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Robotic-assisted laparoscopic surgery for recurrent diverticulitis: experience in consecutive cases and a review of the literature

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Abstract

Background Robotic-assisted laparoscopic surgery has recently gained enthusiasm for application in colorectal surgery. We present the safety and feasibility of using the da Vinci® robotic system for the surgical treatment of sigmoid diverticulitis.

Methods Between August 2008 and November 2009, robotic-assisted laparoscopic anterior rectosigmoid resection (RALS-AR) for diverticulitis was performed in 24 consecutive patients. Demographic data, intraoperative parameters, and postoperative outcomes were assessed.

Results RALS-AR was performed in 14 male (58.3%) and 10 female (41.7%) patients with a diagnosis of recurrent diverticulitis. The mean patient age and BMI were 49.8 ± 9.3 years (range = 30–62 years) and 29.9 ± 6.3 kg/m^2 (range = 15.9–46.9 kg/m^2), respectively. Disease stratification identified 15 cases of uncomplicated (62.5%) and 9 cases of complicated (37.5%) disease. The procedures required 14.1 ± 6.7 min (range = 6–30 min) for robotic docking, 100.5 ± 31.0 min (range = 50–180 min) for surgeon console time, and 224.2 ± 47.1 min (range = 150–330 min) for the total operative time. Robotic docking and surgeon console time represented 51.9% of the total operative time. A primary colorectal anastomosis was fashioned with avoidance of colostomy in all patients. There were no significant intraoperative complications, and none of the procedures required conversion to open, hand-assisted, or conventional laparoscopic technique. The length of hospital stay was 3.4 ± 2.6 days (range = 2–14 days), and the postoperative complication rate was 12.5% ($n = 3$). There were no anastomotic leaks, secondary surgical interventions, or hospital readmissions.

Conclusions Robotic-assisted laparoscopic technique is a safe and feasible option for the surgical treatment of diverticulitis. The approach may be offered to patients with uncomplicated or complicated disease, and it results in a short hospital stay and low complication rate.

Keywords Robotic · Da Vinci · Diverticulitis · Colorectal · Rectosigmoid · Colectomy

The use of laparoscopic surgery has facilitated the development of minimally invasive techniques to perform surgical procedures with reduced surgical trauma, fewer perioperative complications, and quicker patient recovery compared to open surgery [1]. Despite its potential benefits for improving patient outcomes, the use of laparoscopy by many surgeons has been restricted due to a steep learning curve and inherent limitations [2, 3]. This has been especially true in the surgical treatment of diverticulitis, in which acute inflammation and the confined nature of the pelvis may limit visualization and prohibit proper dissection and mobilization through a laparoscopic approach [4]. The presence of significant inflammation, bulky mesenteric tissue, and ill-defined planes of dissection has been associated with conversion rates as high as 40–65% [5–9]. Consequently, conversion to open surgery has been associated with greater complication rates and longer lengths of hospitalization.

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Robotic technology was developed to overcome several of the limitations associated with conventional laparoscopic surgery while maintaining a minimally invasive platform. The successful application of robotic surgery for prostatectomy, as published in the urology literature [10–12], prompted interest in its utilization for treatment of colorectal diseases involving the pelvic anatomy, such as diverticulitis. The aim of this study was to evaluate the safety and feasibility of robotic-assisted laparoscopic surgery (RALS) for diverticulitis through assessment of intraoperative parameters and short-term outcomes of 24 consecutive robotic-assisted laparoscopic anterior rectosigmoid resections.

Materials and methods

Between August 2008 and November 2009, robotic-assisted laparoscopic anterior rectosigmoidectomy was performed in 24 consecutive unselected patients with recurrent diverticulitis at The Methodist Hospital and St. Luke's Episcopal Hospital in Houston, TX. All procedures were performed by a board-certified colon and rectal surgeon (EMH) using the da Vinci® S Surgical System (Intuitive Surgical, Inc., Sunnyvale, CA). This system consists of three separate components: the surgeon's console, an endoscopic tower, and a robotic cart with four interactive arms: one for the camera and three for the robotic instruments.

A de-identified retrospective database was created for the patients and contained demographic information, intraoperative parameters, and postoperative outcomes. Patients' demographic information, including age, gender, and body mass index (BMI), were tabulated along with their American Society of Anesthesiologists (ASA) classification and history of previous abdominal surgery. Operative parameters included robotic docking time, surgeon console time, overall operative time, estimated blood loss (EBL), number and type of intraoperative complications, and need for conversion. Postoperative clinical outcomes included length of hospital stay (LOS), number and type of postoperative complications, and need for readmission or secondary surgical intervention. Statistical analysis was performed using a two-tailed Student's t test (with significance level set at $\alpha = 0.05$).

Operative technique

Initial laparoscopic maneuvers consisted of exploration, lysis of adhesions (LOA), and retraction of the small bowel out of the pelvis after placing the patient in steep Trendelenburg with left side elevated. A 12-mm trocar was placed in the periumbilical region for the camera port. A total of three 8-mm robotic ports and a 12-mm accessory port for laparoscopic assistance were then placed (Fig. 1). When necessary, splenic flexure takedown was performed using conventional laparoscopic technique prior to robotic docking. Neither the ports nor the robot required repositioning once initial docking was performed.

The robotic procedure was performed in a medial-to-lateral approach to avoid initial dissection into the inflammatory process and to facilitate early identification of critical structures, including the left ureter and the inferior mesenteric artery (IMA). The IMA was identified, isolated, and divided. This was followed by dissection in the avascular retroperitoneal plane superiorly to the level of the ligament of Treitz and inferior border of the pancreas and laterally beyond Gerota's fascia to the white line of Toldt. A lateral-to-medial approach was then undertaken, dividing the lateral attachments of the colon from the splenic flexure down to the pelvic inlet.

Attention was then directed to the pelvic portion of the procedure. The presacral plane was entered to expose the upper third of the rectum, taking care to identify and preserve the autonomic nerves. At this level the rectum and mesorectum were sequentially divided, and the diseased segment of the sigmoid was extracorporealized through a 2.5–5.0-cm Pfannenstiel incision following placement of an Alexis® wound retractor (Applied Medical, Rancho Santa Margarita, CA). The diseased portion of the sigmoid was resected, pneumoperitoneum was re-established, and a primary end-to-end circular stapled anastomosis was fashioned under robotic surveillance.

Review of the literature

PubMed, Medline, and Ovid searches were performed using the following terms: (colectomy or diverticulitis or sigmoid or colorectal or colon) and (robot or robotic or telerobotic). One hundred eight articles were identified. The abstracts were reviewed to determine if the articles potentially contained information about robotic-assisted surgery for diverticular disease. This review process narrowed the number of articles for further assessment to 21 [13–33]. These 21 articles were obtained and read in full. Of these, five [20, 21, 26, 29, 33] were excluded because they did not contain sufficient information to extract details on surgeries for diverticular disease, six [16, 17, 19, 23, 28, 31] were excluded because they reviewed techniques without providing patient data, one [15] was excluded because the Automated Endoscopic System for Optimal Positioning, Computer Motion™ (AESOP) robotic device was used, and one [18] was excluded because it dealt with surgeries in animals. Thus, eight studies involving use of the da Vinci® device remained eligible for this review [13, 14, 22, 24, 25, 27, 30, 32].

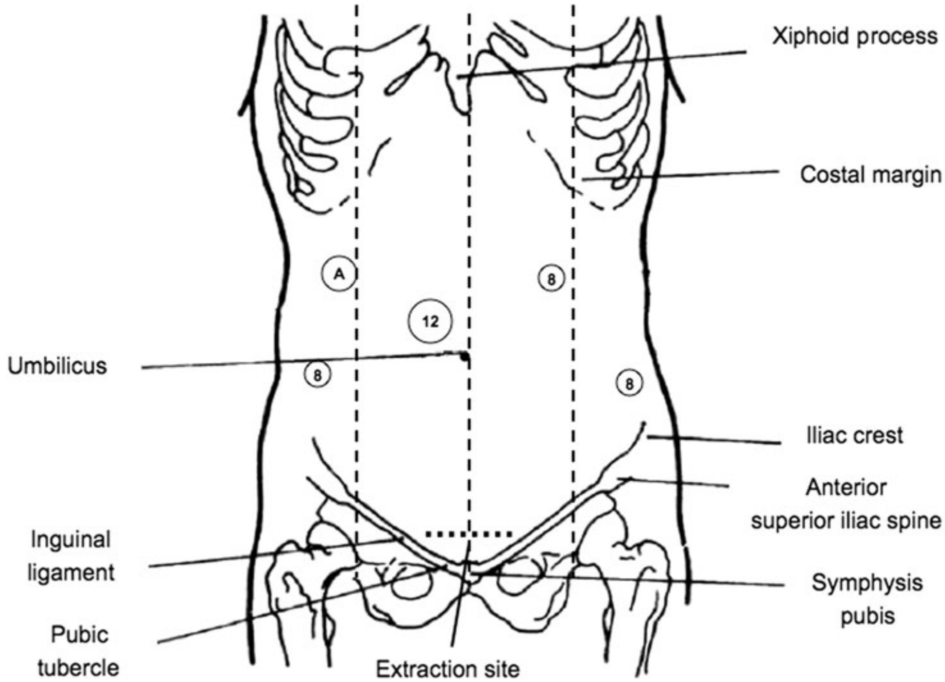

Fig. 1 Port placement for robotic-assisted rectosigmoid resection. (*8*) corresponds to 8-mm ports for robotic instruments, (*12*) corresponds to a 12-mm port for the camera, and (*A*) corresponds to an accessory port for laparoscopic instruments

Results

Robotic-assisted laparoscopic anterior rectosigmoidectomy was performed for 14 male (58.3%) and 10 female (41.7%) patients with a diagnosis of diverticulitis. The patients had a mean age of 49.8 ± 9.3 years (range = 30–62 years), mean BMI of 29.9 ± 6.3 kg/m^2 (range = 15.9–46.9 kg/m^2) and median ASA of 2 (range = 2–3). Of the 24 patients, 12 (50.0%) had one or more prior hospitalizations for an episode of diverticulitis and 16 (66.7%) had prior abdominal surgery. There were 15 cases of uncomplicated (62.5%) and 9 cases of complicated (37.5%) diverticulitis. Stratification of the complicated cases identified Hinchey stage I (2 cases) and stage II (7 cases) disease. The complicated cases included recurrent diverticulitis associated with sigmoid stricture (1 case), pelvic abscess (1 case), colovesicular fistula (1 case), pelvic abscess with enterocolic fistula (1 case), and pelvic abscess with colovesicular fistula (5 cases).

The procedures required a mean of 14.1 ± 6.7 min (range = 6–30 min) for robotic docking, 100.5 ± 31.0 min (range = 50–180 min) for surgeon console time, and 224.2 ± 47.1 min (range = 150–330 min) for the total surgical procedure. Robotic docking and surgeon console time represented 51.9% of the total operative time (6.7% and 45.2%, respectively). The mean estimated blood loss was 89.6 ± 44.8 ml (range = 25–200 ml) and no blood transfusions were required. Ureteral stent placement was not performed for any of the patients, and none of the procedures required conversion to open, hand-assisted laparoscopic, or conventional laparoscopic surgery. A primary colorectal anastomosis was fashioned with avoidance of colostomy in all patients. Three patients with Hinchey stage II disease (fistula formation and significant pelvic abscess) underwent diversion with a loop ileostomy secondary to the severe acute inflammatory nature of their disease.

The mean length of hospital stay was 3.4 ± 2.6 days (range = 2–14 days). Three patients (12.5%) developed postoperative complications (Table 1). Two of these patients developed postoperative ileus requiring placement of a nasogastric tube and extended hospitalization (7 and 14 days, respectively). The third patient presented at the initial postoperative follow-up with a superficial seroma that was drained in the office. There were no anastomotic leaks, and none of the patients required hospital readmission or secondary surgical intervention during 30-day postoperative follow-up.

Discussion

Laparoscopic rectosigmoid resection was first described for the surgical treatment of diverticulitis in 1991 [34] and has since been the focus of several large studies. Most reports demonstrated distinct short-term benefits following laparoscopic rectosigmoid resection, such as reduced hospital stay, reduced analgesic requirements, earlier return of bowel function, and lower complication rates when compared to open surgery. However, several studies also revealed longer operative times (ranging from 90–400 min) [35–37 and high

Table 1 Postoperative outcomes ($n = 24$)

Pt. No.	Pathology (diverticulitis)	Length of stay (days)	Postoperative complications	Secondary interventions
1	Uncomplicated	3	None	None
2	Uncomplicated	2	None	None
3	Uncomplicated	3	None	None
4	Complicated	2	None	None
5	Uncomplicated	2	None	None
6	Uncomplicated	2	Seroma	Local drainage
7	Uncomplicated	2	None	None
8	Uncomplicated	2	None	None
9	Complicated	3	None	None
10	Complicated	3	None	None
11	Uncomplicated	3	None	None
12	Uncomplicated	6	None	None
13	Complicated	2	None	None
14	Complicated	2	None	None
15	Complicated	2	None	None
16	Uncomplicated	2	None	None
17	Uncomplicated	2	None	None
18	Complicated	3	None	None
19	Uncomplicated	4	None	None
20	Uncomplicated	3	None	None
21	Uncomplicated	3	None	None
22	Complicated	14	Postoperative ileus	Nasogastric tube
23	Complicated	7	Postoperative ileus	Nasogastric tube
24	Uncomplicated	4	None	None

Length of stay (days)	Mean ± SD	Range	p value
Uncomplicated ($n = 15$)	2.9 ± 1.1	2–6	NS, $p < 0.23$
Complicated ($n = 9$)	4.2 ± 4.0	2–14	

rates of conversion (ranging from 5–65%) [9, 38]. Conversion to open surgery was associated with greater postoperative complication rates and longer hospitalizations [4]. As a result, laparoscopic surgery has been indicated primarily for patients with uncomplicated diverticulitis [39]. Nonetheless, the use of minimally invasive laparoscopic technique has been increasingly considered for patients with complicated disease.

The application of robotic technology was intended to enhance minimally invasive laparoscopic approaches by overcoming many inherent limitations, including two-dimensional visualization, reduced depth perception, rigid instrumentation, diminished freedom of motion, lack of tactile feedback, instrument tremor, and poor ergonomics [31, 40–42]. Published studies describing the use of the da Vinci® robot for the surgical management of diverticulitis (Table 2) have concluded RALS is relatively safe and technically feasible. The robotic approach afforded numerous advantages, including camera stability, better visualization, additional freedom of motion, enhanced dexterity, and improved ergonomics; nonetheless, several limitations were noted. Weber et al. [13] and Delaney et al. [14] experienced difficulty with splenic flexure mobilization, increased operative times, and lack of tactile and tensile feedback. Braumann et al. [22] suggested that the fixed operative field, inadequate abdominal instrumentation, and need for repositioning were confounding factors. Finally, Rawlings et al. [27] suggested that the restricted nature of the robot placed a greater burden on port placement and limited the opportunity to exchange ports conveniently during a procedure.

The robotic approach in this series afforded several operative advantages when compared to laparoscopic surgery [43]. Specifically, the instrumentation provided motion scaling (i.e., conversion of gross movements at the surgeon console to fine precise movements of the robot)

Table 2 Previous reports of robotic-assisted sigmoid resections for diverticular disease

Reference	Pts.	Diagnosis	Age	Gender	OT (min)	LOS (days)	EBL (cc)	Conversions	Complications
[13]	1	Diverticulitis	50	F	340[a]	3	NR	0	1 (postop ileus)
[14]	2	Diverticular disease	44.3[b]	F	161.5[c]	2.5[b]	200[b]	1	None
[22]	2	Sigma diverticulitis	59.5[b]	1 F 1 M	192[c]	11.5[b]	65[b]	0	None
[24]	4	Diverticulitis	NR	NR	237 ± 6[d]	NR	60 ± 17	1	1 (postop subileus)
[25]	35	Sigma diverticulitis	59.4[b]	NR	202[b]	8.6[b]	NR	1	3 (SSI, ileal perforation, pelvic fluid collection)
[27, 30]	13	Diverticulitis (8), cancer (3), polyp (2)	61 ± 16[e]	7 F[e] 6 M[e]	225 ± 37[e]	6 ± 7.3[e]	90 ± 60[e]	2[f]	1 (transverse colon injury)
[32]	3[g]	Diverticulitis	59[h]	2 F 1 M	230[h]	14[h]	NR	1	NR
Current study	24	Diverticulitis	49.8 ± 9.3	10 F 14 M	224.2 ± 47.1	3.4 ± 2.6	89.6 ± 44.8	0	3 (2 postop ileus, 1 seroma)

EBL estimated blood loss, *LOS* length of stay, *NR* not reported, *OT* operative time, *SSI* surgical site infection

[a] Operative time spans incision to placement of dressing

[b] Mean data

[c] Operative time spans incision to extubation

[d] Operative time spans incision to closure

[e] Mean data from all patients (data were not reported separately for each diagnosis)

[f] Unknown whether any of these patients were being treated for diverticulitis

[g] Number of patients includes values from previous studies

[h] Median value

and eliminated tremor. While laparoscopic instruments offer four degrees of motion (pitch, yaw, insertion, grip), the robotic instrumentation has a unique pulley system at its tips, creating an additional three degrees of freedom (internal pitch, internal yaw, rotation) through "wrist-like" motion [44, 45]. The endo-wristed movements facilitate fine dissection and suture placement, which we found especially useful in cases of fistulizing disease and in those cases with fibrotic planes of dissection. In addition, the extended reach afforded by the robotic instrumentation proved to be most beneficial in patients with a high BMI (>30 kg/m^2) and a narrow pelvis (males). Finally, the overall configuration of the robotic system provided beneficial ergonomic positioning with reduction of surgeon fatigue and elimination of strained posturing. However, while the robotic platform offers several distinct benefits, there are some drawbacks with the approach. These include use of a greater number of ports (five vs. four), larger-sized ports (8 mm vs. 5 mm), and limited ability to operate in adjacent fields (e.g., splenic flexure) without redocking one or more robotic arms.

Taking into consideration the difficulties described in previous robotic surgery reports [13, 14, 27], we utilized a modified robotic port setup (Fig. 1) and performed takedown of the splenic flexure and lysis of adhesions with conventional laparoscopic technique prior to docking. In addition, we limited the focus of the robot to pelvic and rectosigmoid dissection, as evidenced by the fact that combined robotic and console time represented 51.9% of the total case time. The remaining time for the procedures included port placement, laparoscopic exploration and LOA, laparoscopic takedown of the splenic flexure, and specimen extraction and resection. The anastomoses in all cases were created under robotic guidance. Our mean total operative time of 224 min was consistent with the range of previous reports (106–340 min) [13, 14, 22, 24, 25, 27, 30, 32]; however, no distinct trend was observed with respect to the robotic docking, console, or total operative times. This may be attributed to the severity and diversity of disease that presented to our institution.

Use of the robot proved to be particularly valuable with respect to its visual capabilities, including three-dimensional imaging, surgeon control of the camera arm, and platform stability. The high visual acuity and tenfold magnification combined with the medial-to-lateral approach facilitated early identification and preservation of the left ureter without requiring stent placement. The benefit of this approach is reflected in the absence of conversions in our series, which was in line with the low conversion rate noted in the D'Annibale et al. series (2.9%) [25]. This is in contrast with the higher conversion rates described in laparoscopic surgery reports (15.4–23.5%) [46, 47] and has been one of the most important factors in our implementation of this technique. Postoperative outcome analysis revealed a mean length of stay of 3.4 days with no significant difference between patients with uncomplicated and complicated disease (Table 1). Length of stay outcomes compared favorably with previous laparoscopic and robotic surgery reports (3.1–11.8 days [48–50] and 2.5-11.5 days [13, 14, 22, 25, 27, 30], respectively). In addition, our complication rate of 12.5% was in line with previous laparoscopic surgery reports (14.0–18.1%) [48, 49]. The number and type of complications in our series were consistent with those reported for previous robotic surgery series (1–3 complications per study) [13, 14, 22, 24, 25, 27, 30]. No major complications were encountered, and none of the patients required readmission or secondary operative intervention during follow-up.

Nine patients underwent robotic-assisted laparoscopic anterior rectosigmoidectomy for complicated diverticulitis. These cases consisted of sigmoid stricture, enterocolic fistula, colovesicular fistula, and pelvic abscess. We feel these patients benefited most from the use of the robotic approach as it helped overcome difficult dissection in post-inflammatory adhesions and fibrotic tissue planes [51]. None of these patients required conversion, even though these types of cases are typically associated with high conversion rates (25–33%) [52–54]. Furthermore, complication rates between 4% and 49% [55, 56] have been reported following surgery for complicated diverticulitis. In our series, minor complications (i.e., postoperative ileus) developed in two patients with complicated disease; however, both were managed without setback. Three patients with complicated (Hinchey II) disease underwent diversion with a loop ileostomy due to fistula formation and significant pelvic abscess. While not routinely employed for Hinchey stage I or II disease, diversion has been reported as a safe and beneficial option in the presence of significant inflammatory reaction [57–62]. Ileostomy takedown was performed successfully without complication 3 months after their initial procedures.

This report represents the largest series of robotic-assisted laparoscopic surgical procedures for the treatment of diverticulitis in North America. We demonstrated that the procedure is a safe and efficacious approach, and provides visual and operational advantages well suited to colorectal surgery involving pelvic anatomy. When compared with reports of conventional laparoscopic surgery, our series demonstrates the ability to complete the procedure without conversion and results in quality outcomes such as short length of hospital stay and low complication rate. While reports illustrating the safety and feasibility of using the robotic technique for colon and rectal procedures are emerging, increased expense, limited availability, and a high degree of technical training continue to hinder widespread adaptation of its use in the field. Despite these impediments, the technical advantages and quality outcomes of the platform may ultimately result in greater consideration of this approach.

Disclosures Drs. Ragupathi, Ramos-Valadez, and Haas and Mr. Patel have no conflicts of interest or financial ties to disclose.

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