



COMPARISON OF ROBOTIC-ASSISTED VERSUS CONVENTIONAL LAPAROSCOPIC COLECTOMY FOR COLORECTAL CANCER: A MULTICENTER OUTCOMES ANALYSIS

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ABSTRACT

Background: The use of robotic surgery in colorectal surgery has grown in volume, but the benefit of using robotic surgery over laparoscopy for colectomy in CRC is still under discussion as the advantage of the robotic surgery may be offset by longer operative time and increased cost. This multi-center outcomes study compared peri- and oncologic quality measures between robotic-assisted and conventional laparoscopic colectomy.

Methods: A retrospective cohort of 486 non-metastatic colorectal cancer (CRC) patients who underwent elective minimally invasive colectomy (MIC) at four tertiary hospitals. 198 patients who underwent robotic-assisted colectomy, 288 patients underwent conventional laparoscopic colectomy. The primary outcome was a composite of 30-day major morbidity, conversion to open surgery or inadequate oncologic specimen. Secondary outcomes were operative time, blood loss, lymph node yield, margin status, length of stay, readmission, and 90-day initiation of adjuvant chemotherapy if indicated.

Results: There were no differences between groups in baseline age, sex, tumour stage or burden of comorbidities. Robotic colectomy had longer operative time (214.5 +/- 52.8 vs. 174.2 +/- 45.6 minutes, $p < 0.001$), but lower estimated blood loss (82.6 +/- 49.4 vs. 126.8 +/- 72.5 mL, $p < 0.001$) and lower conversion rate (3.0% vs. 8.7%, $p = 0.015$). There was no difference in overall complications (18.2% vs. 22.6%, $p = 0.25$) and a lower, although not statistically significant, rate of major morbidity after robotic surgery (5.6% vs. 9.7%, $p = 0.10$). Lymph node yield was higher in the robotic group (24.8 +/- 8.1 vs. 21.9 +/- 7.4, $p < 0.001$), and R0 resection was achieved in 98.5% versus 96.2% ($p = 0.17$). The composite adverse outcome was seen in 12.1% of the robotic cases and 22.2% of the laparoscopic cases ($p = 0.005$).

Conclusions: Robotic-assisted colectomy was significantly correlated with fewer composite adverse outcomes, higher lymph node yield, less blood loss and fewer conversions, but with a longer operating time. Patient selection and cost-effectiveness assessment are still crucial.

Keywords: Robotic Surgery, Laparoscopic Colectomy, Colorectal Cancer, Conversion, Lymph Node Yield, Minimally Invasive Surgery.

INTRODUCTION

In the hands of trained teams, MIS has become an accepted method for colorectal cancer surgery, thanks to its ability to provide a quicker recovery without compromising the oncologic principles. Initial randomized data from the Clinical Outcomes of Surgical Therapy (COST) study demonstrated that laparoscopically assisted colectomy was associated with comparable cancer recurrence rates to open colectomy, but with a shorter hospital stay and a quicker recovery in the short term [1].

The MRC CLASICC trial also confirmed the feasibility of laparoscopy for colorectal cancer surgery, but conversion and rectal dissection quality were still significant issues [2]. The COLOR II trial showed comparable recurrence and survival rates for laparoscopic and open surgery in selected patients in the long-term follow-up of rectal cancer [3].

The introduction of robotic surgery was driven by the need to overcome the limitations of traditional laparoscopy, such as limited instrument movement, older platforms with 2D vision, tremor amplification and surgeon ergonomic strain. Robotic systems offer stable 3D visualization, wristed instrumentation, motion scaling and ergonomics, which may allow for precise mesocolic dissection or mesorectal dissection in narrow anatomical spaces. The



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technical benefits, however, come with increased equipment expenses, increased docking time, increased operating room use, and a learning curve. There is conflicting evidence, both randomized and observational. A randomized clinical trial comparing robot-assisted to standard laparoscopic right colectomy demonstrated feasibility but did not prove to be cost effective [4]. In the ROLARR trial for rectal cancer, the conversion rate to open laparotomy was not found to be statistically different between robotic surgery performed by surgeons with low and high robotic experience [5]. In contrast, more recent data indicate that robotic surgery can enhance select short-term surgical quality measures, especially for the more experienced surgeon and in technically challenging pelvic surgery [6]. The REAL randomized trial demonstrated better short-term surgical quality with robotic surgery for middle and low rectal cancer, and follow-up study results indicated oncologic benefits in this patient population [7,8].

Few studies are available for the general population of colectomy patients, and the majority of available evidence has been limited to rectal cancer or right colectomy. In everyday practice, direct comparison may be difficult as robotic platforms may be used for obese patients, locally advanced tumours or technically challenging operations. Multicenter real-world analyses may be useful in assessing the benefits of robotic surgery in the broader context beyond the randomized trial. The present study aimed to compare the outcomes of robotic-assisted and conventional laparoscopic colectomy for colorectal cancer in terms of perioperative outcomes, conversion, pathologic quality and early recovery in four tertiary centres.

MATERIALS AND METHODS

Study design and setting: This was a multicenter retrospective outcomes analysis of consecutive adults who underwent elective minimally invasive colectomy for histologically proven colorectal adenocarcinoma at four tertiary referral hospitals. A standardized data collection form was used to review institutional surgical databases, anaesthetic records, pathology reports and follow-up records.

Participants: All patients with colon or upper rectal cancer, age 18 years or older, undergoing elective curative-intent colectomy, either robotic-assisted or conventional laparoscopic approach, were included. Procedures performed were right hemicolectomy, extended right colectomy, left colectomy, sigmoid colectomy, anterior resection for upper rectal cancer and subtotal colectomy. Patients were excluded if they had undergone emergency surgery, palliative bypass or diversion alone, transanal total mesorectal excision, synchronous liver resection, multivisceral exenteration, stage IV disease with non-curative

intent, inflammatory bowel disease, or incomplete 30-day follow-up.

Exposure definition: The cases in the robotic group were completed with a robotic surgical system for the main dissection and the anastomosis phase. The laparoscopic group consisted of the conventional multiport laparoscopic colectomy with straight-stick instruments. Conversion was considered unplanned laparotomy for completion of dissection, vascular control, anastomosis or difficulty during laparotomy. Planned extraction incisions were not considered conversions.

Primary outcome: Composite adverse outcome defined as 30-day major morbidity, conversion to open surgery, positive resection margin or inadequate lymph node yield (less than 12 nodes). Secondary outcomes were operative time, estimated blood loss, intraoperative complications, anastomotic leak, ileus, surgical site infection, Clavien-Dindo grade III or higher complications, length of stay, readmission, lymph node yield, R0 resection and initiation of adjuvant chemotherapy within 90 days in patients who were recommended for adjuvant therapy.

Baseline variables included were age, sex, BMI, ASA class, diabetes, Charlson comorbidity index, prior abdominal surgery, tumour location, neoadjuvant therapy, clinical stage and centre volume. Operative variables were procedure type, intracorporeal versus extracorporeal anastomosis, surgeon experience, and operative duration. Pathologic variables that were included were tumour stage, lymphovascular invasion, margin status and lymph node yield.

Data analysis: Independent t-test or Mann-Whitney U test was used to compare continuous variables. Chi-square or Fisher exact test was used to compare categorical variables. The relationship between robotic approach and the composite adverse outcome was assessed using multivariable logistic regression, adjusting for age, BMI, ASA class, comorbidity index, prior abdominal surgery, tumour location, clinical stage and centre. Odds ratios with 95% confidence intervals are reported. Sensitivity analyses were performed for colon-only cases and for right-sided colectomy. A p value of less than 0.05 was deemed as statistically significant.

RESULTS

Among 534 screened patients, 486 met the inclusion criteria. Robotic-assisted colectomy was performed in 198 patients (40.7%), and conventional laparoscopic colectomy was performed in 288 patients (59.3%). The groups were similar in age, sex, comorbidity index, tumour stage, and ASA class. The robotic group had a slightly higher mean BMI and a greater proportion of intracorporeal anastomoses.

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Table 1. Baseline Characteristics and Tumour Profile

Variable	Robotic (n=198)	Laparoscopic (n=288)	p-value
Age, years	62.8 +/- 10.7	63.9 +/- 11.2	0.28
Male sex, n (%)	112 (56.6)	160 (55.6)	0.83
BMI, kg/m ²	27.6 +/- 4.2	26.5 +/- 4.0	0.004
Charlson index	3.2 +/- 1.5	3.4 +/- 1.6	0.16
ASA III, n (%)	64 (32.3)	104 (36.1)	0.38
Prior abdominal surgery, n (%)	49 (24.7)	77 (26.7)	0.63
Right-sided tumour, n (%)	84 (42.4)	130 (45.1)	0.55
Stage III disease, n (%)	72 (36.4)	111 (38.5)	0.63

Table 2. Operative and Short-Term Clinical Outcomes

Outcome	Robotic	Laparoscopic	p-value
Operative time, min	214.5 +/- 52.8	174.2 +/- 45.6	<0.001
Estimated blood loss, mL	82.6 +/- 49.4	126.8 +/- 72.5	<0.001
Conversion to open, n (%)	6 (3.0)	25 (8.7)	0.015
Overall complications, n (%)	36 (18.2)	65 (22.6)	0.25
Major morbidity, n (%)	11 (5.6)	28 (9.7)	0.10
Anastomotic leak, n (%)	4 (2.0)	9 (3.1)	0.45
Surgical site infection, n (%)	10 (5.1)	22 (7.6)	0.27
Length of stay, days	5.6 +/- 2.4	6.8 +/- 3.1	<0.001

Table 3. Oncologic Quality Indicators and Multivariable Findings

Measure	Robotic	Laparoscopic	p-value / Adjusted effect
Lymph node yield	24.8 +/- 8.1	21.9 +/- 7.4	<0.001
Lymph node yield <12, n (%)	4 (2.0)	18 (6.3)	0.028
R0 resection, n (%)	195 (98.5)	277 (96.2)	0.17
Composite adverse outcome, n (%)	24 (12.1)	64 (22.2)	0.005
Adjuvant therapy within 90 days, n/N (%)	59/72 (81.9)	83/111 (74.8)	0.26
Robotic approach and composite outcome	Adjusted OR 0.53	95% CI 0.31-0.91	p=0.021
BMI per kg/m ² and composite outcome	Adjusted OR 1.05	95% CI 1.00-1.10	p=0.048
Stage III disease and composite outcome	Adjusted OR 1.62	95% CI 1.01-2.61	p=0.047

In colon-only sensitivity analysis, robotic surgery remained associated with lower conversion (2.8% vs. 8.1%, p=0.041) and fewer composite adverse outcomes (11.5% vs. 20.6%, p=0.018). In the right colectomy subgroup, robotic surgery was associated with higher intracorporeal anastomosis use and lower blood loss but longer operative time. No significant difference was observed in 30-day mortality; one death occurred in the laparoscopic group and none in the robotic group.

In this multicenter analysis, robotic-assisted colectomy for colorectal cancer was correlated with fewer composite adverse outcomes, fewer blood losses, higher lymph node yield, shorter hospital stay, and less conversion to open surgery when compared to conventional laparoscopy. These benefits were achieved despite the longer operative time. The overall complication rates were not significantly different, but the direction of effect was towards robotic surgery for major morbidity and surgical site infection.

DISCUSSION

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The observed lower conversion rate is of clinical significance. The conversion from minimally invasive to open surgery is linked to larger wounds, increased pain, prolonged recovery and possible delay in adjuvant therapy. The ROLARR trial did not show a statistically significant reduction in conversion rate for all robotic rectal cancer surgery, but the absolute conversion rate was lower in the robotic arm and signals of benefit were seen in the subgroup of experienced robotic surgeons [5]. Our multi-center cohort may represent a more advanced stage of robotic adoption, as teams are trained, docking is standardized, and surgeons are more familiar with robotic surgery.

This increased yield of lymph nodes in the robotic group could be due to better visualization, stable traction, and accurate dissection of the vessels, but should be interpreted with caution. Tumour biology, pathology processing, extent of mesocolic excision, neoadjuvant therapy and institutional pathology protocols all affect lymph node yield. However, good lymphadenectomy was an important oncologic quality indicator and the percentage of inadequate specimens was a contributing factor to the good composite outcome. Previous randomized right colectomy studies demonstrated feasibility but limited cost-effectiveness [4] and longer-term studies and meta-analyses indicate that robotic right colectomy can offer equivalent oncologic safety with selected perioperative benefits [6].

The longer operating time for robotic surgery is comparable with most published comparisons. Operative time is defined as the time from docking to port placement, positioning of the robotic arm, and team coordination. The more mature the program, the less docking time, and the more efficient the program may be. Operative time vs conversion or specimen quality must be evaluated institutionally due to the significant impact of operating room time and robotic consumables on cost. Patient-centered outcomes, including earlier bowel recovery, reduced pain and quicker return to function, could partially mitigate costs and were not comprehensively measured in this study.

Our results are consistent with the emerging trial evidence. The REAL trial found that experienced surgeons achieved better short-term surgical quality with robotic surgery in middle and low rectal cancer [7] and subsequent follow-up indicated lower locoregional recurrence with robotic surgery in this subset of rectal cancer [8]. But colectomy for colon cancer is not the same as pelvic rectal surgery and benefits can vary depending on the location of the tumour. Conventional laparoscopy is effective and oncologically safe for the simple right or sigmoid colectomy in non-obese patients. Robotic assistance might be particularly helpful in obese patients, narrow pelvis, bulky tumours, adhesions,

intracorporeal anastomosis, and in situations where vascular control is complex [9-10].

The study is limited by the retrospective design. Surgical approach was not randomized, and there may be selection bias even after adjustment. Robotic cases could have been done by different surgeons or centres with varying experience, compliance with the enhanced recovery programme, or case selection. There was no cost data, patient-reported recovery, long-term recurrence or disease-free survival data. The composite endpoint included clinical and pathologic endpoints, providing a better event count but potentially masking differences in individual endpoints. Lastly, follow-up was limited to early outcomes and oncologic equivalence cannot be drawn.

However, the multicenter study design, modern time period, and the use of pathologic quality indicators enhance the applicability of the results. Robotic colectomy seems to be safe and may offer quantifiable perioperative benefits in certain patients and programs. Future prospective studies should incorporate cost-effectiveness, learning curve parameters, long-term oncologic results, and patient-reported recovery.

Conclusion

Robotic-assisted colorectal cancer colectomy was correlated with decreased blood loss, increased lymph node yield, decreased length of stay, decreased composite adverse outcomes and increased operative time, but with a decreased conversion rate when compared to conventional laparoscopic colectomy. The results of this study are consistent with the use of robotic assistance in technically challenging colorectal cancer surgery, but highlight the need for cost and long-term oncologic assessment.

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