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ORIGINAL ARTICLE

Robotics confers an advantage in right hemicolectomy with intracorporeal anastomosis when matched against conventional laparoscopy

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Abstract
Comparisons between robotic and laparoscopic right hemicolectomy have been confounded by variations in operative technique. This study evaluates the two procedures after standardizing the intraoperative steps and perioperative management. Patients who underwent robotic right hemicolectomy with intracorporeal bowel anastomosis between July 2015 and June 2017 were matched with a laparoscopic group. Perioperative management was in accordance to an enhanced recovery protocol. Outcomes and histopathological data were compared. Thirty-two patients were included. Amongst the patients who did not undergo complete mesocolic excision, the median operative time did not differ between the two groups ($p = 0.413$). The robotic group recorded a statistically shorter time for intracorporeal anastomosis (13 vs 19 min, $p = 0.024$). Postoperative recovery and complication rates were similar, except for a greater lymph node harvest in the robotic group (41 vs 31, $p = 0.038$). Robotic surgery achieves short-term results comparable to existing conventional laparoscopy, notwithstanding the advantages of enhanced ergonomics.

Keywords Xi · Robotic · Laparoscopic · Right hemicolectomy · Intracorporeal anastomosis

Introduction

When laparoscopic colectomy was first proposed as an alternative to open surgery, most surgeons were performing extracorporeal anastomoses after exteriorizing the bowel [1–3]. In a right hemicolectomy, this limited the extraction site to an upper midline incision and potentially resulted in undue tension in the bowel and mesentery [4]. These incisions have also been reported to be significantly longer and associated with higher rates of wound-related complications, such as incisional hernia formation, when compared to transverse lower abdominal incisions [5–8]. One of the reasons cited for eschewing an intracorporeal anastomosis is the technical challenge of laparoscopically suturing close the staple enterocolotomy [9, 10]. The introduction of robotics addressed this issue, resulting in many of the publications on robotic hemicolectomies describing intracorporeal instead of extracorporeal anastomoses [11, 12]. Studies comparing robotics and laparoscopy were, therefore, confounded by this discrepancy in operative technique. We aim to compare the outcomes between robotic and laparoscopic right hemicolectomy, while standardizing the method of anastomosis.

Materials and methods

All patients who underwent elective robotic right hemicolectomies by the senior author between July 2015 and June 2017 were retrospectively matched to patients who underwent similar procedures laparoscopically in the same time period by the same surgeon. The allocation of patients to either group was based on availability of the robotic system at the time of operation scheduling. Only intracorporeal bowel anastomoses were performed. This cohort of patients were matched in a 1:1 ratio based on (i) demographics in terms of age and gender, (ii) American Society of Anesthesiologists (ASA) classification, (iii) body mass index (BMI), and (iv) extent of lymphadenectomy in terms of complete mesocolic excision. Hybrid, hand-assisted, and single-port procedures were excluded from the study. Data was extracted

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from a prospectively maintained database and the following outcomes were analyzed: conversion to open surgery, length of postoperative hospital stay, 30-day mortality and unplanned readmissions. Intraoperative and postoperative morbidities were graded according to the Clavien–Dindo classification [13]. Operative videos were also reviewed to document the total operative time and the time taken to perform various phases of the surgery, for example, robot docking and intracorporeal suturing. To minimize observer bias, the recording of postoperative parameters was conducted by independent nursing staff who were not part of the primary surgical team. These indices included (i) pain as measured by means of a subjective visual analogue scale (VAS) immediately after surgery, and at 24 and 48 h postoperatively, (ii) time to first oral intake and diet, (iii) time to first successful urinary void, (iv) time to first defecation. As the assessment of bowel sounds was prone to subjectivity, and dependent on the frequency of physical examination, this parameter was not included in our analysis. For oncological cases, histopathological data like TNM staging, lymph node harvest, and resection margins were compared. All procedures performed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki declaration of 1975, as revised in 2000. Informed consent was obtained from all patients for being included in the study.

Operative technique

The operative techniques for robotic and laparoscopic right hemicolectomy were identical except for the port configurations and instrument energy source used. For the robotic procedures, one of two port configurations was employed—suprapubic or oblique offset costofemoral. For the suprapubic configuration, a 12 mm optical port was used to gain entry into the peritoneal cavity at Palmer's point. This port was later utilized by the bedside assistant. After insufflation of pneumoperitoneum, four 8 mm robotic ports were inserted along the suprapubic skin crease (Fig. 1a). For the offset costofemoral configuration, the 8 mm initial endoscope port (IEP) was inserted through a paraumbilical incision (Fig. 1b). After pneumoperitoneum was achieved, the three remaining robotic ports were distributed between the right anterior superior iliac spine and the left costal margin. Assistance was provided at the bedside through a 12 mm left flank port. All robotic cases were performed using the da Vinci® Xi surgical system (Intuitive Surgical Inc., Sunnyvale, CA, USA). Conventional laparoscopic right hemicolectomy port placement involved a paraumbilical 12 mm port for the establishment of initial pneumoperitoneum, followed by two main operating ports along the left mid-clavicular line (one 12 mm and one 5 mm) and another 5 mm assistant port in the right flank.

For all cases, an inferior approach was adopted for dissection, as described in earlier publications [14]. Dissection in the laparoscopic group was performed using the LigaSure Advance (Covidien, Boulder, CO, USA), whereas an integrated ERBE VIO dV generator (Erbe USA Inc., Marietta, GA, USA) was used to provide mono and bipolar energy to the robotic scissors and fenetrated grasper, respectively. After completion of the retrocecal and retroileal mobilization, a medial approach was adopted for blood vessel identification. Vascular structures were directly sealed and divided using the LigaSure Advance in the laparoscopic group. In the robotic group, Weck Hem-o-lok clips (Teleflex Inc., Research Triangle Park, NC, USA) were used for ligation before dividing the blood vessels with scissors. For curative oncological resections, a standard lymphadenectomy was performed during the earlier part of the series, whereas a complete mesocolic excision (CME) was adopted

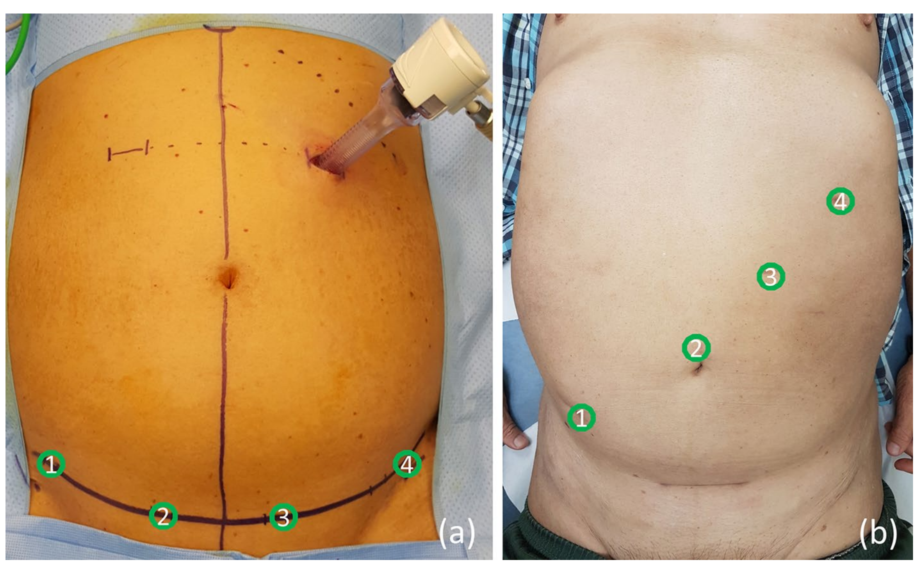

Fig. 1 Port configurations. The **a** suprapubic and **b** oblique offset costofemoral robotic port configurations with the respective port positions as numbered

as standard practice subsequently, with dissection along the superior mesenteric vein. After bowel transection, an intracorporeal isoperistaltic stapled side-to-side anastomosis was completed. The common staple enterocolotomy was sutured close and the mesenteric window was left unsutured. The specimen was extracted via a wound protector through a pfannenstiel incision.

Perioperative management

An enhanced recovery after surgery (ERAS) protocol was implemented in the perioperative management of all patients. No mechanical bowel preparation was administered. A single dose of prophylactic antibiotics (Ceftriaxone 2 g and Metronidazole 500 mg) was administered intravenously at the induction of anesthesia. Upon anesthesia, a Foley catheter and a nasogastric tube were inserted. Patients were either positioned in supine or Lloyd-Davies for the surgery. Local anesthetic infiltration in the form of lignocaine was administered for all patients prior to incision, and supplemented with bupivacaine to the rectus sheath upon completion of surgery. Gastric tubes were removed at the end of surgery, and urinary catheters were removed the morning after. Postoperative analgesia was provided in the form of paracetamol and celecoxib. Opioids in the form of Targin and Oxynorm were supplemented only in cases that reported moderate–severe postoperative pain. Intravenous ondansetron (4 mg) was administered prophylactically every 8 h until the first postoperative morning to reduce the initial postoperative nausea and vomiting. Enteral intake was allowed immediately postoperatively, but limited to 500 ml per day, until patients were able to tolerate that volume without abdominal distension or discomfort. After which, oral intake was escalated to diet as tolerated. Early ambulation was enforced by the ward physiotherapists. Patients were discharged when they were able to tolerate full meal portions and able to ambulate at their pre-operative baseline with adequate pain control.

For statistical analysis, we used the Fisher's exact test for categorical outcomes and the Mann–Whitney U test for continuous data. A P value < 0.05 was considered statistically significant. Analyses were performed using the SPSS software package version 23.0 (SPSS Inc., Chicago, IL, USA).

Results

Sixteen consecutive patients who underwent robotic right hemicolectomy (RAL) were matched with patients from the laparoscopic group (LAP). Analysis of the demographic data showed no statistically significant difference in terms of age, gender, BMI and ASA (Table 1). Most patients underwent curative oncological surgery for colonic adenocarcinoma. Two patients in the RAL group were operated on electively for sealed perforations of the cecum and ileum, respectively. Both groups had one patient each who were offered surgery for broad-based cecal tumors that were eventually reported as a tubular adenoma with low grade dysplasia on histopathology. The sizes and T-stages of the lesions resected in both groups were comparable, as were the axial resection margins. CME was performed for most patients undergoing curative oncological resections except for earlier cases in the series. While the RAL patients had a statistically higher lymph node harvest, this did not translate to a significant difference in the N status of the two groups (Table 2).

Table 1 Demographic data

	Laparoscopic (n = 16)	Robot-assisted (n = 16)	P value
Mean age (SD) in years	69.6 (9.6)	68.6 (10.9)	0.785
Gender			
Male	6 (37.5%)	10 (62.5%)	0.289
Female	10 (62.5%)	6 (37.5%)	
Mean BMI (SD)	24.7 (4.2)	23.7 (3.8)	0.533
ASA			
2	4 (25%)	8 (50%)	0.273
3	12 (75%)	8 (50%)	

Tables 3 and 4 summarize the operative and postoperative results, respectively. The extent of resection and lymphadenectomy were similar in both groups. Apart from five patients (LAP n = 2, RAL n = 3) who underwent an extended right hemicolectomy, all other patients underwent a right hemicolectomy. The time taken for RAL was longer, mainly due to the additional time required for CME. When performing right hemicolectomy without CME, both techniques achieved similar operative times (p = 0.413). Overall, intracorporeal suturing was completed significantly faster in the RAL group (p = 0.024). Postoperative outcomes were essentially the same.

One patient from the LAP group was readmitted on the 15th postoperative day for delirium secondary to pneumonia and poor oral intake. A patient from the RAL group was readmitted on the 18th postoperative day for an intra-abdominal collection that required percutaneous drainage and a course of antibiotics. The histopathological report for this patient was reported as an intramucosal adenocarcinoma, so there was no adjuvant therapy required. The rest of the complications mainly involved ileus that resolved with supportive management.

Table 2 Histopathological data

	LAP (n = 16)	RAL (n = 16)	P value
Median tumor size (range) in cm	4.5 (1.5–10.0)	4.0 (1.5–11.0)	0.498
Tumor T Stage			
Tis	0	1	0.694
T1	1	0	
T2	2	1	
T3	9	10	
T4	3	2	
NA	1	2	
Tumor N stage			
N0	9	7	0.632
N1	3	5	
N2	3	2	
NA	1	2	
Median number of lymph nodes positive	0 (0–10)	0.5 (0–13)	0.780
Median number of lymph nodes harvested	31 (12–47)	41 (20–89)	0.038
Median proximal margin (cm) (range)	12.0 (2.5–32.4)	8.5 (4.5–50.0)	0.448
Median distal margin (cm) (range)	7.5 (3.5–23.0)	9.3 (4.0–17.0)	0.313

Table 3 Operative outcomes

	LAP (n = 16)	RAL (n = 16)	P value
Median operative duration (range) in minutes	162.5 (120–285)	212.5 (160–335)	0.023
Median docking time (range) in minutes	NA	4:12 (2:38–11:58)	NA
Median suture time (range) in minutes	19:49 (11:10–39:55)	13:10 (10:24–19:28)	0.024
Patients who underwent CME	11	12	1.000
Median operative duration without CME (range) in minutes	170 (125–260)	177.5 (175–215)	0.413
Median operative duration with CME (range) in minutes	155 (120–285)	217.5 (160–335)	0.032

Table 4 Postoperative outcomes

	LAP (n = 16)	RAL (n = 16)	P value
Median length of stay (range) in days	4.5 (3–16)	4.5 (2–13)	0.402
Median interval to first oral fluid intake (range) in hours	7 (2–24)	8 (3–21)	0.224
Median interval to first oral dietary intake (range) in hours	69 (24–166)	67 (33–186)	0.752
Median interval to first bowel output (range) in hours	59 (9–162)	48 (27–140)	0.800
Median interval to first urine void (range) in hours	31 (20–149)	28 (21–212)	0.564
Median 0H pain VAS	0 (0–5)	0 (0–4)	0.956
Median 24H pain VAS	0.5 (0–8)	2.0 (0–5)	0.642
Median 48H pain VAS	0 (0–5)	0 (0–2)	0.669
Readmission within 30 days			
No	15	14	1.000
Yes	1	2	
Clavien–Dindo 30-day morbidity			
0	12	12	0.385
I	2	3	
II	2	0	
III	0	1	

Discussion

Minimally invasive colectomies have become more commonplace since the first series published by Jacobs et al. in 1991 [15]. The benefits of minimally invasive surgery (MIS)—limited trauma of access, reduced postoperative pain and narcotic use, decreased duration of hospitalization—have been described in numerous studies. Initial concerns regarding oncological outcomes have also been addressed in the COST, CLASICC, and COLOR trials [3, 16–19]. As part of the evolution of MIS, robotics has been developed to address the challenges faced by adopters of conventional laparoscopy. However, one of the constant criticisms of robotic colorectal surgery has been the lack of benefit despite the increased operative time and cost. The main role of robotics in colorectal surgery has been proposed by several authors to be in rectal dissection, due to its advantages over laparoscopy when operating in confined spaces [20–23].

The main attraction of robotics is its enhanced optics, ergonomics and precision. One of the earliest reports on robotic colectomy was by Weber et al., who highlighted the enhanced ergonomics conferred by the first-generation da Vinci system [24]. One aspect of a right hemicolectomy that would benefit from these features is the performance of a complete mesocolic excision (CME). Several studies have supported the survival advantages associated with CME, and some of these have expounded on the challenges encountered during laparoscopic CME [25–28]. In the review of our operative videos, the stability of the scope image, the centralization of the working area, and the appropriateness of the image horizon were notably superior in the RAL group. While not objectively proven in the current study, the use of the robot provided subjectively better ergonomics for the operating surgeon. The significantly greater lymph node harvest in our series could possibly be attributed to the superior optical resolution and more precise mesenteric dissection offered by robotics, although arguably this may not have improved the accuracy of nodal staging, since the median nodal harvest in both groups far exceeded international recommendations.

As a trade-off for the optical magnification and finer instrument movements, the use of robotics results in a narrower visual field and a more confined active work area. The absence of haptic feedback from the da Vinci instruments obliges the surgeon to adjust his scope view whenever the instruments are manipulated outside of the visual field to avoid iatrogenic injury to surrounding viscera. This is compounded by the design of the da Vinci surgeon console in which the master controllers can only move either the instruments or the scope depending on which function is actuated by the left foot pedal, resulting in a staggered movement of the robotic arms. These drawbacks are evident in robotic hemicolectomy, as the procedure spans a large operative field across multiple quadrants. Until these technical issues are resolved, we speculate that robotic hemicolectomy will remain a more time-consuming endeavor for surgeons who are equally competent in laparoscopy.

Almost all studies on robotic right hemicolectomy have been conducted using older versions of the da Vinci and some of these have reported the need for redocking and hybrid procedures [29]. While our study population was small, the results from the patients who underwent right hemicolectomy without CME show that robotic procedures do not necessarily take longer than laparoscopy. We attribute this to the enhanced multiquadrant capability of the da Vinci Xi that optimized dissection spanning the right iliac fossa to the splenic flexure, facilitating CME along the axis of the superior mesenteric vessels, and even allowing for extended right hemicolectomies to be completed with a single docking of the robot patient cart. In comparison, earlier publications described the need to change patient tilt and to redock the robot, as the dissection proceeded from the cecum to the hepatic flexure [30]. In our study, the Xi patient cart was brought in from the right side of the operating table, and the robot arms only needed to be docked once regardless of the extent of resection. While other authors have attributed the additional operative time to the docking of the robot, we felt that the relatively short docking time in our series was not a significant contributor to the overall operative time [31]. We postulate that the use of an advanced energy device facilitated the multiple vessel divisions and mesenteric dissection during laparoscopic CME, and perhaps that the use of a robotic vessel sealer might have rendered the two groups comparable in terms of operative duration, at the obvious expense of added cost.

One particular finding that highlights the dexterity of robotic instrumentation is the statistically shorter time that was required to complete the enterocolotomy closure, supporting the benefit of robotics in this phase of the surgery. The wristed movements offered by the articulated robotic instruments compensated for the lack of tactile feedback during knot formation. The visual assessment of suture tension was accurate enough to achieve a 0% suture breakage rate and 0% anastomotic leak rate in our study. Robotics, therefore, has the potential to serve as an enabling tool for surgeons to provide the benefits of an intracorporeal anastomosis to their patients.

Contrary to earlier publications, we were not able to show a superiority of robotics in terms of conversion rate. While earlier studies reported conversion rates of up to 25% in laparoscopic colorectal surgery, all cases in both arms of our study were completed successfully [3, 16, 19]. By including results from only a single surgeon, we have managed to ensure consistency and proficiency in operative technique, at the expense of a more limited sample size. Variations in perioperative protocols and medication have also been kept to a minimum, ensuring that the distinction in outcomes resulted solely from the two different platforms of MIS. Our results suffer from the limitations of a retrospective study, and while matching was performed, unrecognized confounders and selection bias could undeniably affect the validity of the conclusions drawn. In addition, the small sample size made it impractical to perform subset analysis—right hemicolectomy versus extended right hemicolectomy, with or without CME. While the short-term results do not seem to justify the added cost of robotic surgery, we remain cognizant that intangible benefits such as reducing surgeon fatigue and promoting technical sustainability potentially exist. A competent robotic surgeon effectively functions as the operator, camera holder, and assistant. The fact that complex laparoscopic procedures require additional skilled surgical assistants is seldom taken into account during cost-effectiveness analysis studies—the cost of training and the amount of time required for these assistants to achieve proficiency, together with their employment and opportunity costs are often difficult to quantify.

Conclusion

Right hemicolectomy with complete mesocolic excision and intracorporeal bowel anastomosis can be performed safely by laparoscopy and robotics, with the latter platform providing superior ergonomics and potential advantages in oncological outcomes at the expense of added operative time and direct financial cost.

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Compliance with ethical standards

Conflict of interest Dr. James Ngu and Dr. Yvonne Ng declare that they have no conflict of interest. All authors are in agreement with the content of the manuscript. The manuscript has not been published previously and is not under consideration elsewhere.

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