Original Article

Robot-assisted Colon and Rectal Surgery — Experience of 110 Consecutive Cases in a Single Institute

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Key Words
Colorectal cancer;
da Vinci surgical system;
Robotic surgery

Purpose. The utilization of robotics in colorectal surgery is relatively new. This study presents our early experience and short-term outcomes with robotics in colorectal surgery and provides an update on the current status of robotics.
Methods. Between December 2011 and June 2014, 110 patients undergoing robot-assisted colorectal surgery were analyzed retrospectively. Clinicopathologic results including patients' age, gender, clinical staging, operating time, complications, and pathologic status were analyzed.
Results. The cohort comprised 50 women (45.5%) and 60 men (54.5%) with ages ranging from 30 to 89 years (mean, 50.9 years). The average body mass index (BMI) was 26.2 kg/m^2. Sixty-six patients (60.0%) received radical proctectomy with coloanal anastomosis; 23 patients (20.9%), received low anterior resection; 6 (5.5%), for anterior resection; 4 (3.6%), for left hemicolectomy; 6 (5.5%), for right hemicolectomy; 3 patients (2.7%), had abdominoperineal resection; and 2 patients (1.8%), received Hartmann's procedure. The mean estimated blood loss was 65.6 mL (range, 30-200 mL). The mean operating time was 472.5 minutes (range, 305-725 min). There was no conversion in any of the cases. Twenty-three patients (20.9%) had postoperative complications including coloanal anastomosis necrosis in 6 patients, anal stenosis in 4 patients, small bowel obstruction in 3 patients, urinary tract infection in 3 patients, rectourethral fistula in 2 patients, and herpes zoster in 2 patients. There was no intra-operative or 30-day post-operative mortality reported.
Conclusion. We present our early experience of robot-assisted colorectal surgery. Our data show that robot-assisted colorectal surgery is feasible and safe, with acceptable rates of morbidity and mortality. Further prospective follow-up with a larger number of patients is needed to sophisticate and verify the advantages of robot-assisted colorectal surgery.
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Minimal invasive operation has revolutionized the field of general surgery for decades. Since its introduction in 1991, laparoscopic-assisted technique was gradually accepted worldwide because of

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consequent advantages such as less blood loss and postoperative pain, shortened hospital stay, fewer complications and better postoperative quality of life.[1,2] The efficacy of the laparoscopic approach for treatment of colon and rectal cancer has been demonstrated by several randomized controlled trials which showed similar long-term oncological outcomes compared with open surgery.[3-9] However, laparoscopic surgery has various limitations such as two-dimensional views, restricted degrees of motion which are suboptimal in providing retraction and dissection in the deep pelvis, amplification of tremors, and the assistant-dependent camera holding and viewing.[10]

The robotic system has been developed to overcome the shortcomings of conventional laparoscopic surgery. Robotic instruments have up to 7° of fine wrist movement for dissection and retraction, providing precision and ease of surgery in confined spaces.[11] Three-dimensional visualization and the higher magnification of the robotic camera system provide a greater appreciation of depth during operation, which allows surgeons to have considerable advantages including greater precision, improved dexterity and accuracy of anatomical dissection, enhanced visualization and improved access over regular surgery.[12,13] Nevertheless, the use of robotics in colorectal surgery is relatively new. A recent randomized controlled trial had shown that the robot-assisted approach was safe and comparable to the laparoscopic approach for colorectal surgery.[14,15] We performed our first robot-assisted colorectal surgery in December 2011. The aim of this study is to present our early experience and short-term outcomes with robotics in colorectal surgery and provide an update on the current status of robotics.

Materials and Methods

Between December 2011 and June 2014, 110 patients undergoing robot-assisted colorectal surgery at Taipei Medical University Hospital (Taipei, Taiwan) were retrospectively analyzed. We introduced our first robotic colorectal surgery in December 2011 and all procedures were performed by a single surgeon (KLJ). The benefits, disadvantages and cost of alternative surgical procedures were explained to all patients before the operation. The final surgical procedure to be performed was opted by patients and families. This study was approved by the Joint Institutional Review Board of Taipei Medical University. Informed written consent was signed by all patients. Patients were excluded if they had carcinomatosis, T4 tumors that required a multi-organ resection and contraindications for prolonged pneumoperitoneum such as having a severe cardiopulmonary disease or coagulation disorders. Patients with biopsy-proven adenocarcinoma of the rectum were treated with neoadjuvant chemoradiation if initial rectal tumors belong to T3/4 and/or positive lymph nodes staged by pelvic magnetic resonance (MR) images.

Surgical Technique

The da Vinci Surgical System consists of the robotic cart, the vision cart, and the surgeon's console. The patient is under lithotomy after general anesthesia. The patient is secured to the operating table with both arms tucked at bedside and silicon shoulder harnesses are placed in order to support the patient while in the Trendelenburg position. A five-port technique was routinely used. Robotic trocar placement was different design from that of the surgical procedure. We routinely used a monopolar curved scissors on the robotic arm 1, fenestrated bipolar forceps on the robotic arm 2, and ProGrasp™ forceps on the robotic arm 3.

For tumor located at rectum, rectosigmoid junction, or sigmoid colon, the patient is placed in a 30° Trendelenburg position with 15° right lateral tilting to help ensure that the intestines do not block the operative field. The optic port is 3 cm right and above the umbilicus. An 8-mm port (robotic arm 1) is placed in the right lower quadrant 10 cm away from the umbilicus. Two 8-mm ports are placed in the left upper (robotic arm 2) and lower (robotic arm 3) quadrants. Another 12-mm port is placed in the right upper quadrant as on-table assistant port as shown in Fig. 1A. Patients with ascending or proximal transverse colon cancer undergoing right hemicolectomy with ileocolic anastomosis will be performed, the patient are placed in a lithotomy position with 15° left lateral tilting. The ro-

botic cart is brought in from the right side of the operating table. The optic port is 3 cm left and below the umbilicus. An 8-mm port (robotic arm 1) is placed in the midline 10 cm above the umbilicus. Two 8-mm ports are placed in the right lower quadrant (robotic arm 2) and midline 10 cm below the umbilicus (robotic arm 3). Another 12-mm port is placed in the left upper quadrant as on-table assistant port as shown in Fig. 1B. For patients with descending colon or distal third of transverse colon cancer undergoing left hemicolectomy intend to be performed, the optic port is placed 3 cm right and below the umbilicus. An 8-mm port is placed in the midline 10 cm below the umbilicus (robotic arm 1). Two 8-mm ports are placed in the left upper quadrant (robotic arm 2) and midline 10 cm above the umbilicus (robotic arm 3). Another 12-mm port is placed in the right lower quadrant as on-table assistant port as shown in Fig. 1C.

Statistical Analysis

Statistical analysis was performed using SPSS 13.0 for windows (SPSS, Inc., Chicago, IL). We used The chi-square test was employed to compare categorical variables and student t-test was used for comparing continuous variables. The differences were considered significant if the *p* value was smaller than .05.

Results

The clinical characteristics of the patients undergoing robot-assisted surgery are listed in Table 1. There were 50 women (45.5%) and 60 men (54.5%) with ages ranging from 30 to 89 years (mean, 50.9 years) and average body mass index (BMI) of 26.2 kg/m^2. Among them, 87 patients (79.1%) had rectal lesion; 1 (0.9%), recto-sigmoid junction tumor, 12 patients (10.9%), sigmoid colon cancer, 4 (3.6%), descending colon cancer, and 6 patients (5.5%), ascending colon cancer. Sixty-six patients (60.0%) received radical proctectomy with hand-sewn coloanal anastomosis; 23 patients (20.9%), received low anterior resection with colorectal anastomosis; 6 (5.5%), anterior resection; 4 (3.6%), for left hemicolectomy; 6 (5.5%), for

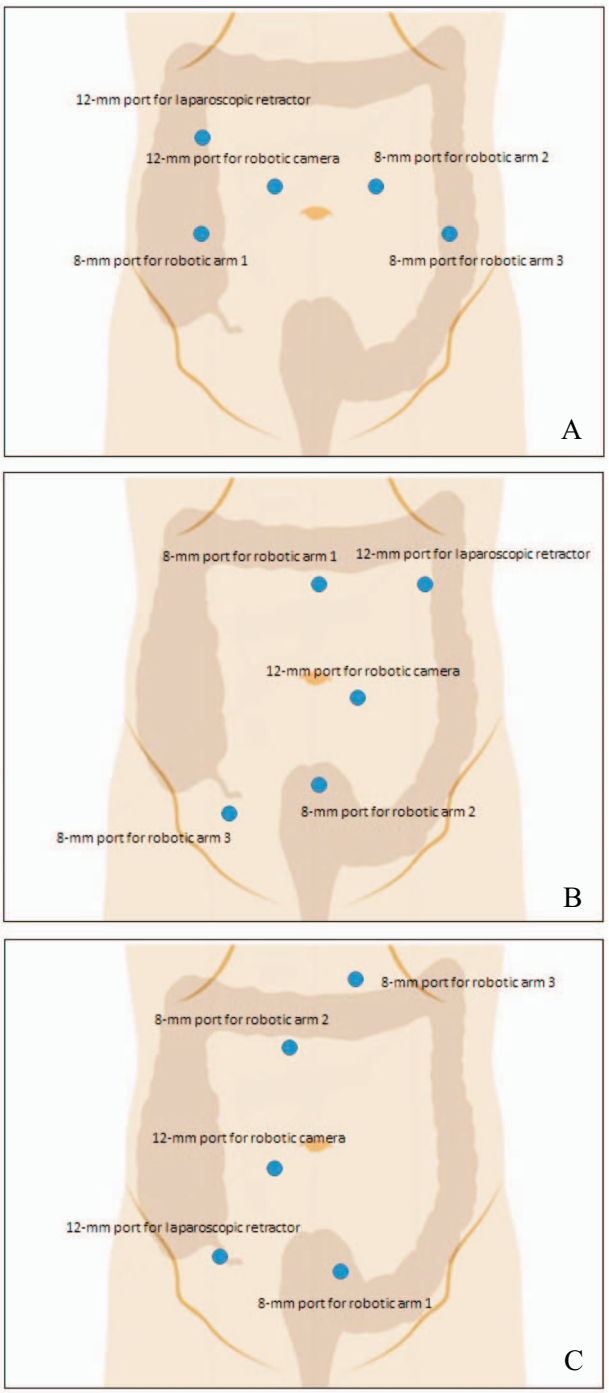

Fig. 1. Port-site design for different type of colorectal surgery. A. Port-site for TME, LAR and AR. A 12-mm camera port, three 8-mm robotic working ports, and one additional (12 mm) on-table assistant ports were placed; B. Port-site for RH; C. Port-site for LH. (TME: total mesorectal excision; LAR: low anterior resection; AR: anterior resection; RH: right hemicolectomy; LH: left hemicolectomy).

Table 1. Demographic characteristics of 110 patients underwent Robot-assisted Surgery

Variable	
Age, years (range)	50.9 (30-89)
Female/male ratio	50/60
BMI (kg/m^2)	26.2
Tumor location (%)	
Rectum	87 (79.1)
R-S junction	1 (0.9)
Sigmoid	12 (10.9)
Descending colon	4 (3.6)
Ascending colon	6 (5.5)
Operation procedure (%)	
TME + CAA	66 (60.0)
LAR	23 (20.9)
APR	3 (2.7)
Hartmann's procedure	2 (1.8)
LH	4 (3.6)
RH	6 (5.5)

BMI = body mass index; R-S = rectosigmoid; TME = total mesorectal excision; CAA = coloanal anastomosis; LAR = low anterior resection; APR = abdominoperineal resection; LH = left hemicolectomy; RH = right hemicolectomy.

right hemicolectomy; 3 patients (2.7%), had abdominoperineal resection; and 2 patients (1.8%), received Hartmann's procedure. For low rectal lesion, 93% of patients had sphincter-saving procedure with coloanal reconstruction.

Among 87 patients with rectal lesion, 3 patients had gastrointestinal stromal tumor (GIST); 2, patients were neuroendocrine tumor; 2, patients had villiotubular adenoma with size large than 3 cm; and 2, patients had gynecology lesion (1 for endometrial cancer with rectum invasion; and 1, for extragonadal endometriosis with rectal wall invasion complicated with colonic obstruction). Fifty-three patients (67.9%) having T3/4 and/or N positive tumors received first preoperative neoadjuvant chemoradiation therapy followed by radical surgical resection. Their Initial MR images showed 4 patients with T2N1 rectal tumors; 1, for T2N2; 10, patients were T3N0; 21, patients were T3N1; and 12, patients had T3N2 lesion; 1, for T4N0; 1, for T4N1; and 3, patients were T4N2 disease. Twenty-five patients received operation only including 13 patients with early rectal cancer staging; 8, patients had stage IV disease; 2, patients refusing preoperative chemoradiation instead of operation first; 1, patient receiving operation only due to old age, and 1, having prostate cancer with pelvis irradiation history. (Table 2)

The clinical results are summarized and analyzed in Table 3. The mean estimated blood loss was 65.6 mL (range, 30-200 mL). The mean operating time was 472.5 minutes (range, 305-725 min). There was no conversion in any of the cases. Overall, postoperative complications were coloanal anastomosis necrosis in 6 patients, anal stenosis in 4 patients, small bowel obstruction in 3 patients, urinary tract infection in 3 patients, rectourethral fistula in 2 patients, and herpes zoster in 2 patients. One patient had rectovaginal fistula, 1 patient had central venous catheter infection, and 1 patient had complicated with upper gastrointestinal bleeding. In 6 patients who developed coloanal anastomosis necrosis, 3 patients had inadequate blood supply after transecting the colon and diverting colostomy was created during operation. Two patients developed coloanal anastomosis necrosis 7 and 10 days after surgery; with one undergoing emergency laparotomy with a diverting colostomy, and the other one patient was managed conservatively with antibiotics and prolonged drainage. All 4 patients with anal stenosis after hand-sewn coloanal anastomosis, all of these patients required anal dilatation under spinal anesthesia in the operation room. The mean length of regaining of bowel peristalsis, resumption of oral diet, and postoperative hospital stay were 3.5, 5.5, and 11 days, respectively. On pathologic examination, the mean number of lymph nodes harvested was 17.3 (range, 2-97). For rectal cancer patients, the mean distal resection margin was 2.53 cm (range, 0.1-7.0 cm). There were 85 patients (97.7%) with an R0 resection and 2 patients (2.3%) with an R1 resection (< 1 mm). The mean circumferential resection margin (CRM) was 1.04 cm (range, 0.1-5.0 cm). Thirteen patients (14.9%) had CRM involvement.

Discussion

Unlike procedures such as laparoscopic cholecystectomy, appendectomy, or OB/GYN surgery, colorectal surgery involved a multiquadrant rather than a fixed operative field. The field of dissection in colo-

Table 2. Characteristics of 87 patients with rectal lesion

Variable	
Distance from anal verge, cm	4.87 (0-12)
Classification (%)	
Adenocarcinoma	78 (89.7)
GIST	3 (3.4)
Neuroendocrine tumor	2 (2.3)
Villotubular adenoma	2 (2.3)
Endometrial cancer	1 (1.1)
Endometriosis	1 (1.1)
Preoperative CCRT	
No	25
Yes	53
Pre-treatment stage (by MRI)	
T2 N1	4
T2 N2	1
T3 N0	10
T3 N1	21
T3 N2	12
T4 N0	1
T4 N1	1
T4 N2	3
Distal resection margins (cm)	2.53 (0.1-7.0)
R0	85 (97.7)
R1	2 (2.3)
CRM (cm)	1.04 (0-5.0)
Clear	74 (85.1)
Involved	13 (14.9)

GIST = gastrointestinal stromal tumor; CCRT = chemoradiation therapy; MRI = magnetic resonance imaging; CRM = circumferential resection margin.

Table 3. Clinicopathologic results

Estimated blood loss (mL)	65.6 (30-200)
Operation time (min)	472.5 (305-725)
Hospital staying (d)	11 (8-28)
Time to first flatus (d)	3.5 (1-11)
Time to normal diet (d)	5.5 (5-11)
Conversion to open surgery (%)	0 (0)
Lymph node retrieval number	17.3 (2-97)
Complications (%)	23 (20.9)
Neorectum necrosis	6
Anal stenosis	4
Small bowel obstruction	3
Urinary tract infection	2
Rectourethral fistula	2
Herpes zoster	2
Rectovaginal fistula	1
CVC infection	1
UGI bleeding	1

CVC = central venous catheter; UGI = upper gastrointestinal.

rectal surgery is wider and multidimensional, which requires sophisticated assistance in camera-holding and traction-countertraction for providing an optimal operating condition. The robotic system has been developed to overcome the shortcomings of these disadvantages. By the using of the robotic system, surgeons are in direct control of both the operative view and robotic instruments for dissection and retraction. Having a stable operating platform, together with three-dimensional visualization and the higher magnification of the robotic camera system, surgeons can easily identify of small anatomical structures and achieve nerve preservation without compromising oncological radicality, thus reducing the incidence of urinary, sexual and anorectal dysfunction after operation.

A Cochrane systematic review shows that robot-assisted surgery for colorectal cancer is safe and feasible, with acceptable rates of morbidity and mortality.[16] The overall rate of reported complications ranged from 0-42.7%. In the present study, 23 patients (20.9%) had postoperative complications and no intra-operative or 30-day post-operative mortality was reported. This may be due to heterogeneity in reporting of various complications; some studies reported all complications while others reported only major complications. In addition, there was also heterogeneity in surgeons; single versus group, or experienced and experts versus experienced and trainees, which may impact the rate of complications, conversions and operating time.

In general, most studies reported a longer operating time for robot surgery.[2,17-20] This is taken as one of the disadvantages of robotic surgery, in addition to the lack of tactile feedback and higher cost. Notwithstanding, some investigators found opposing results.[21,22] These conflicting reports on operating time may reflect to the learning curve in robotic rectal surgery. It is believed that the operating time would decrease with accumulation of experience among surgeons.

Although robot-assisted colorectal surgery had been regarded as a revolution of the minimal invasive surgery, and proved to be a feasible and safe technique, clinical utilization rate had remained low. However, there are several unique benefits attributed to

several short-term clinical outcomes such as adaptation time, alleviated difficulty of perineal phase, and early recovery of functional outcomes. Further follow-up with a larger number of patients is necessary to sophisticate and verify the advantages of robot-assisted colorectal surgery.

Conclusion

We present our early experience of robot-assisted colorectal surgery. Our data shows that robot-assisted colorectal surgery is feasible and safe, with acceptable rates of morbidity and mortality. Further prospective follow-up with a larger number of patients is needed to sophisticate and verify the advantages of robot-assisted colorectal surgery.

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原　著

機器手臂手術運用在大腸直腸外科 — 單一機構 110 病例的早期經驗

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目的　機器手臂手術在大腸直腸外科上的使用是比較新的。這項研究提出了我們使用機器手臂大腸直腸手術的早期經驗和短期成果，並提供目前機器人的當前狀態。

方法　自民國 100 年 12 月到民國 103 年 6 月，我們對 110 例接受機器手臂大腸直腸手術的患者進行回顧性的分析。臨床的資料，包括了病人的年齡，性別，臨床分期，手術時間，併發症和病理狀態進行分析研究。

結果　有 50 名女性 (45.5%) 和 60 名男性 (54.5%)，年齡介乎 30 至 89 歲 (平均 50.9 歲)。平均身體質量指數 (BMI) 為 26.2 kg/m^2。66 位病人 (60.0%) 接受了根除性直腸切除並大腸肛門吻合手術，23 例 (20.9%) 接受了低位前切除手術，6 例為 (5.5%) 為前切除手術，4 例 (3.6%) 接受左半結腸切除手術，6 例 (5.5%) 為右半結腸切除手術，3 例 (2.7%) 有腹部會陰聯合切除手術，另 2 例 (1.8%) 接受 Hartmann's 手術。平均估計失血量為 65.6 毫升 (範圍為 30-200 毫升)。平均手術時間為 472.5 分鐘 (範圍 305-725 分鐘)。所有病人都沒有發生手術中從機器手臂手術轉換成傳統剖腹手術的案例。23 名患者 (20.9%) 有術後併發症，包括腸壞死有 6 例，肛門狹窄 4 例，小腸阻塞 3 例，尿路感染 3 例，2 例患者直腸尿道廔管和兩位病人發生帶狀皰疹感染。在本研究中，並沒有發生術中或 30 天的術後死亡率的報導。

結論　我們提出我們運用機器手臂手術在大腸直腸外科的早期經驗。我們的數據顯示，機器人輔助大腸直腸癌手術是安全可行的，病人手術後併發症都在合理的範圍內，且病人都沒有因手術造成的三十日內死亡率。我們還需要進一步的前瞻性研究及累積更多的病人經驗，來驗證機器人輔助大腸直腸癌手術的優點。

關鍵詞　大腸直腸癌、達文西手術系統、機器手臂手術。