exposing the superior mesenteric vein. After transection of the ileocolic artery and vein, lymphadenectomy is extended cranially along the superior mesenteric vein, reaching the root of the middle colic artery. Rarely the root of the right colic artery has its origin directly from the superior mesenteric artery. The venous anatomy is highly anomalous. Mobilization of the hepatic flexure is required in almost all cases. When the retroperitoneum is divided at the hepatic flexure, the duodenum and Gerrotta's fascia should be preserved behind the subperitoneal fascia. Told's fusion fascia is incised as far cranially and caudally as possible. Finally, the ileocecal region is flipped up from the caudal side, preserving the right gonadal vessels and ureter, and the dissection is continued medially. The resection of the right colon and reconstruction are performed extracorporeally. A small skin incision is made just around the umbilicus where the trocar for camera was initially placed. An end-to-end ileocolonostomy is performed using the triangulating stapling technique [11].

Sigmoidectomy (D3 lymphadenectomy): The medial aspect of the rectosigmoid mesocolon is incised to mobilize the retroperitoneal space, preserving both hypogastric nerves. The inferior mesenteric artery (IMA) is divided at its origin from the aorta except in patients (1) over 80 years old, (2) with severe diabetes mellitus, or (3) with severe systemic atherosclerosis. The inferior mesenteric vein is divided at the same level as the IMA. Following retroperitoneal mobilization, with preservation of the left ureter and gonadal vessels, lateral peritoneal reflection is incised and continued to the median layer. The resection of the specimen and reconstruction is performed extracorporeally as described for right hemicolectomy. When the anal side of the colon is too short to permit extracorporeal anastomosis, intracorporeal colorectal division and anastomosis with the double-stapling technique using a circular stapler is performed. In Japanese patients, the sigmoid colon is sufficiently long that mobilization of the splenic flexure rarely is needed. In this series, nine cases of upper sigmoid colon cancer near the sigmoid-descending colon junction required splenic flexure mobilization.

Lower anterior resection: The pelvis is approached following the division of the main artery. The rectosigmoid colon is pulled cranially and dissection is continued laterally, providing excellent exposure of the pelvic space. The peritoneal reflection is incised on the anterior wall of the rectum, resecting Denonvillier's fascia to expose the seminal vesicle in men or the vaginal wall in women, and the rectum is mobilized distally so that levator ani is exposed circumferentially. After determining the line of division on the anal side of the rectum, the mesorectum is incised circumferentially. A Pfannenstiel incision is created, using a wound protector to maintain intra-abdominal pressure while introducing a linear stapler to use through the incision. The rectal stump is irrigated to avoid anastomotic recurrences. The continuity of the digestive tract is restored with a double-stapling technique using a circular stapler.

Table 1 Demographics and clinical characteristics

Gender (M/F)	249/149
Age [median (range)] (years)	66.9 (29–95)
Location	
Cecum	13
Ascending colon	86
Transverse colon	27
Descending colon	21
Sigmoid colon	164
Rectum	97
Pathology	
Cancer	406
Others	2
Stage	
0, I	139
II	112
III	118
IV	39
Procedure	
Ileocecal resection	24
Right hemicolectomy	79
Transverse colectomy	21
Left hemicolectomy	21
Sigmoidectomy	169
Anterior resection	81
Hartmann procedure	4
APR	7

APR, Abdominoperineal resection

Table 2 Reasons for conversion from laparoscopic to open procedure

Dense adhesion	2
Extensive local invasion	4
Uncontrollable bleeding	3
Inability to complete rectal division	3
Impossible of realizing preoperative marking of location	1

Table 3 Operative variables as a function of the level of lymph node dissection

	RHC			Sigmoidectomy			Anterior resection		
Level of dissection	D1	D2	D3	D1	D2	D3	D1 (n = 1)	D2	D3
Time of operation (min)	133.2 ± 35.2	176.8 ± 49.7#	185.4 ± 38.3#	112.8 ± 47.3	157.1 ± 52.5	174.9 ± 46.2*	240	196.2 ± 41.6	223.0 ± 49.3
Blood loss (ml)	57.2 ± 43.5	117.6 ± 85.9	108.0 ± 98.6	68.8 ± 44.0	87.1 ± 108.3	71.5 ± 78.5	280	67.7 ± 59.0	122.6 ± 100.9

* $p < 0.05$ between D2 and D1

# $p < 0.05$ between D1

RHC: right hemicolectomy

Results

Four hundred and four patients, eight of whom had multiple lesions requiring surgical treatment, underwent laparoscopic colorectal resection during the 7-year study period; 408 lesions were resected in all. This cohort included 249 men and 149 women, with a mean age of 66.9 years (range 29 to 95 years). Demographic data, tumor stage, and surgical procedures are shown in Table 1. Five patients underwent two different procedures for synchronous lesions at different sites of the large bowel. Rectal cancer was treated by a variety of procedures. In theory, total mesenteric excisions should be performed for low rectal cancers and partial mesenteric excision for upper rectal cancers. According to the standardized Japanese consent form for the surgical treatment of rectal cancer, lateral lymph node dissection is to be performed for advanced low rectal cancer. Nevertheless, there were seven abdominoperineal resections and four Hartmann procedures. These patients were informed of the need for open lateral lymph node dissection, but they selected a laparoscopic procedure, based on the perceived risk:benefit ratio.

Conversion

Conversion to an open procedure was performed in 13 patients (3.2%) (Table 2). Three of four tumors with extensive local invasion were rectal cancers, and all had invaded the urinary tract. In another patient, mesenteric panniculitis had extended to an extremely low level of the mesorectum. Uncontrollable bleeding occurred in three cases, one each from the left renal vein, root of the inferior mesenteric artery, and superior mesenteric vein. Rectal division failed in three cases: in one case it was unclear whether the tumor extended to the line of transection, while in two cases exposure was compromised because the tumor was huge and patient was obese. Dense adhesions precluded laparoscopic resection, one following an appendectomy and another after total hysterectomy, where it was impossible to insert even the first trocar.

Table 4 Short-term outcomes

	POD
Walking [median (range)]	1 (1–3)
Passing flatus [median (range)]	1.9 (1–6)
Postoperative hospital stay [median (range)]	11.1 (5–35)

POD, postoperative day

Operative variables

There were 24 D1, 125 D2, and 245 D3 dissections, excluding conversions to open procedures. The operation was performed with curative intent in 381 cases (96.9%), which included patients with liver and lung metastases that were resected subsequently.

Time of operation and estimated blood loss are shown in Table 3 and Fig. 1. The time of operation for D3 was longer than D1 or D2 for ileocecal resection, right hemicolectomy, and sigmoidectomy, whereas times for left hemicolectomy and anterior resection were independent of level of lymph node dissection. For D3 lymph node dissections, the time of operation of the left hemicolectomy and anterior resection were longer than for sigmoidectomy and ileocecal resection. The blood loss was similar for the different levels of lymph node dissection regardless of the primary procedure, and blood loss with D3 dissection of anterior resection was greater than with sigmoidectomy.

Short-term outcomes

As for postoperative course, the median number of days until flatus was passed was 1.9 (range, 1–6) and the median

Table 5 Complications of laparoscopic colorectal surgery

	Colon (n = 301)	Rectum (n = 97)	Overall
Intraoperative complications			6 (1.5%)
Vascular injury	3 (1.0%)	0	3 (0.75%)
Bowel injury	0	0	0
Ureter injury	0	0	0
Inability to complete rectal division	0	3 (3.1%)	3 (0.75%)
Postoperative complications	3 (1.0%)	3 (3.1%)	51 (12.8%)
Wound infection	11 (3.7%)	5 (5.2%)	16 (4.2%)
Anastomotic leakage	2 (0.7%)	7 (7.2%)	9 (2.3%)
Small bowel obstruction	0	9 (9.3%)	9 (2.3%)
Anastomotic bleeding	0	3 (3.1%)	3 (0.75%)
Bowel ischemia	3 (1.0%)	0	3 (0.75%)
Urinary retention	0	3 (3.1%)	3 (0.75%)
Small bowel injury recognized postoperatively	0	1 (1.0%)	1 (0/25%)
Ureteral injury recognized postoperatively	0	1 (1.0%)	1 (0/25%)
Abscess	1 (0.3%)	0	1 (0/25%)
Enteritis	1 (0.3%)	0	1 (0/25%)
Port-site/incisional hernia	3 (1.0%)	1 (1.0%)	4 (1.0%)
Total	24 (8.0%)	33 (34.0%)	57 (14.3%)
Reoperations	4 (1.3%)	3 (3.1%)	7 (1.8%)
Deaths	0	0	0

hospital stay was 11.1 (range 5–35) days, excluding patients with postoperative complications and whose who had metastatic lesions requiring a second procedure (Table 4). Intraoperative and postoperative complications are shown in Table 5. Neither bowel nor ureteral injury was appreciated intraoperatively, but one case of each became apparent postoperatively. The ureteral injury unfortunately was concomitant with anastomotic leakage following low anterior resection and presented as urine coming from the drain on postoperative day 7. This patient required an ileostomy for diversion of the fecal stream and placement of a double-J ureteral catheter. Anastomotic leakage occurred in one patient following colonic reconstruction and in eight patients following rectal reconstruction with the intracorporeal double-stapling technique. Three cases of bowel ischemia occurred. In one case, the marginal artery was incidentally clipped during transverse colectomy, and two cases presented as ischemia of the anal side of a sigmoid colon anastomosis. In both cases, the length of colon that was preserved was excessively long given that the inferior mesenteric artery had been divided. Hyperpyrexia, leukocytosis, and an elevated serum C-reactive protein concentration in the early postoperative period prompted us to perform endoscopy, and the ischemia was recognized prior to perforation. Both patients underwent reoperation, and the ischemic segment was resected, and a stoma was constructed.

Learning curves

Learning curves were created for right hemicolectomy, sigmoidectomy, and anterior resection for rectal cancer with D2 or D3 lymph node dissection (Fig. 2). In right hemicolectomy, the operation time for the first 40 cases was the same as for the most recent 40 cases, although blood loss was less in the latter period. The incidence of complications in the two periods was similar. The time of operation for sigmoidectomy was shorter for the middle 40 cases period than the last 34 cases, because the proportion of cases done by the author's first assistant was high. Blood loss was similar across time, but the incidence of major complications was higher in the first 40 cases than in the middle and last periods. Time of operation and blood loss were similar in the first and last groups of anterior resection. However, three conversions to open surgery because of problems related to rectal division occurred in the first 40 cases whereas no open conversion was required in the most recent period.

Discussion

The superiority in short-term outcome of laparoscopic colorectal surgery over conventional surgery has been established for over a decade. Our experience is similar to

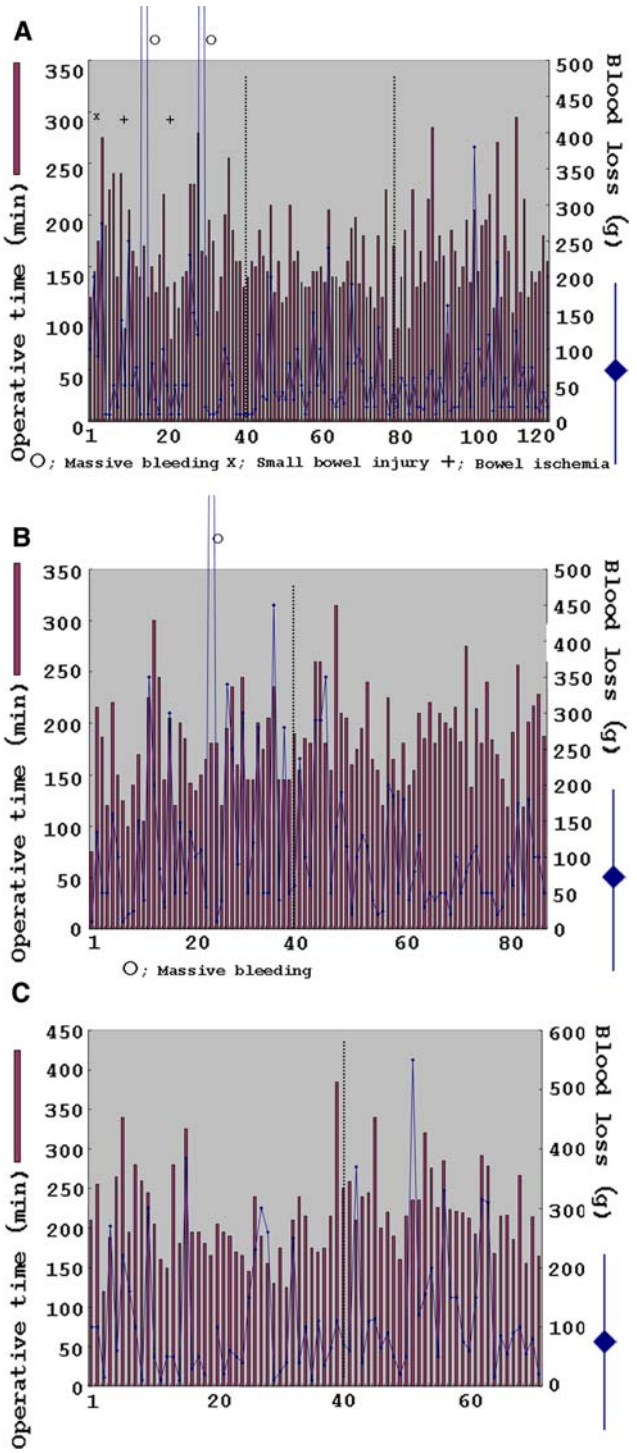

Fig. 2 Learning curves for laparoscopic colorectal surgery. A: right hemicolectom. B: sigmoidectomy. C: anterior resection

other large series [2–4]. More rapid return of bowel function, as evidenced by passage of flatus, represents a clear advantage of laparoscopic procedures. The mean postoperative hospital stay (11.1 days) was relatively long compared with data from the clinical outcomes of surgical therapy (COST) group [12]. This difference could represent differences in national insurance and financial systems between the USA and Japan. The disadvantages of laparoscopic surgery are longer time of operation and higher cost. However the time for sigmoidectomy and right hemicolectomy were considered acceptable. In this series, mean operative times for sigmoidectomy with D2 or D3 lymph node dissection were 170.1 min in the first 40 cases and 167.2 min in the next 40 cases; for right hemicolectomy, these times were 182.2 min and 192.7 min, respectively. The time of operation for low anterior resection was long but included patients who were obese or had huge tumors. So, patient selection is an important consideration in laparoscopic rectal surgery. Blood loss was less with laparoscopic surgery than with open surgery, and the need for blood transfusion was rare. Time of operation and blood loss were greater with more extensive lymph node dissection, regardless of the type of operation. However with low anterior resection, lymph node dissection was a smaller part of the overall procedure, and most time and blood loss were related to mobilization of the rectum. We believe that D3 lymph node dissection is necessary for advanced cancer when sigmoidectomy or right hemicolectomy is performed. The evidence is less clear for transverse colectomy and low anterior resection.

Although all conversions to an open procedure were due to various intraoperative complications, problems transecting the rectum accounted for almost half of the conversions. However, the rate of conversion was low in comparison with randomized controlled trials [9, 10, 13, 14]. Our conversion rate (3.2%) also was similar to or lower than rates in large series previously reported by well-trained surgeons [5, 15, 16]. Several factors contributed to our relatively low conversion rate. First, the definition of morbid obesity was vague and the patients in our series were relatively thin. Second, the author was already an accomplished laparoscopic surgeon at the start of the study, and he was experienced operating under difficult circumstances, such as performing laparoscopic surgery in a nonvirgin abdomen. And finally, our technique of rectal division using a conventional device allowed for easy division of even lower rectal cancers in patients with a narrow pelvis [11]. The most common postoperative complications included wound infection, small-intestinal obstruction, anastomotic leakage, urinary injury, and bowel ischemia. However, the rate for each complication was generally low and compared favorably with historic controls [17, 18]. Incidence of anastomotic leakage was low, despite the fact that nearly 10% of cases involved the double-stapling technique for rectal surgery. This rate compares favorably with reports in open series [19, 20]. There were no operative deaths but several operative

misadventures occurred early in this series within the first 40 cases for each procedure.

Division of the distal rectum under pneumoperitoneum using an open device was used since 2002, permitting extremely low levels of anastomoses [11]. Although the rate of anastomotic leakage did not decrease with the introduction of this technique, conversions to open procedures have all but disappeared.

The learning curves for all procedures were similar. Only blood loss in right hemicolectomy was lower in the last 40 cases. However, complications decreased and flattened out after 40 cases in right hemicolectomy and sigmoidectomy. The curve for laparoscopic rectal surgery was flat. Some authors have reported that, for laparoscopic colonic resections generally, the level of skill becomes adequate with 10–20 cases [21, 23], but their series were smaller than ours [22] and involved pooled results from multiple centers; yet, these results were essentially consistent with ours. At this point, the consensus is that approximately 20 cases are needed to achieve competence [7–10, 12]. Our experience suggests that this number may be an underestimation. We feel that the conversion rate should be considered the critical variable rather than of time of operation, as time of operation is contaminated by the increasing complexity of the procedures, and more generous indications for laparoscopic procedures.

The short-term outcome in our series of over 400 laparoscopic procedures was favorable, although a number of nonfatal intraoperative and postoperative complications occurred. The learning curve for performing a safe and oncologically satisfactory procedure was 40 cases for right hemicolectomy and sigmoidectomy. It was not possible to determine parameters for anterior resection of rectal cancer. Skill acquisition for laparoscopic intracorporeal rectal division and anastomosis requires further study.

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