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ORIGINAL ARTICLE

Robotic versus laparoscopic right colectomy for nonmetastatic pT4 colon cancer: A European multicentre propensity score-matched analysis

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Abstract

Aim: Minimally invasive surgery has been increasingly adopted for locally advanced colon cancer. However, evidence comparing robotic (RRC) versus laparoscopic right colectomy (LRC) for nonmetastatic pT4 cancers is lacking.

Methods: This was a multicentre propensity score-matched (PSM) study of a cohort of consecutive patients with pT4 right colon cancer treated with RRC or LRC. The two surgical approaches were compared in terms of R0, number of lymph nodes harvested, intra- and postoperative complication rates, overall (OS), and disease-free survival (DFS).

Results: Among a total of 200 patients, 39 RRC were compared with 78 PS-matched LRC patients. The R0 rate was similar between RRC and LRC (92.3% vs. 96.2%, respectively; $p=0.399$), as was the odds of retrieving 12 or more lymph nodes (97.4% vs. 96.2%; $p=1$). No significant difference was noted for the mean operating time (192.9 min vs. 198.3 min; $p=0.750$). However, RRC was associated with fewer conversions to laparotomy (5.1% vs. 20.5%; $p=0.032$), less blood loss (36.9 vs. 95.2 mL; $p<0.0001$), fewer postoperative complications (17.9% vs. 41%; $p=0.013$), a shorter time to flatus (2 vs. 2.8 days; $p=0.009$), and a shorter hospital stay (6.4 vs. 9.5 days; $p<0.0001$) compared with LRC. These results were confirmed even when converted procedures were excluded from the analysis. The 1-, 3- and 5-year OS ($p=0.757$) and DFS ($p=0.321$) did not significantly differ between RRC and LRC.

Conclusion: Adequate oncological outcomes are observed for RRC and LRC performed for pT4 right colon cancer. However, RRC is associated with lower conversion rates and improved short-term postoperative outcomes.

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For affiliations refer to page 1580.

KEYWORDS
locally advanced colon cancer, minimally invasive surgery, propensity score matching, right colon cancer, robotic surgery, T4 cancer

INTRODUCTION

In recent decades, minimally invasive surgery (MIS) has been globally accepted as the gold standard treatment for right colon cancer [1–10]. Laparoscopic right colectomy (LRC) is associated with improved postoperative outcomes, including faster recovery, shorter hospital stays, lower blood loss, and similar oncological outcomes compared to those for open surgery [1–6, 8, 11–14]. Nevertheless, the safety and feasibility of laparoscopic surgery for locally advanced colonic cancer have long been a matter of debate [15–21], and concerns remain about the routine implementation of MIS for clinical T4 cancers [22]. Approximately 15% of all diagnosed colon cancers are classified as pathological T4 (pT4) cancers [23, 24]. According to the American Joint Committee on Cancer (AJCC) classification [25], locally advanced colonic cancer is classified as T4a in cases of tumour invasion of the visceral peritoneum and as T4b in cases of tumour invasion or adhesion to adjacent structures and organs [25, 26]. Radical surgical resection (i.e., R0) followed by adjuvant chemotherapy represents the gold standard for nonmetastatic pT4 colon cancers, despite being burdened by poorer prognosis and greater technical complexity when performing en bloc resections [16, 17, 22, 27]. Compelling evidence advocates laparoscopic resection over open resection for nonmetastatic pT4 colon cancers because laparoscopic resection is associated with better clinical outcomes and equivalent oncological outcomes [21, 28–32]. The robotic approach, which is a further implementation of MIS, has also been adopted for locally advanced colon cancers. However, only a few studies have analysed the outcomes of robotic surgery for T4 colon cancer [31, 33, 34], highlighting the paucity of related literature.

Therefore, this propensity score-matched (PSM) study aimed to evaluate the technical feasibility, clinical and oncological safety, and postoperative outcomes of RRC versus LRC performed for nonmetastatic pT4 right colon cancers in a European multicentre patient cohort.

> **What does this paper add to the literature?**
>
> This is the first multicentre propensity score-matched study that analysed the clinical and oncological safety of robotic versus laparoscopic right colectomy for nonmetastatic pT4 right colon cancers, demonstrating that robotic surgery provides equivalent oncological radicality than laparoscopy, being also associated with lower conversion to open surgery and improved short-term postoperative outcomes.

MATERIALS AND METHODS

Data source, study design and population

This study was designed as a PSM analysis of the Minimally invasivE surgery for oncological Right ColectomY (MERCY) Study Group database [35–38]. The MERCY Study Group collaborators generated a multicentre retrospective cohort of adult patients with nonmetastatic right colon adenocarcinoma (AJCC stages 0–III) who underwent elective resection, curative-intent LRC or RRC (performed with da Vinci Surgical Platforms, Intuitive Surgical Ltd., Sunnyvale, CA, USA) in six European countries (France, Ireland, Italy, Spain, Switzerland and the UK) [35]. All procedures were carried out between January 2014 and December 2020 [35] by experienced colorectal surgeons (senior surgeons with at least 5 years of experience in minimally invasive colorectal surgery) who had completed their learning curve in minimally invasive right colectomy (at least 16 RRC and 25 LRC procedures [39]). All right colectomies were performed according to standardized surgical techniques, with central vascular ligation and at least standard D2-lymphadenectomy. All patients were treated and followed up after surgery according to standardized international and national protocols.

The inclusion criteria were as follows: (1) age ≥18 years; (2) histologically proven pT4 adenocarcinoma; (3) right colon cancer (i.e., caecum, ascending colon or hepatic flexure); (4) AJCC TNM stage IIb/IIc (T4a/T4b, N0, M0) and TNM stage IIIb/IIIc (T4a/T4b, N+, M0); (4) curative intent; (5) elective setting; and (6) robotic (RRC) or laparoscopic (with straight instruments, LRC) approach.

Patients with extended right colectomies with middle colic artery ligation at the origin were excluded. Patients who presented with synchronous colorectal cancer or metastatic disease, as well as those who had undergone open surgery and hand-assisted procedures, were also excluded. The type of surgical approach (i.e., robotic or laparoscopic surgery) and the type of ileocolic anastomosis (i.e., intracorporeal or extracorporeal) used depended on the surgeon's advice and preference at each centre.

This was a retrospective study dealing exclusively with anonymous clinical record data from prospectively maintained local databases routinely collected from health databases. This research was declared to the National Commission for Data Protection and Liberties (2210699) and approved by the Institutional Review Board (00011558). Personal data were collected after informing the involved patients and were treated in accordance with the ethical standards of the Helsinki Declaration. This study is reported according to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) 2021 guidelines [40, 41].

Study outcomes and definitions

The primary outcomes were oncological results after surgical resection based on the status of the resection margins (i.e., R0) and the number of harvested lymph nodes. The secondary outcomes included operative variables, postoperative morbidity and mortality and survival rates.

Pre-, intra- and postoperative data were retrospectively collected from prospectively maintained databases. The baseline preoperative characteristics included age, sex, body mass index (BMI), American Society of Anaesthesiologists (ASA) physical status classification system, type of comorbidity, previous surgical history, Charlson comorbidity index, tumour location and neoadjuvant therapy. Intraoperative outcomes included the operating time, unplanned conversion to open surgery, estimated blood loss, tumour size, tumour stage (according to the eighth edition of the AJCC classification system [25, 26]), resection margin status (i.e., R0 or R1), and number of lymph nodes harvested. R1 resection margins were defined as the presence of viable tumour cells at ≤1 mm from the resection margin [26]. Intraoperative blood loss was determined by direct measurement of collected blood (from swabs, suction bottles, drainage bags, etc.). Finally, postoperative outcomes included complications (defined according to the Clavien–Dindo classification [42]), anastomotic leakage, time to flatus, time to regular diet, length of hospital stay (LOS), 30-day readmissions and mortality. Referral for adjuvant chemotherapy was determined in accordance with the standard of care after local multidisciplinary team approval. Anastomotic leakage was defined as all conditions characterized by clinical or radiological anastomotic dehiscence, with or without the need for surgical revision. All types of complications and mortality were recorded during the hospital stay or within 90 days after surgery. Additionally, the recurrence rate, disease-free survival (DFS), and overall survival (OS) were analysed and compared between the RRC and LRC groups. All patients were followed up until death or the last follow-up date (updated up to January 2023). Local recurrence was defined as any recurrence in or near the site of the original primary tumour, whereas distant recurrence was defined as any recurrence occurring as distant metastases according to the TNM classification [43, 44]. Survival was estimated based on the duration of follow-up starting from the date of surgery. Censoring was defined as the date of the last follow-up if no event occurred. DFS was defined as the interval between surgery and the date of recurrence or censoring at the last follow-up. OS was defined as the time from diagnosis to the last documented follow-up or death due to any cause.

Statistical analysis

Patients were divided into two groups according to the type of surgical approach used: RRC or LRC. All patients who required an unplanned conversion to laparoscopic (in the case of RRC) or open (in the case of RRC and LRC) approaches were maintained in their original group based on an intention-to-treat analysis. For the descriptive analysis, means and standard deviations (SDs) are reported herein for continuous variables, whereas frequencies and percentages (%) are provided for categorical variables. Comparisons between RRC and LRC were made using student's *t* test or the Mann–Whitney test for continuous variables and the chi-squared test or Fisher's exact test for categorical variables. Whenever indicated, the odds ratio (OR) and 95% confidence interval (CI) were also estimated. To lessen the selection bias inherent in a retrospective study, a PSM analysis was performed to compare the treatment (i.e., RRC and LRC) outcomes by accounting for the different covariates that might have played a role in the selection of robotic versus laparoscopic surgery [45–49]. The propensity score was obtained from a logistic regression model that included the following covariates: age, sex, ASA score, tumour size, tumour location, tumour category (pT4a/pT4b), node category (pN0/pN1/pN2), need for multivisceral resection, centre and year of surgery. Notably, the model included the year of surgery to counterbalance potential historical bias. The surgical approach (i.e., RRC vs. LRC) was entered into the regression model as the dependent variable. A 1:2 nearest neighbour case-control match without replacement was used [45–49]. The two PS-matched groups were subsequently compared with respect to the study outcomes. The OS and DFS rates at 1, 3 and 5 years were assessed using the Kaplan–Meier method and compared between groups using the log-rank (Mantel–Cox) test. As suggested by several authors [36, 50, 51], survival analysis was also conducted and reported for the entire study population.

All the statistical analyses were performed using SPSS statistical software (Statistical Package for Social Science, IBM SPSS Statistics, version 28 for Macintosh; IBM Corp., with Essential for R plug-in).

RESULTS

Study population

The study population comprised 200 patients with pT4 right colon cancer who underwent elective RRC ($n=45$) or LRC ($n=155$). The number of robotic procedures increased over time; robotic procedures were applied in 4.8% of the pT4 cases in 2014 and in 28.6% of the pT4 cases in 2020. Patients' demographic and clinical characteristics are presented in Table 1. Before matching, the RRC and LRC groups significantly differed in terms of age and ASA score, with a higher mean age and a greater frequency of ASA III in the LRC group. In terms of comorbidities, no differences were noted between RRC and LRC patients. The clinical tumour size and location and histopathological tumour characteristics were similar between the groups; however, a trend toward a greater frequency of multivisceral resection was noted in the RRC group (42.2%) than in the LRC group (27.1%) ($p=0.066$), mirroring the greater prevalence of pT4b in the RRC group (42.2%) than in the LRC group (26.5%).

After PSM, 39 RRC patients were compared to 78 LRC patients (Figure 1). The demographic, clinical and histopathological characteristics of the RRC and LRC patients after PSM are presented in

TABLE 1 Demographic, clinical, and histological characteristics of patients with pT4 right colon cancer in the RRC and LRC groups before and after propensity score matching.

Variables	Before PSM (*n* = 200)			After PSM (*n* = 117)		
	RRC group (*n* = 45)	LRC group (*n* = 155)	*p*-value	RRC group (*n* = 39)	LRC group (*n* = 78)	*p*-value
Demographic and clinical variables						
Male, *n* (%)	23 (51.1)	75 (48.4)	0.866	19 (48.7)	38 (48.7)	1
Age (mean [SD])	66.24 (17.05)	72.33 (12.41)	**0.025**	68.35 (14.26)	70.38 (13.42)	0.344
Age >75 years, *n* (%)	13 (28.9)	75 (48.4)	**0.026**	11 (28.2)	33 (42.3)	0.160
BMI (mean [SD])	26.78 (3.91)	26.40 (5.02)	0.253	26.08 (3.59)	26.54 (5.68)	0.657
Obesity (BMI ≥30 kg/m^2), *n* (%)	8 (20.5)	31 (23.8)	0.829	5 (12.8)	15 (19.2)	0.440
ASA, *n* (%)			**0.004**			0.588
I	6 (13.3)	9 (5.8)		4 (10.3)	6 (7.7)	
II	30 (66.7)	82 (52.9)		26 (66.7)	46 (59)	
III	8 (17.8)	60 (38.7)		8 (20.5)	25 (32)	
IV	1 (2.2)	4 (2.6)		1 (2.5)	1 (1.3)	
Cardiovascular diseases, *n* (%)	16 (35.6)	65 (41.6)	0.394	16 (41)	33 (42.3)	0.958
Pulmonary diseases, *n* (%)	2 (4.4)	16 (10.3)	0.265	2 (5.1)	10 (12.8)	0.369
Kidney diseases, *n* (%)	3 (6.7)	12 (7.7)	0.553	3 (7.7)	5 (6.4)	0.900
Neurocognitive disorders, *n* (%)	1 (2.2)	10 (6.5)	0.287	1 (2.6)	2 (2.6)	0.922
Diabetes, *n* (%)	9 (20)	30 (19.4)	0.646	9 (23.1)	12 (15.4)	0.593
Comorbidity >1, *n* (%)	19 (42.2)	66 (42.6)	0.604	17 (43.6)	35 (44.9)	0.958
Charlson comorbidity score (mean [SD])	5.16 (2.21)	5.31 (2.40)	0.631	5.16 (2.21)	5.38 (1.89)	0.554
Previous abdominal surgery, *n* (%)	15 (33.3)	59 (38.1)	0.599	13 (33.3)	32 (41)	0.546
Patients with multivisceral resection, *n* (%)	19 (42.2)	42 (27.1)	0.066	15 (38.5)	22 (28.2)	0.295
Organs involved						
Abdominal wall	4	7		3	3	
Omentum	10	20		8	12	
Duodenum	4	2		3	2	
Small bowel	1	1		1	0	
Gallbladder	3	7		3	4	
Bladder	1	1		1	0	
Pararenal fats	0	1		0	1	
Liver (wedge)	1	0		1	0	
Gonadic vessel	1	0		1	0	
Fallopian tube	0	1		0	1	
Stomach (wedge)	0	4		0	3	
Sigmoid colon	1	0		0	0	
Patients >1 extra-colic organ resected*, *n* (%)	6 (31.6)	4 (9.5)	0.057	5 (33.3)*	3 (13.6)*	0.228
Preoperative imaging assessment on computed tomography scan						
Clinical tumour size (largest dimension, cm) (mean [SD])	4.58 (1.91)	5.24 (2.36)	0.268	4.58 (1.92)	5.54 (2.31)	0.122
Tumour location, *n* (%)			0.721			0.988
Caecum	15 (33.3)	62 (40)		13 (33.4)	25 (32.1)	
Ascending colon	19 (42.3)	59 (38.1)		16 (41)	33 (42.3)	
Hepatic flexure	11 (24.4)	34 (21.9)		10 (25.6)	20 (25.6)	

TABLE 1 (Continued)

Variables	Before PSM (*n* = 200)			After PSM (*n* = 117)		
	RRC group (*n* = 45)	LRC group (*n* = 155)	*p*-value	RRC group (*n* = 39)	LRC group (*n* = 78)	*p*-value
Histopathological variables						
Stage of disease AJCC			0.369			0.829
Stage II (pT4 N0 M0)	12 (26.7)	54 (34.8)		10 (25.6)	22 (28.2)	
Stage III (pT4 N1 or N2 M0)	33 (73.3)	101 (65.2)		29 (74.4)	56 (71.8)	
pT stage, *n* (%)			0.063			0.412
pT4a	26 (57.8)	114 (73.5)		23 (59)	53 (66.9)	
pT4b	19 (42.2)	41 (26.5)		16 (41)	25 (33.1)	
pN stage, *n* (%)			0.272			0.921
N0	12 (26.7)	54 (34.8)		10 (25.6)	22 (28.2)	
N1	20 (44.4)	49 (31.6)		18 (46.2)	33 (42.3)	
N2	13 (28.9)	52 (33.6)		11 (28.2)	23 (29.5)	
Lymphovascular invasion, *n* (%)	23 (51.1)	88 (56.8)	0.502	19 (48.7)	45 (57.7)	0.432
Perineural invasion, *n* (%)	12 (26.7)	58 (37.4)	0.216	10 (25.6)	31 (39.7)	0.154
Tumour size (largest dimension, cm) (median [SD])	4.51 (1.91)	4.77 (1.92)	0.393	4.53 (2.02)	4.97 (1.79)	0.245
Tumour grade, *n* (%)			0.779			0.910
Well differentiated	9 (20)	37 (23.9)		8 (20.5)	18 (23.1)	
Moderately differentiated	18 (40)	64 (41.3)		15 (38.5)	31 (39.7)	
Poorly differentiated	18 (40)	54 (34.8)		16 (41)	29 (37.2)	
Adjuvant treatment, *n* (%)	35 (77.8)	107 (69)	0.351	29 (74.4)	57 (73.1)	1

Note: Significant *p*-values are indicated in bold.

Abbreviations: AJCC, American Joint Committee on Cancer; ASA, American Society of Anaesthesiology; BMI, body mass index; LRC, laparoscopic right colectomy; PSM, propensity score matching; RRC, robotic right colectomy; SD, standard deviation; TNM, tumour, nodes and metastasis score.

*Percentage calculated of number of patients with multivisceral resection.

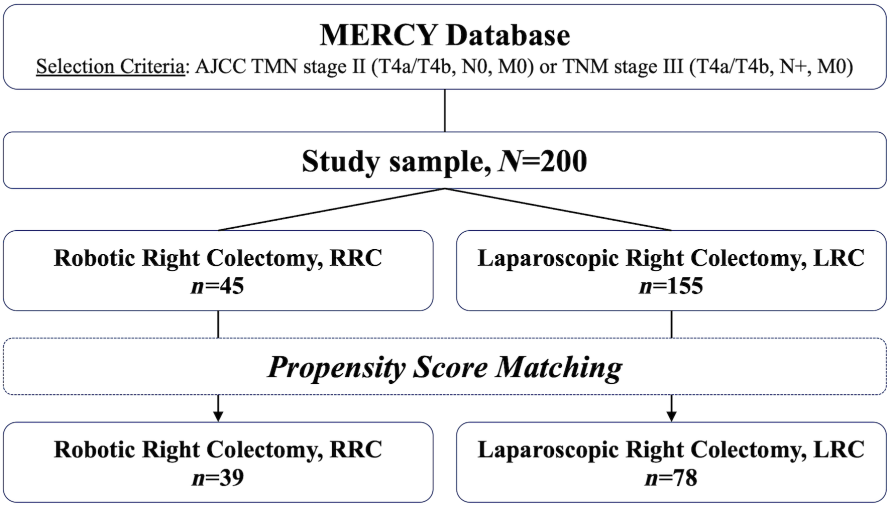


FIGURE 1 Flowchart of the study population selection and propensity score matching.

Table 1. The groups were well balanced (all respective *p*-values >0.05); furthermore, the propensity score showed adequate discrimination accuracy between the treatment groups (with an area under the curve [AUC] of 0.71; range: 0.61–0.82). Overall, 76 (65%) cancers were classified as T4a (59% in the RRC group vs. 67.9% in the LRC group), and 41 (35%) were classified as T4b (41% in the RRC group vs. 32.1% in the LRC group). Overall, 86 patients (73.5%) received adjuvant treatment, without difference between the groups.

Pathological outcomes

The pathological outcomes are displayed in Table 2. An R0 resection was obtained in the vast majority of patients (94.9%), without a significant difference between RRC and LRC (92.3% for RRC vs. 96.2% for LRC; $p=0.399$). A microscopic residual tumour (i.e., R1) was detected in three (7.7%) and three (3.8%) patients in the RRC and LRC groups, respectively, whereas no macroscopic residual disease (i.e., R2) was observed. At least 12 lymph nodes were retrieved during most right colectomies in both the RRC (97.4%) and LRC (96.2%) groups ($p=1$), but the average number of lymph nodes harvested during the operation (documented in the pathology report) was slightly greater in the RRC group (29.2 [median: 27] lymph nodes) than in the LRC group (26.3 [median: 23] lymph nodes; $p=0.076$).

Operative and postoperative outcomes

Operative and postoperative outcomes are displayed in Table 2. Focusing on intraoperative outcomes, RRC and LRC had comparable mean operating times (193 min for RRC vs. 198 min for LRC; $p=0.750$). RRC was associated with significantly less intraoperative blood loss (36.9 mL for RRC vs. 95.2 mL for LRC; mean difference: −58.3 mL; $p<0.0001$) and a lower conversion rate (5.1% for RRC vs. 20.5% for LRC; $p=0.032$; OR: 0.21; 95% CI: 0.04–0.96) than LRC. In the RRC group, conversion to open surgery was due to technical difficulties related to invasion of the duodenum ($n=2$) during multivisceral resection, whereas in the LRC group, conversion was required due to bleeding ($n=2$), invasion of adjacent organs ($n=11$), or technical difficulties related to tumour size ($n=3$). Conversion to open surgery was more frequent during LRC requiring a multivisceral resection (36.4%) than during LRC not associated with a multivisceral resection (14.3%) ($p=0.058$). Ileocolic anastomosis was performed intracorporeally more frequently in the RRC group (74.4%) than in the LRC group (34.6%) (OR = 5.47; 95% CI: 2.3–12.9; $p<0.0001$). Stapled anastomoses were performed in the great majority of patients (77.8%), with a significant difference between the groups (97.4% of stapled anastomosis in the RRC group vs. 67.9% in the LRC group; $p<0.0001$). The hand-sewn anastomoses were all extracorporeal and were performed mainly during laparoscopic procedures (96.2%). Only one anastomosis in the RRC group was hand-sewn; this was an extracorporeal anastomosis performed during a converted procedure.

Only two (2.6%) intraoperative complications occurred (bleeding), both during laparoscopic procedures. Focusing on postoperative outcomes, RRC was associated with fewer complications (17.9% for RRC vs. 41% for LRC; $p=0.013$; OR = 0.31; 95% CI: 0.12–0.80), a shorter time to flatus (2 days for RRC vs. 2.85 days for LRC; mean difference = 0.85 day; $p=0.009$) and a shorter LOS (6.4 days for RRC vs. 9.5 days for LRC; mean difference = 3.15 days; $p=0.004$). No group-related differences were noted for the severity of postoperative complications according to the Clavien–Dindo classification

TABLE 2 Intra- and postoperative outcomes in patients with pT4 right colon cancer in the RRC and LRC groups after propensity score matching ($n=117$).

Variables	RRC group ($n=39$)	LRC group ($n=78$)	p-value
Intraoperative variables			
Operative time (min) (mean [SD])	192.97 (38.68)	198.31 (65.98)	0.750
Conversion to laparotomy, *n* (%)	2 (5.1)	16 (20.5)	**0.032**
Operative blood loss (mL) (median [SD])	36.9 (36.1)	95.2 (82.23)	**<0.0001**
Type of side-to-side anastomosis, *n* (%)			
Intracorporeal	29 (74.4)	27 (34.6)	**<0.0001**
Use of ICG fluorescence, *n* (%)	4 (10.3)	3 (3.8)	0.220
Intraoperative complication, *n* (%)	0	2 (2.6)	0.552
Postoperative variables			
Number of transfused patients, *n* (%)	3 (7.7)	8 (10.3)	0.750
Time to flatus (mean [SD])	2 (0.87)	2.85 (1.56)	**0.009**
Return to regular diet (mean [SD])	3.21 (2.35)	4.40 (2.95)	0.109
Postoperative morbidity, *n* (%)	7 (17.9)	32 (41)	**0.013**
Patients with >1 complication*, *n* (%)	3 (42.9)	12 (37.5)	1
Dindo–Clavien classification*, *n* (%)			0.366
I/II	5 (71.4)	21 (65.6)	
III/IV	1 (14.3)	10 (31.3)	
V	1 (14.3)	1 (3.1)	
Wound infection, *n* (%)	0	2 (2.6)	0.552
Prolonged ileus, *n* (%)	3 (7.7)	6 (7.7)	1
Intra-abdominal abscess, *n* (%)	1 (2.6)	5 (6.4)	0.662
Anastomotic leakage, *n* (%)	2 (5.1)	7 (9)	0.716
Hospital stay, days (mean [SD])	6.38 (5.1)	9.5 (6)	**0.004**
Mortality at 90 days, *n* (%)	1 (2.6)	1 (1.3)	1
Readmission within 60 days, *n* (%)	0	7 (9)	0.094
Pathological variables			
Harvested lymph nodes (mean [SD])	29.2 (11.99)	26.3 (13.10)	0.076
≥12, *n* (%)	38 (97.4)	75 (96.2)	1

TABLE 2 (Continued)

Variables	RRC group ($n=39$)	LRC group ($n=78$)	p-value
Resection margin status, n (%)			
R0	36 (92.3)	75 (96.2)	0.399

Note: Significant p-values are indicated in bold.

Abbreviations: ICG, indocyanine green; LRC, laparoscopic right colectomy; RRC, robotic right colectomy; SD, standard deviation; TNM, tumour, nodes and metastasis score.

*The percentage refers to the number of patients with postoperative complication.

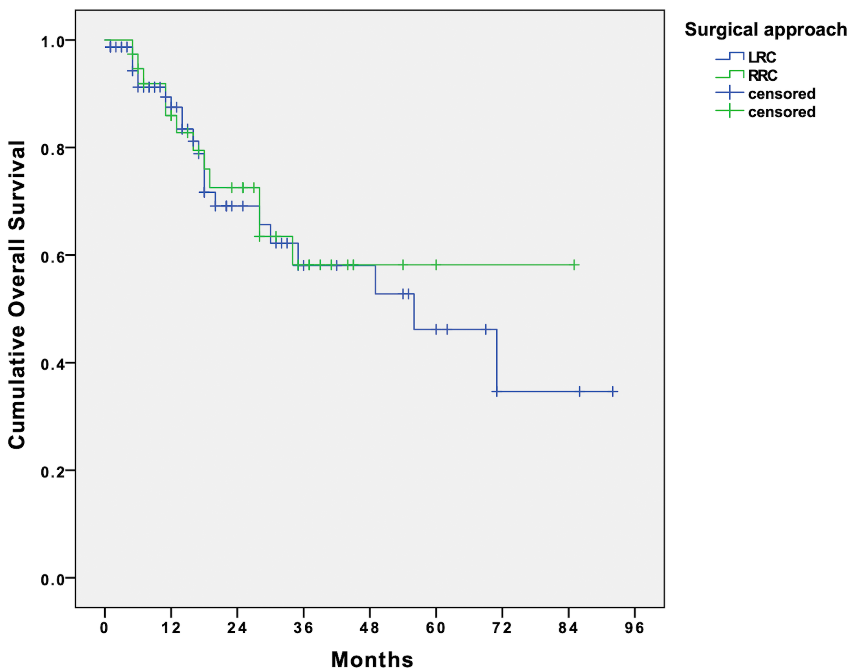
($p=0.366$); more specifically, considering the main types of postoperative complications, no difference was noted for the occurrence of anastomotic leakage, postoperative ileus, wound infections, intra-abdominal abscess, blood transfusion, and mortality, whereas hospital readmission showed a trend toward a higher frequency in the LRC group (9% vs. 0%; $p=0.094$). The overall 90-day mortality was 1.7% ($n=2$); one patient per group died due to sepsis.

As a sensitivity analysis, we compared RRC and LRC with respect to postoperative outcomes after excluding the converted cases ($n=18$). The results are consistent with those observed for the entire PS-matched sample. In particular, RRC was associated with significantly less blood loss ($p=0.001$), fewer postoperative complications (16.2% vs. 40.3%; $p=0.014$), a shorter time to flatus ($p=0.026$), a shorter time to regular diet ($p=0.035$), and a shorter hospital stay ($p=0.001$) than LRC. No group-related differences were noted for the operating time, anastomotic leakage, ileus, severity of postoperative complications, R0 status, hospital readmission rate or number of harvested lymph nodes.

Survival

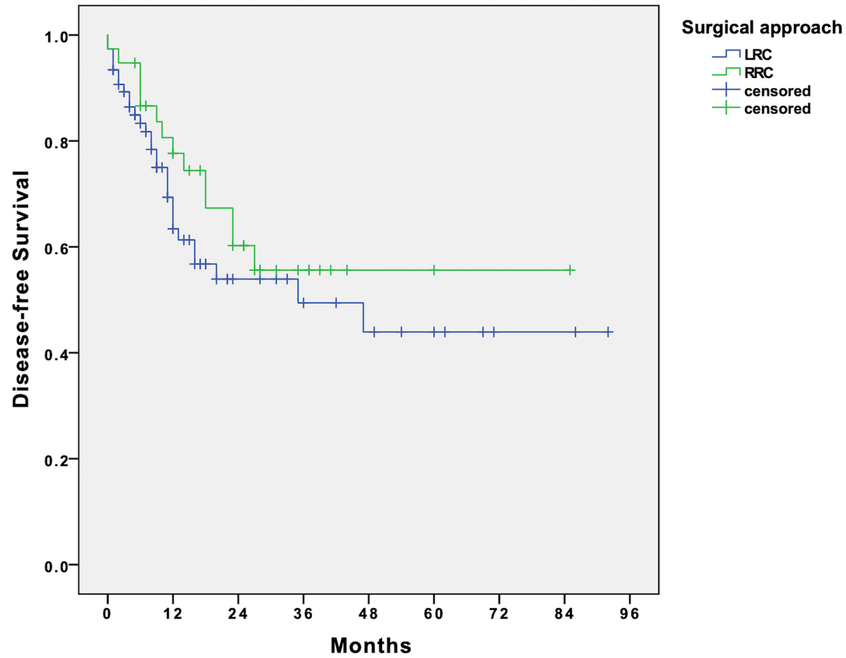
The mean follow-up time was 23.2 (SD: 19.9; range 1–92 months). The OS and DFS curves are shown in Figures 2 and 3, respectively. The 1-, 3- and 5-year OS rates were 86%, 58.2% and 29.1%, respectively, for the RRC group and 87.5%, 58.1% and 39.6%, respectively, for the LRC group ($p=0.757$). The 1-, 3-, and 5-year DFS rates were 77.7%, 48.6% and 27.8%, respectively, for the RRC group and 63.4%, 49.4% and 36.6%, respectively, for the LRC group ($p=0.321$). Disease recurrence over the entire follow-up period was observed in 14 (35.9%) patients in the RRC group and 29 (37.7%) patients in the LRC group ($p=1$). Overall, 8 (6.8%) patients had local recurrences, and 43 (36.8%) patients had distant metastases, without differences between the RRC and LRC groups ($p=0.877$).

Survival analyses of the entire study sample (without PSM, $n=196$) revealed similar OS and DFS rates. In particular, the 1-,



	Number at risk			
Time	*T0*	*12 months*	*36 months*	*60 months*
RRC	38	27	10	1
LRC	77	44	12	6

FIGURE 2 Kaplan–Meier curve of overall survival.



	Number at risk			
Time	*T0*	*12 months*	*36 months*	*60 months*
RRC	38	24	7	1
LRC	77	30	10	5

FIGURE 3 Kaplan–Meier curve of disease-free survival.

3- and 5-year OS rates were 87.7%, 60.1% and 40%, respectively, for the RRC group ($n=44$) and 85.3%, 67.6% and 53.4%, respectively, for the LRC group ($n=152$) ($p=0.992$). The 1-, 3- and 5-year DFS rates were 77.8%, 52.6% and 39%, respectively, for the RRC group and 72%, 56.9% and 50.8%, respectively, for the LRC group ($p=0.654$).

DISCUSSION

To the best of our knowledge, this study is the first multicentre PSM analysis comparing short- and long-term outcomes between RRC and LRC for nonmetastatic pT4 right colon cancer patients. The present results suggest that, facing comparable oncological outcomes (R0, number of harvested lymph nodes, OS and DFS), RRC is associated with significantly better peri- and postoperative outcomes in terms of reduced conversion to laparotomy, lower perioperative blood loss, lower morbidity and faster recovery than LRC.

Achieving R0 resection with adequate lymph node clearance is the pillar of surgical oncology [52, 53]. In the case of T4 colon cancer, achieving negative margins may require technically demanding procedures, potentially including en bloc resection of adjacent tumour-invaded organs (i.e., in patients with pT4b disease). This also represents the reason why T4 cancer has been considered an exclusion criterion in most randomized controlled trials comparing MIS to open surgery for colorectal cancer [1, 6–8, 11], limiting the body of evidence concerning locally advanced cancer. However, MIS, including robotic surgery, has also been increasingly adopted for patients with pT4-stage disease [21, 28–32, 34]. During the past decade, the number of minimally invasive colectomies performed worldwide for locally advanced colon cancer has increased exponentially. Between 2010 and 2014, approximately 35% of pT4 colon cancer cases recorded in the National Cancer Database in the USA were treated laparoscopically or robotically [31]. Similarly, Pacheco and Harris-Gendron in the USA reported a shift toward robotic surgery for T4 colorectal cancers (4.1% robotic resections in 2010 vs. 19.1% in 2017) [33], which is consistent with the data observed in the MERCY database. Globally, in the MERCY European multicentre cohort, the use of robotic surgery has shown an increasing trend over time, particularly for intracorporeal anastomosis [35] but also for pT4 colon cancer.

The feasibility of robotic surgery, particularly for T1–T3 right colon cancer [54], has been explored in recent years. On the one hand, many authors have reported theoretical advantages, such as a higher rate of textbook outcomes [55], shorter LOS [56–58], lower conversion rate [55–57, 59, 60], reduced time to flatus [60] and faster learning curve [39, 61], for RRC than for LRC. However, the only randomized controlled trial comparing RRC versus LRC published thus far showed similar short- and long-term outcomes between the two surgical approaches [9, 10]. Nevertheless, evidence is limited, particularly when evaluating the role of robotic surgery in the subset of patients with pT4 stage right colon cancer [62] (Table 3).

TABLE 3 Summary of the relevant literature about the outcomes of robotic surgery in patients with T4 colon cancer.

First author and year	Parascandola et al. (2021)[34]			El-Sharkawy et al. (2021)[31]		Pacheco & Harris-Gendron (2022)[33]		Present study	
Study design	Retrospective PSM study			Retrospective PSM study		Retrospective study		Retrospective PSM study	
Study time frame	2010–2016			2010–2014		2015–2017		2014–2020	
Data source	National Cancer Database			National Cancer Database		National Cancer Database		MERCY database	
Country	United States of America			United States of America		United States of America		Europe (multicentre)	
Total sample (*n*)	26 260			21 998		27 319		200	
Sample after PSM (*n*)	2628			11 224				117	
Surgical approach	**Open surgery ($n = 876$)**	**Laparoscopic surgery ($n = 876$)**	**Robotic surgery ($n = 876$)**	**Open surgery ($n = 5612$)**	**MIS ($n = 5612$)**	**Open surgery ($n = 14239$)**	**MIS ($n = 13080$)**	**Laparoscopic surgery w($n = 78$)**	**Robotic surgery ($n = 39$)**
Right colon cancer, *n* (%)	390 (44.5)	379 (43.3)	396 (45.2)	n/a	n/a	14 642 (53.5)		78 (100)	39 (100)
Multivisceral resection, *n* (%)	n/a	n/a	n/a	(19.4)	(13.2)	n/a	n/a	22 (28.2)	15 (38.5)
Operative time (min) (mean/median [SD/range])	n/a	n/a	n/a	n/a	n/a	n/a	n/a	198.31 (65.98)	192.97 (38.68)
Conversion to open surgery, *n* (%)	/	**180 (20.6)**	**111 (12.7)**	/	1681 (22.3)*	/	n/a	**16 (20.5)**	**2 (5.1)**
Overall postoperative morbidity, *n* (%)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	**32 (41)**	**7 (17.9)**
Mortality, *n* (%)	**34 (3.9)**	**17 (1.9)**	**20 (2.3)**	**404 (7.2)**	**191 (3.4)**	n/a	n/a	1 (1.3)***	1 (2.6)***
Length of hospital stay (mean/median [SD/range])	n/a	n/a	n/a	**8.66 (7.51)**	**7.04 (6.19)**	n/a	n/a	**9.5 (6)**	**6.38 (5.1)**
R0, *n* (%)	719 (82.1)	756 (86.3)	736 (84)	**4429 (78.9)**	**4595 (81.9)**	n/a	n/a	75 (96.2)	36 (96.2)
Lymph nodes harvested (mean [SD])	n/a	n/a	n/a	n/a	n/a	**18 (11)**	**19 (11)**	26.3 (13.10)	29.2 (11.9)
≥12 harvested lymph nodes, *n* (%)	**781 (89.2)**	**824 (94.1)**	**821 (93.7)**	**4960 (88.4)**	**5168 (92.1)**	**12 576 (88.3)**	**12 061 (92.2)**	75 (96.2)	38 (97.4)
Overall survival rates	**45.5% at 5 years**	**51.8% at 5 years**	**51.6% at 5 years**	**40.5% at 5 years**	**46% at 5 years**	n/a	n/a	87.5% at 1 year, 58.1% at 3 years and 39.6% at 5 years	86% at 1 year, 58.2% at 3 years and 29.1% at 5 years
Disease-free survival rates	n/a	n/a	n/a	n/a	n/a	n/a	n/a	63.4% at 1 year, 49.4% at 3 years and 36.6% at 5 years	77.7% at 1 year, 48.6% at 3 years and 27.8% at 5 years

Note: Statistically significant results are shown in bold.

Abbreviations: MIS, minimally invasive surgery; n/a, not assessed; PSM, propensity score matching; SD, standard deviation.

*Calculated on the overall MIS population ($n = 7532$). ***Mortality at 60 days.

A retrospective study conducted by Parascandola et al. compared robotic, laparoscopic, and open resection for the management of pT4 colon cancer [34]. Based on the National Cancer Database in the United States, 876 cases of T4 colon cancer per treatment approach were analysed after applying PSM. Compared with open surgery, laparoscopic and robotic colectomies were associated with significantly higher odds of harvesting 12 or more lymph nodes, shorter time from surgery to chemotherapy, decreased mortality hazards, and increased OS [34]. Moreover, there was no significant difference between the robotic and laparoscopic approaches in terms of short- or long-term oncological outcomes, apart from a decreased odds of conversion to laparotomy in the robotic group. However, in the study by Parascandola et al. [34], no distinction was made between the different procedures required for the resection of pT4 colon cancer lesions, which included partial, subtotal, or total colectomies. Less than half of the cancers (43.2%–45.2%, depending on the surgical approach group) were located at the level of the ascending colon, hepatic flexure, or caecum. Thus, the sample was highly heterogeneous despite the similar stage (T4) because, although debated, right and left colon cancers present significant differences in terms of genetic components, pathophysiology, and prognosis [63–66].

Based on the National Cancer Database, sponsored by the American College of Surgeons and the American Cancer Society in the United States, El-Sharkawy et al. [31] published a PSM analysis aimed at comparing survival outcomes between patients who underwent MIS (laparoscopic and robotic) and those who underwent open surgery for pT4 colon cancer. Overall, 34.2% of patients underwent MIS, but unfortunately, the specific rate of robotic and laparoscopic procedures was not reported. Additionally, the exact location of T4 colon cancer was not described. Notably, a high rate of conversion from MIS to open surgery was described (22.3%), supporting the complexity of MIS resection for pT4 cancer and most likely indicating variable surgeon expertise in MIS among the numerous facilities (>1500) that contributed to the cohort. Nevertheless, compared with open surgery, MIS was associated with improved postoperative mortality, surgical margins, lymph node harvest and five-year survival [31]. In particular, the advantage of an adequate lymph node harvest (≥12) associated with MIS was also reported by Pacheco and Harris-Gendron [33] based on 2015–2017 data from the National Cancer Database.

In contrast to the previous literature, which essentially consisted of heterogeneous retrospective databases, the present study involved a PSM analysis of a very specific cohort of patients, namely, those presenting with nonmetastatic pT4 right colon cancer treated by experienced surgeons via a minimally invasive approach. Despite its retrospective nature, the homogeneity of the sample concerns not only the cancer stage (pT4) but also the tumour location (only right colon cancer) and the type of MIS. Moreover, the PSM method allowed us to compare RRC and LRC considering most of the clinical and pathological variables that might influence the choice of surgical technique, including the surgical centre and the year of surgery, thus providing more precise insights into the outcomes of RRC and LRC for pT4 right colon cancer.

R0 resection was achieved in 92.3% of patients who underwent RRC and 96.2% of those who underwent LRC, but these two groups were not significantly different. In a recent meta-analysis by Podda et al. [32], R0 resection was obtained in 91.6% of laparoscopic colectomies for pT4 tumours, whereas Parascandola et al. [34] achieved negative margins in 86.3% of laparoscopic resections and 84% of robotic resections. In this study, as in the previous literature [31, 33, 34], the mean number of harvested lymph nodes was greater in the RRC group than in the LRC group; however, when assessing the frequency of retrieving 12 or more lymph nodes, no difference was noted between RRC and LRC (97.4% vs. 96.2%, respectively), suggesting that adequate oncological resection can be achieved with both minimally invasive surgical approaches. However, it is not possible to conclude based on the present retrospective data whether the robotic approach allows for more precise central ligation, facilitating more extended lymphadenectomy (e.g., complete mesocolic excision, CME), than does LRC. Moreover, there is a lack of international consensus on the role and technical requirements of CME [67], which deserves further focused trials.

When addressing intraoperative outcomes, RRC performed for pT4 right colon cancer is associated with a significantly lower rate of conversion (5.1% vs. 20.5%) to open surgery. Notably, all operators were experienced surgeons in MIS and robotic surgery, which may explain the low rate of conversion in the RRC group. Conversely, the rate of conversion in the LRC group was similar to that previously reported for T4 colon cancers [31, 34], which might reflect the inherent drawbacks of laparoscopy with straight instruments in complex colorectal resection, namely, the limited range of motion, the lack of flexible instruments, the two-dimensional view, and the poor ergonomics, particularly when multivisceral resection is needed. This can also explain the reduced blood loss (36.9 mL vs. 95.2 mL) and greater rate of intracorporeal anastomosis (74.4% vs. 34.6%) in the RRC group than in the LRC group. Several studies have suggested that unplanned conversion from MIS to open right colectomy may negatively impact postoperative recovery, morbidity and survival [35, 38, 68–70]. However, this finding was not confirmed in the present study, as it was in previous investigations [31, 34], where the oncological outcomes associated with RRC or LRC did not differ. Moreover, when excluding converted procedures from the analyses, the postoperative outcomes, namely, the rate of postoperative complications and recovery, remained significantly better in the RRC group than in the LRC group, suggesting that the observed results are related to the surgical approach and cannot be explained only by the higher rate of conversion to laparotomy observed in the LRC group.

In the present study, the operating times of the RRC and LRC groups were comparable (192.9 min vs. 198.3 min, respectively). This result is likely related to the experience of the surgical teams involved, but it also suggests that robotic platforms may facilitate complex surgical gestures in locally advanced disease (i.e., T4 tumours), helping to overcome the aforementioned drawbacks of laparoscopy [35, 39].

RRC procedures were also associated with significantly improved postoperative outcomes, including shorter time to flatus

(−0.85 day), reduced overall postoperative morbidity (OR = 0.31), and shorter LOS (−3.15 days). Based on recent evidence, performing an intracorporeal instead of an extracorporeal anastomosis during minimally invasive right colectomy might lead to potential benefits, such as reduced short-term morbidity, faster recovery, and shorter LOS [36, 71–76]. Moreover, these results are consistent with several studies that reported improved in-hospital and short-term outcomes in patients who underwent robotic colectomy [77–82]. However, regarding the type and severity of postoperative complications, there was no significant difference between RRC and LRC in terms of anastomotic leakage or severe Clavien–Dindo complications.

Focusing on the long-term outcomes, the 1-, 3- and 5-year OS and DFS in the present study were similar between the RRC and LRC groups, both in the PSM and entire cohorts, and were consistent with previous results shown in other studies on T4 colon cancer [20, 31, 32, 83–85]. According to the meta-analysis by Podda et al. [32], laparoscopic colectomy for T4 colon cancer was associated with pooled 3- and 5-year OS rates of 77.8% and 49.9%, respectively, and with pooled 3- and 5-year DFS rates of 64.1% and 54.9%, respectively.

Although this study represents the first multicentre PSM analysis of RRC versus LRC for pT4 right colon cancer, the current results should be interpreted with caution considering several limitations. First, the retrospective design is associated with potential selection and reporting bias, providing a limited number of routinely collected variables for analyses. In an effort to mitigate this limitation, only experienced colorectal surgeons and referral centres applying enhanced recovery protocols were included. In addition, we utilized a PSM analysis to make RRC and LRC comparable despite the absence of randomization. Indeed, when RCTs are not available, the best evidence might be obtained from a nonrandomized study with a PSM design based on a prospectively maintained database and an intention-to-treat analysis [86]. Finally, it was not possible to perform a cost-effectiveness analysis of RRC versus LRC because the specific costs of surgical instruments, operating room occupancy, maintenance of the robotic platforms, and hospital stay were not available or estimable due to considerable variance across countries or within Europe. Nevertheless, it must be emphasized that the higher financial costs associated with RRC over LRC represent a major barrier to the widespread adoption of robotic platforms; thus, future studies with cost–benefit analyses are advocated [82]. However, since RRC could be associated with better perioperative outcomes (i.e., reduced conversion to laparotomy, lower perioperative blood loss, lower morbidity, and faster recovery than LRC), this could impact the perioperative costs and the burden of pT4 colon cancer on both the patient and the health care provider.

In conclusion, the present study provides evidence to support the feasibility of MIS for nonmetastatic pT4 right colon cancer. Compared with LRC, RRC appears to be technically feasible, providing oncological adequacy and improved short-term postoperative outcomes, such as a lower risk of conversion to open surgery, reduced blood loss, a greater rate of intracorporeal anastomosis, lower morbidity, and a shorter LOS. Thus, the present results support the application of robotic surgery in performing complex colonic resections in oncological patients.

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CONFLICT OF INTEREST STATEMENT

The authors confirm that there are no conflicts of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

ETHICS STATEMENT

This research was declared to the National Commission for Data Protection and Liberties (2210699) and approved by the Institutional Review Board (00011558). Personal data were collected after informing the involved patients and were treated in accordance with the ethical standards of the Helsinki Declaration.

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REFERENCES

1. Buunen M, Veldkamp R, Hop WC, Kuhry E, Jeekel J, Haglind E, et al. Survival after laparoscopic surgery versus open surgery for colon cancer: long-term outcome of a randomised clinical trial. Lancet Oncol. 2009;10:44–52. https://doi.org/10.1016/S1470-2045(08)70310-3
2. Deijen CL, Vasmel JE, de Lange-de Klerk ESM, Cuesta MA, Coene PLO, Lange JF, et al. Ten-year outcomes of a randomised trial of laparoscopic versus open surgery for colon cancer. Surg Endosc. 2017;31:2607–15. https://doi.org/10.1007/s00464-016-5270-6
3. Bagshaw PF, Allardyce RA, Frampton CM, Frizelle FA, Hewett PJ, McMurrick PJ, et al. Long-term outcomes of the australasian randomized clinical trial comparing laparoscopic and conventional open surgical treatments for colon cancer: the Australasian laparoscopic colon Cancer study trial. Ann Surg. 2012;256:915–9. https://doi.org/10.1097/SLA.0b013e3182765ff8
4. Fleshman J, Sargent DJ, Green E, Anvari M, Stryker SJ, Beart RW Jr, et al. Laparoscopic colectomy for cancer is not inferior to open surgery based on 5-year data from the COST study group trial. Ann Surg. 2007;246:655–62. https://doi.org/10.1097/SLA.0b013e318155a762
5. Green BL, Marshall HC, Collinson F, Quirke P, Guillou P, Jayne DG, et al. Long-term follow-up of the Medical Research Council CLASICC trial of conventional versus laparoscopically assisted resection in colorectal cancer. Br J Surg. 2013;100:75–82. https://doi.org/10.1002/bjs.8945
6. Guillou PJ, Quirke P, Thorpe H, Walker J, Jayne DG, Smith AM, et al. Short-term endpoints of conventional versus laparoscopic-assisted surgery in patients with colorectal cancer (MRC CLASICC trial): multicentre, randomised controlled trial. Lancet. 2005;365:1718–26. https://doi.org/10.1016/S0140-6736(05)66545-2
7. Jayne DG, Thorpe HC, Copeland J, Quirke P, Brown JM, Guillou PJ. Five-year follow-up of the Medical Research Council CLASICC trial of laparoscopically assisted versus open surgery for colorectal cancer. Br J Surg. 2010;97:1638–45. https://doi.org/10.1002/bjs.7160
8. Lacy AM, Delgado S, Castells A, Prins HA, Arroyo V, Ibarzabal A, et al. The long-term results of a randomized clinical trial of laparoscopy-assisted versus open surgery for colon cancer. Ann Surg. 2008;248:1–7. https://doi.org/10.1097/SLA.0b013e31816a9d65
9. Park JS, Choi GS, Park SY, Kim HJ, Ryuk JP. Randomized clinical trial of robot-assisted versus standard laparoscopic right colectomy. Br J Surg. 2012;99:1219–26. https://doi.org/10.1002/bjs.8841
10. Park JS, Kang H, Park SY, Kim HJ, Woo IT, Park IK, et al. Long-term oncologic after robotic versus laparoscopic right colectomy: a prospective randomized study. Surg Endosc. 2019;33:2975–81. https://doi.org/10.1007/s00464-018-6563-8
11. Veldkamp R, Kuhry E, Hop WC, Jeekel J, Kazemier G, Bonjer HJ, et al. Laparoscopic surgery versus open surgery for colon cancer: short-term outcomes of a randomised trial. Lancet Oncol. 2005;6:477–84. https://doi.org/10.1016/S1470-2045(05)70221-7
12. Yamamoto S, Inomata M, Katayama H, Mizusawa J, Etoh T, Konishi F, et al. Short-term surgical outcomes from a randomized controlled trial to evaluate laparoscopic and open D3 dissection for stage II/III colon cancer: Japan Clinical Oncology Group Study JCOG 0404. Ann Surg. 2014;260:23–30. https://doi.org/10.1097/SLA.0000000000000499
13. Liao CH, Tan EC, Chen CC, Yang MC. Real-world cost-effectiveness of laparoscopy versus open colectomy for colon cancer: a nationwide population-based study. Surg Endosc. 2017;31:1796–805. https://doi.org/10.1007/s00464-016-5176-3
14. Nelson H, Sargent DJ, Wieand HS, Fleshman J, Anvari M, Stryker SJ, et al. A comparison of laparoscopically assisted and open colectomy for colon cancer. N Engl J Med. 2004;350:2050–9. https://doi.org/10.1056/NEJMoa032651
15. Veldkamp R, Gholghesaei M, Bonjer HJ, Meijer DW, Buunen M, Jeekel J, et al. Laparoscopic resection of colon Cancer: consensus of the European Association of Endoscopic Surgery (EAES). Surg Endosc. 2004;18:1163–85. https://doi.org/10.1007/s00464-003-8253-3
16. Chang GJ, Kaiser AM, Mills S, Rafferty JF, Buie WD, Standards Practice Task Force of the American Society of Colon and Rectal Surgeons. Practice parameters for the management of colon cancer. Dis Colon Rectum. 2012;55:831–43. https://doi.org/10.1097/DCR.0b013e3182567e13
17. Zerey M, Hawver LM, Awad Z, Stefanidis D, Richardson W, Fanelli RD, et al. SAGES evidence-based guidelines for the laparoscopic resection of curable colon and rectal cancer. Surg Endosc. 2013;27:1–10. https://doi.org/10.1007/s00464-012-2592-x
18. Nagata H, Kawai K, Hata K, Tanaka T, Nozawa H, Ishihara S. Laparoscopic surgery for T4 colon cancer: a risk factor for peritoneal recurrences? Surgery. 2020;168:119–24. https://doi.org/10.1016/j.surg.2020.02.026
19. Bretagnol F, Dedieu A, Zappa M, Guedj N, Ferron M, Panis Y. T4 colorectal cancer: is laparoscopic resection contraindicated? Color Dis. 2011;13:138–43. https://doi.org/10.1111/j.1463-1318.2010.02380.x
20. Shukla PJ, Trencheva K, Merchant C, Maggiori L, Michelassi F, Sonoda T, et al. Laparoscopic resection of t4 colon cancers: is it feasible? Dis Colon Rectum. 2015;58:25–31. https://doi.org/10.1097/DCR.0000000000000220
21. de'Angelis N, Vitali GC, Brunetti F, Wassmer CH, Gagniere C, Puppa G, et al. Laparoscopic vs. open surgery for T4 colon cancer: a propensity score analysis. Int J Color Dis. 2016;31:1785–97. https://doi.org/10.1007/s00384-016-2646-y
22. Network, N.C.C. NCCN Clinical Practice Guidelines in Oncology: Colon Cancer. Version 3.2023—September 21, 2023.
23. de Neree Tot Babberich MPM, Detering R, Dekker JWT, Elferink MA, Tollenaar R, Wouters M, et al. Achievements in colorectal cancer care during 8 years of auditing in The Netherlands. Eur J Surg Oncol. 2018;44:1361–70. https://doi.org/10.1016/j.ejso.2018.06.001
24. Segelman J, Akre O, Gustafsson UO, Bottai M, Martling A. External validation of models predicting the individual risk of metachronous peritoneal carcinomatosis from colon and rectal cancer. Color Dis. 2016;18:378–85. https://doi.org/10.1111/codi.13219
25. Weiser MR. AJCC 8th edition: colorectal Cancer. Ann Surg Oncol. 2018;25:1454–5. https://doi.org/10.1245/s10434-018-6462-1
26. Amin MB, Greene FL, Edge SB, Compton CC, Gershenwald JE, Brookland RK, et al. The eighth edition AJCC cancer staging manual: continuing to build a bridge from a population-based to a more "personalized" approach to cancer staging. CA Cancer J Clin. 2017;67:93–9. https://doi.org/10.3322/caac.21388
27. Benson AB, Venook AP, Al-Hawary MM, Arain MA, Chen YJ, Ciombor KK, et al. Colon cancer, version 2.2021, NCCN Clinical Practice Guidelines in Oncology. J Natl Compr Cancer Netw. 2021;19:329–59. https://doi.org/10.6004/jnccn.2021.0012
28. Takahashi R, Hasegawa S, Hirai K, Hisamori S, Hida K, Kawada K, et al. Safety and feasibility of laparoscopic multivisceral resection for surgical T4b colon cancers: retrospective analyses. Asian J Endosc Surg. 2017;10:154–61. https://doi.org/10.1111/ases.12355

29. Nagasue Y, Akiyoshi T, Ueno M, Fukunaga Y, Nagayama S, Fujimoto Y, et al. Laparoscopic versus open multivisceral resection for primary colorectal cancer: comparison of perioperative outcomes. J Gastrointest Surg. 2013;17:1299–305. https://doi.org/10.1007/s11605-013-2222-5
30. Park JH, Park HC, Park SC, Sohn DK, Oh JH, Kang SB, et al. Laparoscopic approach for left-sided T4 colon cancer is a safe and feasible procedure, compared to open surgery. Surg Endosc. 2019;33:2843–9. https://doi.org/10.1007/s00464-018-6579-0
31. El-Sharkawy F, Gushchin V, Plerhoples TA, Liu C, Emery EL, Collins DT, et al. Minimally invasive surgery for T4 colon cancer is associated with better outcomes compared to open surgery in the National Cancer Database. Eur J Surg Oncol. 2021;47:818–27. https://doi.org/10.1016/j.ejso.2020.09.003
32. Podda M, Pisanu A, Morello A, Segalini E, Jayant K, Gallo G, et al. Laparoscopic versus open colectomy for locally advanced T4 colonic cancer: meta-analysis of clinical and oncological outcomes. Br J Surg. 2022;109:319–31. https://doi.org/10.1093/bjs/znab464
33. Pacheco FA, Harris-Gendron S. Trends of minimally invasive surgery and adequate lymph node harvest in pT4 colon adenocarcinoma: a National Cancer Database Analysis. World J Colorectal Surg. 2022;11:79–83. https://doi.org/10.4103/wjcs.wjcs_8_23
34. Parascandola SA, Horsey ML, Hota S, Sparks AD, Tampo MMT, Kim G, et al. Surgical resection of T4 colon cancers: an NCDB propensity score-matched analysis of open, laparoscopic, and robotic approaches. J Robot Surg. 2021;15:701–10. https://doi.org/10.1007/s11701-020-01166-4
35. Group, M.S.C. Predictors of surgical outcomes of minimally invasive right colectomy: the MERCY study. Int J Color Dis. 2022;37:907–18. https://doi.org/10.1007/s00384-022-04095-w
36. de'Angelis N, Piccoli M, Casoni Pattacini G, Winter DC, Carcoforo P, Celentano V, et al. Right colectomy with Intracorporeal anastomosis: a European multicenter propensity score matching retrospective study of robotic versus laparoscopic procedures. World J Surg. 2023;47:2039–51. https://doi.org/10.1007/s00268-023-07031-3
37. de'Angelis N, Schena CA, Piccoli M, Casoni Pattacini G, Pecchini F, Winter DC, et al. Impact of operation duration on postoperative outcomes of minimally-invasive right colectomy. Color Dis. 2022;24:1505–15. https://doi.org/10.1111/codi.16243
38. Martinez-Perez A, Piccoli M, Casoni Pattacini G, Winter DC, Carcoforo P, Celentano V, et al. Conversion to open surgery during minimally invasive right colectomy for cancer: results from a large multinational European study. J Laparoendosc Adv Surg Tech A. 2023;33:344–50. https://doi.org/10.1089/lap.2022.0434
39. de'Angelis N, Lizzi V, Azoulay D, Brunetti F. Robotic versus laparoscopic right colectomy for colon Cancer: analysis of the initial simultaneous learning curve of a surgical fellow. J Laparoendosc Adv Surg Tech A. 2016;26:882–92. https://doi.org/10.1089/lap.2016.0321
40. von Elm E, Altman DG, Egger M, Pocock SJ, Gotzsche PC, Vandenbroucke JP, et al. The strengthening the reporting of observational studies in epidemiology (STROBE) statement: guidelines for reporting observational studies. Int J Surg. 2014;12:1495–9. https://doi.org/10.1016/j.ijsu.2014.07.013
41. Skrivankova VW, Richmond RC, Woolf BAR, Yarmolinsky J, Davies NM, Swanson SA, et al. Strengthening the reporting of observational studies in epidemiology using Mendelian randomization: the STROBE-MR statement. JAMA. 2021;326:1614–21. https://doi.org/10.1001/jama.2021.18236
42. Dindo D, Demartines N, Clavien PA. Classification of surgical complications: a new proposal with evaluation in a cohort of 6336 patients and results of a survey. Ann Surg. 2004;240:205–13. https://doi.org/10.1097/01.sla.0000133083.54934.ae
43. Read TE, Mutch MG, Chang BW, McNevin MS, Fleshman JW, Birnbaum EH, et al. Locoregional recurrence and survival after curative resection of adenocarcinoma of the colon. J Am Coll Surg. 2002;195:33–40. https://doi.org/10.1016/s1072-7515(02)01224-3
44. Qaderi SM, Galjart B, Verhoef C, Slooter GD, Koopman M, Verhoeven RHA, et al. Disease recurrence after colorectal cancer surgery in the modern era: a population-based study. Int J Color Dis. 2021;36:2399–410. https://doi.org/10.1007/s00384-021-03914-w
45. Austin PC. An introduction to propensity score methods for reducing the effects of confounding in observational studies. Multivar Behav Res. 2011;46:399–424. https://doi.org/10.1080/00273171.2011.568786
46. Heinze G, Juni P. An overview of the objectives of and the approaches to propensity score analyses. Eur Heart J. 2011;32:1704–8. https://doi.org/10.1093/eurheartj/ehr031
47. Austin PC. A critical appraisal of propensity-score matching in the medical literature between 1996 and 2003. Stat Med. 2008;27:2037–49. https://doi.org/10.1002/sim.3150
48. Austin PC. Balance diagnostics for comparing the distribution of baseline covariates between treatment groups in propensity-score matched samples. Stat Med. 2009;28:3083–107. https://doi.org/10.1002/sim.3697
49. Zhang Z, Kim HJ, Lonjon G, Zhu Y, AME Big-Data Clinical Trial Collaborative Group. Balance diagnostics after propensity score matching. Ann Transl Med. 2019;7, 16:16. https://doi.org/10.21037/atm.2018.12.10
50. Brazauskas R, Logan BR. Observational studies: matching or regression? Biol Blood Marrow Transplant. 2016;22:557–63. https://doi.org/10.1016/j.bbmt.2015.12.005
51. Austin PC. The performance of different propensity score methods for estimating marginal hazard ratios. Stat Med. 2013;32:2837–49. https://doi.org/10.1002/sim.5705
52. Argiles G, Tabernero J, Labianca R, Hochhauser D, Salazar R, Iveson T, et al. Localised colon cancer: ESMO clinical practice guidelines for diagnosis, treatment and follow-up. Ann Oncol. 2020;31:1291–305. https://doi.org/10.1016/j.annonc.2020.06.022
53. Mohan HM, Evans MD, Larkin JO, Beynon J, Winter DC. Multivisceral resection in colorectal cancer: a systematic review. Ann Surg Oncol. 2013;20:2929–36. https://doi.org/10.1245/s10434-013-2967-9
54. Mirkin KA, Kulaylat AS, Hollenbeak CS, Messaris E. Robotic versus laparoscopic colectomy for stage I–III colon cancer: oncologic and long-term survival outcomes. Surg Endosc. 2018;32:2894–901. https://doi.org/10.1007/s00464-017-5999-6
55. Farah E, Abreu AA, Rail B, Salgado J, Karagkounis G, Zeh HJ 3rd, et al. Perioperative outcomes of robotic and laparoscopic surgery for colorectal cancer: a propensity score-matched analysis. World J Surg Oncol. 2023;21:272. https://doi.org/10.1186/s12957-023-03138-y
56. Genova P, Pantuso G, Cipolla C, Latteri MA, Abdalla S, Paquet JC, et al. Laparoscopic versus robotic right colectomy with extra-corporeal or intra-corporeal anastomosis: a systematic review and meta-analysis. Langenbeck's Arch Surg. 2021;406:1317–39. https://doi.org/10.1007/s00423-020-01985-x
57. Tschann P, Szeverinski P, Weigl MP, Rauch S, Lechner D, Adler S, et al. Short- and long-term outcome of laparoscopic- versus robotic-assisted right colectomy: a systematic review and meta-analysis. J Clin Med. 2022;11:2387. https://doi.org/10.3390/jcm11092387
58. Lauka L, Brunetti F, Beghdadi N, Notarnicola M, Sommacale D, de'Angelis N. Advantages of robotic right colectomy over laparoscopic right colectomy beyond the learning curve: a systematic review and meta-analysis. Ann Laparosc Endosc. 2020;5:5.
59. Spinoglio G, Bianchi PP, Marano A, Priora F, Lenti LM, Ravazzoni F, et al. Robotic versus laparoscopic right colectomy with complete mesocolic excision for the treatment of colon cancer: perioperative outcomes and 5-year survival in a consecutive series of 202 patients. Ann Surg Oncol. 2018;25:3580–6. https://doi.org/10.1245/s10434-018-6752-7
60. Solaini L, Bazzocchi F, Cavaliere D, Avanzolini A, Cucchetti A, Ercolani G. Robotic versus laparoscopic right colectomy: an updated systematic review and meta-analysis. Surg Endosc. 2018;32:1104–10. https://doi.org/10.1007/s00464-017-5980-4

61. Ferraro L, Formisano G, Salaj A, Giuratrabocchetta S, Giuliani G, Salvischiani L, et al. Robotic right colectomy with complete mesocolic excision: senior versus junior surgeon, a case-matched retrospective analysis. Int J Med Robot. 2022;18:e2383. https://doi.org/10.1002/rcs.2383
62. de'Angelis N, Micelli Lupinacci R, Abdalla S, Genova P, Beliard A, Cotte E, et al. Robotic-assisted right colectomy. Official expert recommendations delivered under the aegis of the French Association of Surgery (AFC). J Visc Surg. 2022;159:212–21. https://doi.org/10.1016/j.jviscsurg.2022.04.001
63. Bourakkadi Idrissi M, El Bouhaddouti H, Mouaqit O, Ousadden A, Ait Taleb K, Benjelloun EB. Left-sided colon cancer and right-sided colon cancer: are they the same cancer or two different entities? Cureus. 2023;15, e37563:e37563. https://doi.org/10.7759/cureus.37563
64. Benedix F, Kube R, Meyer F, Schmidt U, Gastinger I, Lippert H, et al. Comparison of 17,641 patients with right- and left-sided colon cancer: differences in epidemiology, perioperative course, histology, and survival. Dis Colon Rectum. 2010;53:57–64. https://doi.org/10.1007/DCR.0b013e3181c703a4
65. Meguid RA, Slidell MB, Wolfgang CL, Chang DC, Ahuja N. Is there a difference in survival between right- versus left-sided colon cancers? Ann Surg Oncol. 2008;15:2388–94. https://doi.org/10.1245/s10434-008-0015-y
66. Suttie SA, Shaikh I, Mullen R, Amin AI, Daniel T, Yalamarthi S. Outcome of right- and left-sided colonic and rectal cancer following surgical resection. Color Dis. 2011;13:884–9. https://doi.org/10.1111/j.1463-1318.2010.02356.x
67. Wang C, Gao Z, Shen K, Shen Z, Jiang K, Liang B, et al. Safety, quality and effect of complete mesocolic excision vs. non-complete mesocolic excision in patients with colon cancer: a systemic review and meta-analysis. Color Dis. 2017;19:962–72. https://doi.org/10.1111/codi.13900
68. Mueller AN, Vossler JD, Yim NH, Harbison GJ, Murayama KM. Predictors and consequences of unplanned conversion to open during robotic colectomy: an ACS-NSQIP database analysis. Hawaii J Health Soc Welf. 2021;80:3–9.
69. Lee YF, Albright J, Akram WM, Wu J, Ferraro J, Cleary RK. Unplanned robotic-assisted conversion-to-open colorectal surgery is associated with adverse outcomes. J Gastrointest Surg. 2018;22:1059–67. https://doi.org/10.1007/s11605-018-3706-0
70. Bhama AR, Charlton ME, Schmitt MB, Cromwell JW, Byrn JC. Factors associated with conversion from laparoscopic to open colectomy using the National Surgical Quality Improvement Program (NSQIP) database. Color Dis. 2015;17:257–64. https://doi.org/10.1111/codi.12800
71. van Oostendorp S, Elfrink A, Borstlap W, Schoonmade L, Sietses C, Meijerink J, et al. Intracorporeal versus extracorporeal anastomosis in right hemicolectomy: a systematic review and meta-analysis. Surg Endosc. 2017;31:64–77. https://doi.org/10.1007/s00464-016-4982-y
72. Allaix ME, Degiuli M, Bonino MA, Arezzo A, Mistrangelo M, Passera R, et al. Intracorporeal or extracorporeal ileocolic anastomosis after laparoscopic right colectomy: a double-blinded randomized controlled trial. Ann Surg. 2019;270:762–7. https://doi.org/10.1097/SLA.0000000000003519
73. Bollo J, Turrado V, Rabal A, Carrillo E, Gich I, Martinez MC, et al. Randomized clinical trial of intracorporeal versus extracorporeal anastomosis in laparoscopic right colectomy (IEA trial). Br J Surg. 2020;107:364–72. https://doi.org/10.1002/bjs.11389
74. Malczak P, Wysocki M, Pisarska-Adamczyk M, Major P, Pedziwiatr M. Bowel function after laparoscopic right hemicolectomy: a randomized controlled trial comparing intracorporeal anastomosis and extracorporeal anastomosis. Surg Endosc. 2022;36:4977–82. https://doi.org/10.1007/s00464-021-08854-8
75. Milone M, Elmore U, Vignali A, Gennarelli N, Manigrasso M, Burati M, et al. Recovery after intracorporeal anastomosis in laparoscopic right hemicolectomy: a systematic review and meta-analysis. Langenbeck's Arch Surg. 2018;403:1–10. https://doi.org/10.1007/s00423-017-1645-y
76. Gomez Ruiz M, Espin-Basany E, Spinelli A, Cagigas Fernandez C, Bollo Rodriguez J, Maria Enriquez Navascues J, et al. Early outcomes from the minimally invasive right colectomy anastomosis study (MIRCAST). Br J Surg. 2023;110:1153–60. https://doi.org/10.1093/bjs/znad077
77. Miller PE, Dao H, Paluvoi N, Bailey M, Margolin D, Shah N, et al. Comparison of 30-day postoperative outcomes after laparoscopic vs robotic colectomy. J Am Coll Surg. 2016;223:369–73. https://doi.org/10.1016/j.jamcollsurg.2016.03.041
78. Dolejs SC, Waters JA, Ceppa EP, Zarzaur BL. Laparoscopic versus robotic colectomy: a national surgical quality improvement project analysis. Surg Endosc. 2017;31:2387–96. https://doi.org/10.1007/s00464-016-5239-5
79. Tagliabue F, Burati M, Chiarelli M, Fumagalli L, Guttadauro A, Arborio E, et al. Robotic vs laparoscopic right colectomy—the burden of age and comorbidity in perioperative outcomes: an observational study. World J Gastrointest Surg. 2020;12:287–97. https://doi.org/10.4240/wjgs.v12.i6.287
80. Al-Mazrou AM, Chiuzan C, Kiran RP. The robotic approach significantly reduces length of stay after colectomy: a propensity score-matched analysis. Int J Color Dis. 2017;32:1415–21. https://doi.org/10.1007/s00384-017-2845-1
81. Benlice C, Aytac E, Costedio M, Kessler H, Abbas MA, Remzi FH, et al. Robotic, laparoscopic, and open colectomy: a case-matched comparison from the ACS-NSQIP. Int J Med Robot. 2017;13. https://doi.org/10.1002/rcs.1783
82. Zheng J, Zhao S, Chen W, Zhang M, Wu J. Comparison of robotic right colectomy and laparoscopic right colectomy: a systematic review and meta-analysis. Tech Coloproctol. 2023;27:521–35. https://doi.org/10.1007/s10151-023-02821-2
83. Kim KY, Hwang DW, Park YK, Lee HS. A single surgeon's experience with 54 consecutive cases of multivisceral resection for locally advanced primary colorectal cancer: can the laparoscopic approach be performed safely? Surg Endosc. 2012;26:493–500. https://doi.org/10.1007/s00464-011-1907-7
84. Vignali A, Ghirardelli L, di Palo S, Orsenigo E, Staudacher C. Laparoscopic treatment of advanced colonic cancer: a case-matched control with open surgery. Color Dis. 2013;15:944–8. https://doi.org/10.1111/codi.12170
85. Wang H, Chen X, Liu H, Mou T, Deng H, Zhao L, et al. Laparoscopy-assisted colectomy as an oncologically safe alternative for patients with stage T4 colon cancer: a propensity-matched cohort study. BMC Cancer. 2018;18:370. https://doi.org/10.1186/s12885-018-4269-x
86. Lonjon G, Boutron I, Trinquart L, Ahmad N, Aim F, Nizard R, et al. Comparison of treatment effect estimates from prospective nonrandomized studies with propensity score analysis and randomized controlled trials of surgical procedures. Ann Surg. 2014;259:18–25. https://doi.org/10.1097/SLA.0000000000000256

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