Journal of Robotic Surgery (2019) 13:765–772
https://doi.org/10.1007/s11701-018-00914-x

ORIGINAL ARTICLE

Robotic-assisted surgery for complicated and non-complicated diverticulitis: a single-surgeon case series

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Received: 29 June 2018 / Accepted: 13 December 2018 / Published online: 23 January 2019

Abstract
Laparoscopic colectomy is the preferred approach for surgical management of non-complicated diverticulitis, with lower complication rates, shorter length of stay, and decreased narcotic use compared with open surgery. Complicated diverticulitis, characterized by abscess, fistula or stricture, is more difficult to manage with minimally invasive surgery, with reports of higher conversion rates, prolonged operative time, longer length of stay, and increased complication rates. The robotic platform may provide an alternative safe and feasible option for managing complicated diverticulitis with minimally invasive surgery. A prospectively maintained database of robotic-assisted colorectal surgery performed at our university-affiliated community hospital was used to identify consecutive patients who underwent robotic-assisted surgery for complicated or non-complicated diverticulitis. Thirty-two patients with non-complicated diverticulitis and 36 patients with complicated diverticulitis had surgery between January, 1, 2014 and September 30, 2017. The database was used to compare the two groups of patients in regard to operative time, estimated blood loss, ureteral stent usage, conversions, ostomies, pelvic drains, post-operative complications, length of stay, return of bowel function, and post-operative narcotic use. Comparison of the two groups revealed significant differences in operative times (172 vs. 196 min, $p=0.01$), conversions (3.1% vs. 22.2%, $p=0.03$), ostomies (9.4% vs. 33.3%, $p=0.04$), and pelvic drains (3.2% vs. 28.6%, $p=0.02$). No significant differences were noted for estimated blood loss, complications, return of bowel function, narcotic use, length of stay, or readmissions. Four complicated diverticulitis patients had intra-operative ureteral stents, and there were no ureteral injuries in either group. Patients with complicated diverticulitis required longer operative time, and more often required conversion, an ostomy, and a pelvic drain. Robotic-assisted surgery is safe and feasible for both non-complicated and complicated diverticulitis.

Keywords Complicated diverticulitis · Robotic · Conversion · Ostomy · Narcotic · Ureteral stent

Introduction

Laparoscopic colectomy is the preferred method for surgical treatment of non-complicated diverticulitis (ND) [1]. Compared with open surgery, patients undergoing laparoscopic resection often require longer operative time (OT), but experience less post-operative pain, reduced hospital length of stay (LOS), and less short-term and long-term post-operative morbidity [2–5]. Complicated diverticulitis (CD), characterized by abscess, fistula, or stricture, often contribute to a more difficult dissection. Thickened and inflamed tissues, obliterated anatomic planes, involvement of "innocent bystander" organs, and distorted anatomy may lead to increased bleeding, inability to identify safe routes of dissection, and increased risk of injury to other organs. When comparing laparoscopy for CD with ND, higher conversion rates and complication rates have been demonstrated for patients with CD [6, 7]. Conversion seems to be an independent predictor of worse outcomes, associated with increased OT, longer LOS, and higher post-operative complication rates [8, 9].

The robotic-assisted approach has several advantages over laparoscopy that may prove useful in overcoming the operative challenges with CD: high-definition 3D images with tenfold magnification, motion filtering to decrease tremor, a surgeon-controlled camera on a stable platform, a third operating arm controlled by the surgeon, and "wristed" instrumentation. The da Vinci platform is particularly useful for fine dissection around the inferior mesenteric vessels, sharp

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dissection in Heald's plane, identification of the ureters, identification and preservation of the autonomic nerves, and intra-corporeal suturing. Although there is a growing body of literature documenting outcomes for robotic-assisted surgery for ND, the data currently available examining robotic-assisted surgery for CD are limited [10–17].

In this study, we compared outcomes of robotic-assisted surgery in patients with ND and CD to examine the safety and feasibility of a robotic-assisted approach in these patients.

Materials and methods

A database was initiated in January 2014 for all robotic-assisted colon and rectal surgery. Data collected includes age, gender, body mass index (BMI), comorbidities, prior abdominal surgery, indication for surgery, OT, conversions, ostomies required, ureteral catheters utilized, pelvic drains placed, estimated blood loss (EBL), return of bowel function (ROBF), LOS, post-operative complications, and readmission rate. This study was approved by the Institutional Review Board of Emory University (IRB #98836).

The patient is positioned on the operating table in modified lithotomy position with upper extremities tucked and padded alongside the torso. It is helpful to use a foam mattress (author preference Prime Medical Trendelenburg OR Table Pad STP100) to prevent patient movement during Trendelenburg positioning. An upper body warming system (author preference 3M™ Bair Paws™ Flex) is recommended to maintain normothermia. Orogastric tube decompression and bladder catheterization are standard. Anesthesia personnel and cart are located at the head of the table.

A 12 mm x 130 mm Applied Kii® balloon blunt tip system (author preference) is placed in the right middle quadrant using an open technique, a laparoscope is introduced, and the abdomen is explored. The patient is placed in moderate Trendelenburg position with the right side of the patient tilted toward the floor. The goal is for the abdominal contents to clear out of the pelvis allowing access to the medial aspect of the recto-sigmoid mesentery.

Port placement for a single-dock procedure using the da Vinci Si platform is demonstrated in Fig. 1. Port 1 (P1) is placed in the right lower quadrant (RLQ), using an 8-mm port nested in a 12-mm port, enabling use of the da Vinci EndoWrist Stapler. Port 2 (P2) is positioned in the right upper quadrant (RUQ), a few centimeters lateral to the falciform ligament, and P3 is placed at the midclavicular line in the left upper quadrant (LUQ) a few centimeters caudad to P2. The assistant port (A1) is placed lateral to the camera port, along the right anterior axillary line. The patient cart is docked over the left lower corner of the operating room table.

First, the surgeon and assistant retract the left colon and sigmoid colon medially, and dissection proceeds along the line of Toldt proximally toward the splenic flexure and

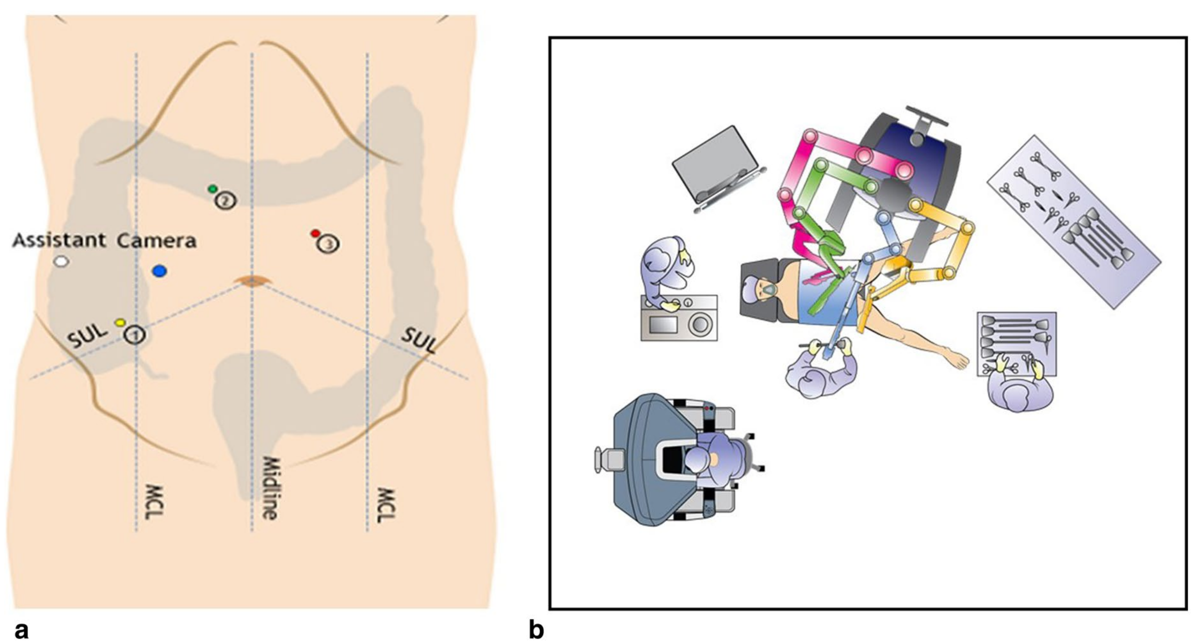

Fig. 1 **a** Port placement for single docking with da Vinci Si for diverticulitis of sigmoid colon. Port 1 is an 8-mm port nested inside a 12-mm port. Port 2 is placed a few centimeters to the right of the falciform ligament. Port 3 is caudad to Port 2 and left midclavicular. **b** Patient is in moderate Trendelenburg position, right side tilted down. The patient cart is docked over the left lower corner of the bed

distally to the upper third of the rectum, being careful to identify and preserve the left ureter. When significant progress has been made, the recto-sigmoid is retracted anteriorly and laterally so as to put the medial peritoneum on tension. The medial peritoneum is incised, allowing CO_2 insufflation to enter the retroperitoneum and reveal the plane between the mesorectal fascia and presacral fascia. This avascular plane is sharply dissected, and the inferior hypogastric nerves and the distal pelvic nerve plexus are identified and preserved. Dissection proceeds until sufficient mobility of the posterior attachments of the rectum has been achieved, then the right lateral attachments are divided. Next, the surgical assistant retracts the rectum cephalad and right, and the surgeon dissects down the left side of the pelvis. Lastly, the assistant retracts the rectum cephalad and posterior, while the surgeon dissects anteriorly, connecting the two lateral dissections.

A location at the upper third of the rectum, or below the most distal inflammation (whichever is lower), is selected for distal transection, which is achieved using the EndoWrist Stapler. The sigmoid can now be retracted anteriorly and laterally, exposing the inferior mesenteric artery (IMA) at its origin. During this portion of the dissection, the left ureter and aortic hypogastric nerve plexus are clearly visualized and protected. The IMA is divided and medial to lateral dissection may proceed until the left colon is free, at times up to the inferior border of the pancreas.

When adequate mobilization for a tension-free anastomosis has been achieved, an appropriate proximal transection point is chosen, and the remaining mesocolic vessels at this level are divided. A transverse colotomy is created distal to the transection point, allowing an EEA stapler anvil to be placed inside the left colon. The colotomy is closed with a running suture (author preference 2 – 0 Stratafix™), the proximal colon is stapled, and the anvil is brought out through the distal end of the proximal colon. End-to-end anastomosis is performed using robotic-assistance. Irrigation is performed with normal saline mixed with gentamycin and clindamycin. The specimen is delivered via a muscle-sparing enlargement of the camera port or P1. If a temporary ileostomy is needed, the camera port incision is modified for stoma placement.

Patients undergoing elective colon surgery at our institution are enrolled in an Enhanced Recovery After Surgery (ERAS) protocol. The protocol includes pre-operative education, ultrasound-guided transversus abdominus plane (TAP) block, peri-operative alvimopan (Entereg®), post-operative intravenous acetaminophen (Ofirmev®), post-operative ketorolac (Toradol®), and minimization of narcotic use. Patients are started on a clear liquid diet the day of surgery and are advanced to a fiber-restricted soft diet after flatus or bowel movement. Patients are encouraged to ambulate starting the night of surgery, with emphasis on increasing ambulation daily. Foley catheter removal occurs on the second post-operative morning.

OT was defined as time from first incision to closure of last incision. Conversions were defined as patients who required extension of an incision other than what is expected for specimen extraction. EBL was retrieved from the anesthesia record. Post-operative complications included any complication during the 60 days following surgery. LOS was defined as time of admission to time of discharge order. Mortality was defined as death from any cause within 60 days following surgery.

Basic patient characteristics such as age, gender, and American Society of Anesthesiologists (ASA) class were summarized in a demographic table. Means and standard deviations were used for continuous variables, and counts and percentages were used for categorical variables. Comparisons were made between ND and CD patient groups. For comparisons of continuous variables, two-sample *t* tests were utilized unless the data were not distributed normally, in which case a Wilcoxon rank-sum test was used. In the case of non-normally distributed data, median and interquartile range were reported instead of mean and standard deviation. Categorical variables were compared with Chi-squared tests or Fisher's exact tests in the case of small numbers. All tests were two-sided when possible and used an alpha level of 0.05 for significance. Statistical analysis was conducted using R-project software version 3.4 [18].

Results

Eighty-nine patients required surgery for diverticular disease from January, 2014 to June, 2017 (Fig. 2). Of these, 21 patients underwent open surgery due to peritonitis (7), large bowel obstruction (6) and urgent surgery related to phlegmon (8). The remaining 68 patients were managed with robotic-assisted colectomy, and these patients were the focus of our study (Table 1). Baseline characteristics between the ND and CD group were comparable in all categories. Hypertension, hyperlipidemia, gastroesophageal reflux disease, coronary artery disease, and hypothyroidism were the most common medical comorbidities. Number of prior abdominal surgeries in all patients ranged from 0 to 5 (mean = 1.2).

Out of the study cohort, 28 patients (41%) were men, mean age was 60.5 (range 38–90) years, and mean BMI was 28.7 (range 20–48) kg/m^2. Patients had an average of 3.2 (range 0–11) significant comorbidities, and 40 (59.7%) patients had prior abdominal surgery. Indications for robotic surgery were recurrent diverticulitis in 32 (47.1%), abscess in 20 (29.4%), fistula in 11 (16.2%), and stricture in 5 (7.4%) of patients. For all patients, average OT was 184 (range 104–302) minutes, average EBL was 115 (0–1200) mL, and average LOS was 4.2 (range 2.5–14) days.

Fig. 2 Flow diagram of 89 consecutive patients operated on for diverticulitis

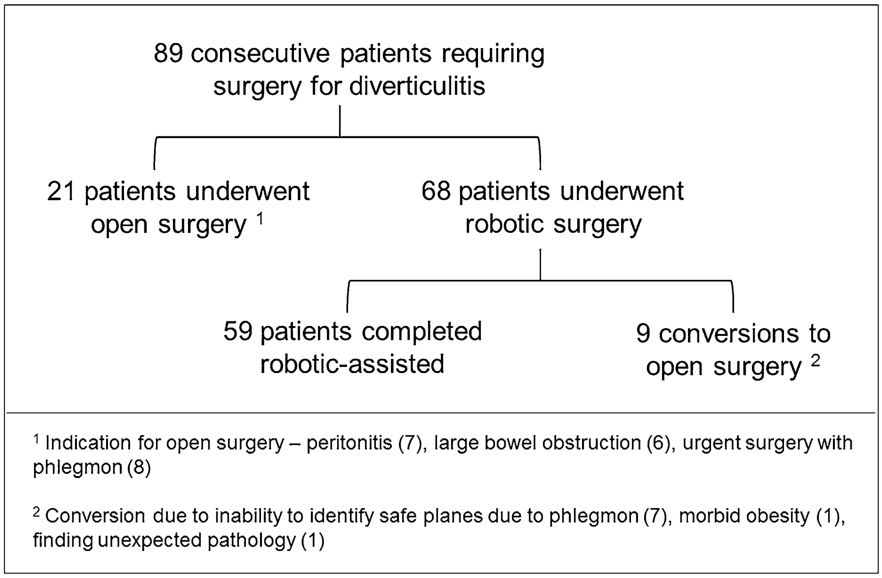

Table 1 Patient demographics and surgery indications

	Non-complicated diverticulitis ($n=32$)	Complicated diverticulitis ($n=36$)	p value
Patient demographics			
Age—mean (range)	59 (42–77)	62 (38–90)	0.314
Gender—male/female (%)	12/20 (37.5/62.5)	16/20 (44.4/55.6)	0.738
BMI—mean (range)	28.8 (20–48)	28.7 (22–38)	0.876
Number of comorbidities—mean (range)	2.9 (0–11)	3.4 (0–7)	0.33
Patient with prior abdominal surgery (%)	18 (56.3)	22 (61.1)	0.997
Indication for surgery (%)			< 0.01
Recurrent disease	32 (100)	0 (0)	
Abscess	0 (0)	20 (55.6)	
Fistula	0 (0)	11 (30.6)	
Stricture	0 (0)	5 (13.9)	
Type of surgery (%)			0.045
AR	29 (90.6)	24 (66.7)	
AR with DLI	3 (9.4)	9 (25.0)	
Hartmann's procedure	0 (0)	3 (8.3)	

AR anterior resection, *DLI* diverting loop ileostomy

All 32 ND patients had recurrent disease, whereas the 36 CD patients had diverticulitis complicated by abscess (56%), fistula (31%), or stricture (14%). Specifically, preoperative imaging revealed 20 patients with abscess, seven patients with colovesical fistula and abscess, three patients with colonic stricture, two patients with colonic stricture and abscess, two patients with colovaginal fistula and abscess, one patient with colovesical fistula, and one patient with colovaginal fistula. Five patients required percutaneous drainage prior to staged elective surgery, while 2 patients required urgent surgery on the same hospital admission of the most recent acute flare. Twenty-nine (91%) patients with ND were managed with anterior resection (AR) and three patients (9%) had AR with diverting loop ileostomy (DLI). Of the 36 patients with CD, 24 patients (67%) had AR, 9 (25%) had AR with DLI, and 3 (8%) had a Hartmann's procedure.

A comparison of intra-operative and post-operative outcomes between ND and CD groups demonstrated no significant differences in EBL, ROBF, or readmission rate (Table 2). The 60-day mortality rate was 0% in both groups. Significant differences between the groups were noted in OT, number of conversions, ostomies created, and pelvic drains placed. Mean OT for the ND group was 171 (range 104–258) min compared to 196 (range 120–302) min in the CD group ($p=0.011$). There was one conversion in the ND

Table 2 Results

	Non-complicated diverticulitis ($n=32$)		Complicated diverticulitis ($n=36$)		p value
OR time in minutes mean (range)	171.8	(104–258)	195.6	(120–302)	0.011
Conversion to open (%)	1	(3.1)	8	(22.2)	0.030
Ostomy (%)	3	(9.4)	12	(33.3)	0.037
Drain placed (%)	1	(3.1)	10	(27.8)	0.015
EBL in mL mean (range)	82.9	(0–400)	142.5	(0–1200)	0.621
Ureteral catheters utilized (%)	0	(0)	4	(11.1)	0.116
Complication (%)	5	15.6	14	(38.9)	0.062
ROBF day (range)	2.5	(1–7)	2.8	(1–12)	0.248
LOS in days mean (range)	3.8	(2.5–13)	4.5	(2.5–14)	0.052
MS04 equivalent dose during POD 1–4 mean (range)	87.7	(0–562)	85.3	(8–532)	0.458
Readmit 60 days mean (%)	1	(3.1)	4	(11.1)	0.427
Mortality 60 days mean (%)	0	0	0	(0)	–

MS04 morphine sulfate, *POD* post-operative day

group (3%) compared to eight conversions (22%) in the CD group ($p=0.03$). The reasons for conversion were inability to visualize structures and planes due to phlegmon (7), morbid obesity (1), and discovery of unrelated pathology (1). In the ND group, three patients received ostomies (9%) compared to 12 patients (33%) in the CD group ($p=0.037$), and one patient (3%) in the ND group and ten patients (27.8%) in the CD group had drains placed intra-operatively ($p=0.015$). No patients in the ND group and four patients in the CD group required ureteral catheters, and there were no ureteral injuries.

Although there were higher numbers of complications and longer LOS in the CD group, these did not reach statistical significance. In the ND group, five patients (16%) experienced post-operative complications compared to 14 patients (39%) in the CD group ($p=0.062$). Mean length of stay in ND group was 3.8 days (range 2.5–13 days) compared to 4.5 days (range 2.5–14 days) in the CD group ($p=0.052$). Morphine equivalent doses during the first four post-operative days were similar between the two groups, with ND patient requiring 88 (range 0–562) mg and CD patients using 85 (range 8–532) mg ($p=0.458$).

Discussion

In our series examining robotic-assisted surgery for diverticulitis, patients had a mean OT of 184 (range 104–302) min, mean EBL of 115 (range 0–1200) mL, and mean LOS of 4.2 (range 2.5–14) days. When comparing robotic surgery for ND and CD, there were differences in mean OT (171 vs. 196 min, $p=0.011$), conversion rates (3.1% vs. 22.2%, $p=0.03$), ostomy creation rates (9.4% vs. 33.3%, $p=0.037$), and drain usage (3.1% vs 27.8%, $p=0.015$). There were no significant differences regarding EBL, ROBF, readmission rate, or narcotic use between groups. Although the differences were not statistically significant, higher complication rates (38.9% vs. 15.6% $p=0.062$) and longer LOS (4.5 vs. 3.8 days, $p=0.052$) were noted in the CD cohort.

Our results demonstrate that robotic surgery can be safe and feasible for both ND and CD. Because of the inflammation and distortion of natural anatomic planes, many consider minimally invasive surgery for diverticular disease to be more difficult than other colorectal operations [19, 20]. Robotic-assisted surgery for colorectal disease has gained popularity due to enhancements in visualization and dexterity with the newest da Vinci platform, enabling more surgeons to offer patients minimally invasive surgery for complicated diseases. Our series compares favorably with previously published reports of minimally invasive surgery for diverticulitis (Table 3). Our mean OT of 196 min in the CD group is comparable to those published by others (mean OT 207–272 min) [14, 15]. Our mean EBL of 143 mL is similarly comparable to a mean EBL of 300 mL published by Elliott and colleagues [14]. Our conversion rates, 3.1% for ND and 22.2% for CD, are similar to those found in the literature. Conversion rates are strongly influenced by the severity of diverticular disease, with published conversion rates of 3.2–4.8% for patients with ND, and of 0–61% for patients with CD [6, 14, 15, 21–26].

ERAS pathways are increasingly common in colorectal surgery. Some of the outcomes reported in this study should be at least partially attributed to our ERAS protocol. Patients in both groups experienced early ROBF (2.5 days for ND and 2.8 days for CD), low mean morphine equivalent dosage during the first four post-operative days (87.7 mg for ND and 85.3 mg for CD), and LOS of 3.8 and 4.5 days, respectively. The ROBF and

Table 3 Review of recent literature regarding minimally invasive surgery for complicated and non-complicated diverticulitis

Author [citation]	Patients	Diagnosis	Surgical approach	OT (min)	Ostomy n (%)	EBL (mL)	Conversions n (%)	Complications n (%)	LOS (days)	Readmissions n (%)
Elliot et al. [14]	11	CD	Rob	272.0	2 (18)	300.0	2 (18)	3 (27)	6.5	1 (9%)
	20		Lap	254.0	0	215.0	0	6 (30)	4.2	2 (10%)
Maciel et al. [15]	20	CD	Rob	207.7	1	101.3	0	4 (20)	3.5	–
	55		Lap	126.7	2	187.7	8 (15)	16 (29)	4.6	–
Ragupathi et al. [22]	9	CD	Rob	224.2	3 (33)	89.6	0	2 (8)	4.2	0 (0%)
	15	ND			0			1 (4)	2.9	
Rotholtz et al. [23]	72	CD	Lap	193.0	7 (10)	–	13 (18)	16 (22)	4.7	–
	188	ND		156.0	0	–	6 (3)	23 (12)	3.3	–
Rosen et al. [24]	98	ND and CD	Lap	168.0	18 (18)	–	17 (38)	19 (19)	5.7	7 (7.1%)
Bhakta et al. [25]	139	CD	Lap	145.1	–	109.7	17 (12)	29 (21)	5.8	–
	437	ND		128.5	–	80.1	57 (13)	53 (12)	5.1	–
Abbass et al. [27]	21	CD	Lap	254.0	1 (5)	216.0	0	8 (38)	4.0	2 (10%)
	21	ND		281.0	1 (5)	221.0	2 (10)	7 (33)	4.0	1 (5%)
Current study	36	CD	Rob	195.6	12 (33)	142.5	8 (22)	14 (39)	4.5	4 (11.1%)
	32	ND		171.8	3 (9)	82.9	1 (3)	5 (16)	3.8	1 (3.1%)

LOS observed in our patients is commensurate with other authors' experiences following minimally invasive colorectal surgery. A review of the literature for similar patients reveals ROBF ranges from 1.4 to 3.4 days [23, 25] and mean LOS ranges from 3.3 to 6.8 days [14, 15, 22, 23, 25, 27, 28]. Sixty-day readmission rates in ND and CD patients in our study were 3% and 11%, again similar to those found in other studies (4–10%) [27, 28].

We report complication rates of 15.6% in the ND group and 38.9% in the CD group. This is similar to complication rates reported by other authors in similar cohorts of patients (12% in ND to 20.9–30% in CD patients) [14, 15, 23–25]. We also report ostomy rates, an outcome of particular concern to patients. Patients with ND had an ostomy rate of 9.4%, all of which were diverting loop ileostomies, while those with CD had an ostomy rate of 33.3%, with 9 (25%) diverting loop ileostomies and three (8.3%) end colostomies. Ostomy rates for diverticular disease in the literature range from 0 to 30%, depending on the complexity of the disease [23, 24, 27, 28].

Identification of the ureters is a critical step during surgery for diverticulitis and can be quite challenging in patients with CD. Ureteral stents are commonly used to assist with ureteral identification, but placing stents adds time and increases cost related to a procedure. In this series, only four patients had intra-operative ureteral stents placed, both in the CD group, and there were no ureteral injuries in any patient. Subjectively, our surgeon's experience was the 3D imaging and 10x magnification afforded by the robotic platform was particularly useful for identifying the ureter in a field distorted by significant pathology.

Several limitations of our study must be acknowledged. This study represents the experience of a single surgeon in a university-affiliated community hospital and may not be translatable to the experiences of other surgeons in different institutions. Secondly, although this represents the largest study looking at robotic-assisted surgery for CD and ND, our patient numbers are relatively small and limit our ability to make some conclusions. Third, although collected prospectively, our data were analyzed retrospectively, and vulnerable to any biases related to retrospective review. Finally, we did not examine cost associated with the robotic platform, which is a common area of criticism for robotic surgery utilization. Several studies comparing outcomes of robotic and laparoscopic colorectal surgery have shown similar outcomes but increased costs in patients undergoing robotic surgery [29–32]. More recent studies, however, have shown similar costs [12] or improved cost-effectiveness with certain aspects of robotic surgery relative to laparoscopic surgery [10]. This is an area in need of further study.

Conclusions

This retrospective case series demonstrates that robotic-assisted surgery is safe and feasible for patients with ND and CD. In our experience, patients with complicated diverticulitis required longer OT, had higher conversion rates, and were more likely to have temporary ostomies and pelvic drains. Although not statistically significant, we did note an increased incidence of complications and longer LOS in the CD group. The superior visualization and maneuverability provided by the robotic platform may increase the feasibility of a minimally invasive approach for patients with CD.

Acknowledgements The authors thank Sebastian Perez, MSPH, and Satyen Tripathi, MA, for their contributions to this study.

Author contributions TJPO and SAR substantial contributions to conception and design, or acquisition of data, or analysis and interpretation of data. JX, TJPO, SAR drafting the article or revising it critically for important intellectual content. SAR final approval of the version to be published.

Funding None.

Compliance with ethical standards

Conflict of interest Dr. Rosen has been paid by Intuitive Surgical for teaching courses on robotic colorectal surgery. Dr. Rosen has been paid by CSATS as an expert reviewer of robotic colorectal surgery videos. Dr. Paul Olson and Ms. Xia declare that they have no conflict of interest.

References

1. Ambrosetti P, Gervaz P (2016) Management of sigmoid diverticulitis: an update. Updates Surg 68:25–35
2. Senagore AJ, Duepree HJ, Delaney CP, Dissanaike S, Brady KM, Fazio VW (2002) Cost structure of laparoscopic and open sigmoid colectomy for diverticular disease: similarities and differences. Dis Colon Rectum 45(4):485–490
3. Senagore AJ (2005) Laparoscopic sigmoid colectomy for diverticular disease. Surg Clin North Am 85(1):19–24, vii
4. Purkayastha S, Constantinides VA, Tekkis PP et al (2006) Laparoscopic vs. open surgery for diverticular disease: a meta-analysis of nonrandomized studies. Dis Colon Rectum 49(4):446–463
5. Klarenbeek BR, Veenhof AA, Bergamaschi R et al (2009) Laparoscopic sigmoid resection for diverticulitis decreases major morbidity rates: a randomized control trial: short-term results of the Sigma Trial. Ann Surg 249:39–44
6. Vargas HD, Ramirez RT, Hoffman GC et al (2000) Defining the role of laparoscopic-assisted sigmoid colectomy for diverticulitis. Dis Colon Rectum 43(12):1726–1731
7. Scheidbach H, Schneider C, Rose J et al (2004) Laparoscopic approach to treatment of sigmoid diverticulitis: changes in the spectrum of indications and results of a prospective, multicenter study on 1545 patients. Dis Colon Rectum 47(11):1883–1888
8. Gervaz P, Pikarsky A, Utech M et al (2001) Converted laparoscopic colorectal surgery. Surg Endos 15(8):827–832

9. Marusch F, Gastinger I, Schneider C et al (2001) Importance of conversion for results obtained with laparoscopic colorectal surgery. Dis Colon Rectum 44(2):207–214 (discussion 214–16)
10. Holzmacher JL, Luka S, Aziz M, Amdur RL, Agarwal S, Obias V (2017) The use of robotic and laparoscopic stapling devices during minimally invasive colon and rectal surgery: a comparison. J Laparoendosc Adv Surg Tech 27(2):151–155
11. Miller PE, Dao H, Paluvoi N, Bailey M, Margolin D, Shah N, Vargas HD (2016) Comparison of 30-day postoperative outcomes after laparoscopic vs robotic colectomy. J Am Coll Surg 223:369–373
12. Hollis RH, Cannon JA, Singletary BA, Korb ML, Hawn MT, Heslin MJ (2016) Understanding the value of both laparoscopic and robotic approaches compared to the open approach in colorectal surgery. J Laparoendosc Adv Surg Tech 26(11):850–856
13. Dehal A, Patel S, Park H, Nguyen P, Yuhan R, Ruan J (2016) Robotic colorectal surgery: our initial experience. Am Surg 82:907–910
14. Elliot PA, McLemore EC, Abbass MA, Abbas MA (2015) Robotic versus laparoscopic resection for sigmoid diverticulitis with fistula. J Robot Surg 9(2):137–142
15. Maciel V, Lujan HJ, Plasencia G et al. Diverticular disease complicated with colovesical fistula: laparoscopic versus robotic management. Int Surg 2014; 99(3):203–210. https://doi.org/10.9738/INTSURG-D-13-00201.1
16. Gorgun E, Aytac E, Gurland B, Costedio MM (2015) Case-matched comparison of robotic vs laparoscopic colorectal surgery: initial institutional experience. Surg Laparosc Endosc Percutan Tech 25(5):e148–e151
17. Deutsch GB, Anantha Sathyanarayana S, Gunabushanam V et al (2012) Robotic vs laparoscopic colorectal surgery: an institutional experience. Surg Endosc 26:956–963
18. R Core Team (2017) R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/
19. Stam MAW, Draaisma WA, Pasker PCM, Consten ECJ, Broeders IAMJ (2017) Sigmoid resection for diverticulitis is more difficult than for malignancies. Int J Colorectal Dis 32:891–896
20. Celentano V (2017) Laparoscopic sigmoid resection for diverticulitis is rarely a suitable case for the initial phase of the learning curve. Int J Colorectal Dis 32:1095–1096
21. Köckerling F, Schneider C, Reymond MA et al (1999) Laparoscopic colorectal surgery study group (LCSSG). Laparoscopic resection of sigmoid diverticulitis–results of a multicenter study. Surg Endosc 13:567–571
22. Ragupathi M, Ramos-Valadez DI, Patel CB, Haas EM (2011) Robotic-assisted laparoscopic surgery for recurrent diverticulitis: experience in consecutive cases and a review of the literature. Surg Endosc 25(1):199–206
23. Rotholtz NA, Canelas AG, Bun ME, Laporte M, Sadava EE, Ferrentino N, Guckenheimer SA (2016) Laparoscopic approach in complicated diverticular disease. World J Gastrointest Surg 8(4):308–314
24. Rosen DR, Hwang GS, Ault GT. Ortega AE, Cologne KG (2017) Operative management of diverticulitis in a tertiary care center. Am J Surg 214:37–41
25. Bhakta A, Tafen M, Glotzer O et al (2016) Laparoscopic sigmoid colectomy for complicated diverticulitis is safe: review of 576 consecutive colectomies. Surg Endosc 30:1629–1634
26. Laurent SR, Detroz B, Detry O, Degauque C, Honore P, Meurisse M (2005) Laparoscopic sigmoidectomy for fistulized diverticulitis. Dis Colon Rectum 48(1):148–152
27. Abbass MA, Tsay AT, Abbas MA (2013) Laparoscopic resection of chronic sigmoid diverticulitis with fistula. JSLS 17:636–640
28. Wen Y, Althans AR, Brady JT et al (2017) Evaluating surgical management and outcomes of colovaginal fistulas. Am J Surg 213:553–557
29. Juo YY, Hyder O, Haider AH, Camp M, Lidor A, Ahuja N (2014) Is minimally invasive colon resection better than traditional approaches?: first comprehensive national examination with propensity score matching. JAMA Surg 149:177–184
30. Maeso S, Reza M, Mayol JA, Blasco JA, Guerra M, Andradas E, Plana MN (2010) Efficacy of the Da Vinci surgical system in abdominal surgery compared with that of laparoscopy: a systematic review and meta-analysis. Ann Surg 252:254–262
31. Park EJ, Cho MS, Baek SJ et al (2015) Long-term oncologic outcomes of robotic low anterior resection for rectal cancer: a comparative study with laparoscopic surgery. Ann Surg 261:129–137
32. Kim CW, Kim CH, Baik SH (2014) Outcomes of robotic-assisted colorectal surgery compared with laparoscopic and open surgery: a systematic review. J Gastrointest Surg 18:816–830