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Robotic versus laparoscopic right colectomy with complete mesocolon excision for right-sided colon cancer: a systematic review and meta-analysis

Mohamed Ali Chaouch[1*], Amine Gouader[2], Bassem Krimi[2], Mohamed Aziz Daghmouri[3], Paolo Pietro Bianchi[4], Guglielmo Niccolò Piozzi[5], Jim S. Khan[5], Wahid Fattal[6], Christoph Reissfelder[6] and Hani Oweira[6]

Abstract

Background Right colectomy with complete mesocolic excision (CME) is considered the standard for right-sided colon cancer. While laparoscopic CME (LCME) is widely performed, robotic CME (RCME) has emerged as an alternative approach. This systematic review and meta-analysis compared the perioperative, pathological, and oncological outcomes of RCME and LCME.

Methods Following PRISMA 2020 guidelines, randomized and controlled clinical trials comparing RCME and LCME were analyzed. Primary outcomes included operative morbidity, blood loss, bleeding, conversion to open surgery, and operative time. Odds ratios (OR) or mean differences (MD) with 95% confidence intervals (CIs) were calculated using a random-effects model. Certainty of evidence was assessed using GRADE.

Results Seven studies comprising 733 patients (364 RCME and 369 LCME) were included. Postoperative morbidity did not differ significantly between RCME and LCME (OR 0.95, 95% CI 0.66–1.37; $p=0.79$). Blood loss was comparable between groups (MD −4.6 mL, 95% CI −27.7 to 18.5; $p=0.70$). RCME showed a lower conversion rate to open surgery (OR 0.07, 95% CI 0.01–0.52; $p=0.01$), though this was based on a few events and low-certainty evidence. Operative time was longer with RCME (MD 45.6 min, 95% CI 27.5–63.8; $p<0.00001$). There were no significant differences in postoperative ileus (OR 0.88, 95% CI 0.40–1.92; $p=0.74$), hospital stay (MD −0.10 days, 95% CI −0.61 to 0.40; $p=0.69$), or lymph node yield (MD 2.05, 95% CI −1.53–5.63; $p=0.26$). Oncological outcomes were similar between RCME and LCME for disease-free survival (OR 1.25, 95% CI 0.48–3.30; $p=0.65$) and overall survival (OR 1.00, 95% CI 0.14–7.20; $p=1.00$). The certainty of evidence ranged from low to moderate for most endpoints.

Conclusions RCME and LCME demonstrate comparable surgical, pathological, and oncological outcomes. RCME may be associated with a lower conversion rate, though this finding is uncertain due to the limited number of events and inter-study heterogeneity. Further high-quality randomized trials are warranted to confirm these observations and clarify cost-effectiveness.

*Correspondence:
Mohamed Ali Chaouch
Docmedalichaouch@gmail.com

Full list of author information is available at the end of the article

Keywords Robotic surgery, Laparoscopic surgery, Complete mesocolon excision, Colon cancer, Surgical outcomes

Introduction

Colorectal cancer remains one of the leading causes of cancer-related mortality worldwide [1]. The evolution of surgical techniques has played a crucial role in improving oncological outcomes, reducing morbidity, and enhancing patient quality of life. Among these advances, complete mesocolic excision (CME), first introduced by Hohenberger et al. in 2009, represents a standardized oncological principle based on sharp dissection along embryological planes with central vascular ligation [2]. This technique optimizes lymph node harvest and local control but may increase operative complexity and risk of vascular injury or postoperative morbidity [1, 3]. In recent decades, surgical approaches for CME have evolved significantly, transitioning from open colectomy to minimally invasive techniques, including laparoscopic and robot-assisted surgery [3]. Laparoscopic right colectomy with CME (LCME) has gained widespread adoption because of its minimally invasive advantages, including less blood loss, reduced postoperative pain, and shorter hospital stay compared with open surgery [4]. However, LCME remains technically demanding, requiring meticulous dissection along major mesenteric vessels to achieve an oncologically complete resection [5]. To overcome the ergonomic and visual limitations of laparoscopy, robotic right colectomy (RCME) has emerged as a promising approach offering stable three-dimensional visualization, tremor filtration, and articulated instruments that facilitate precise central vascular dissection [6]. These features may aid in performing CME safely and consistently, particularly in anatomically challenging cases. Nevertheless, robotic surgery entails longer operative times and higher costs, and its true benefit for CME-specific oncologic dissection remains uncertain. Most previous meta-analyses have evaluated robotic versus laparoscopic right colectomy without verifying whether CME was consistently performed, or they pooled both right- and left-sided colectomies [3]. As a result, the distinct oncologic implications of robotic assistance in confirmed CME procedures remain unclear. This evidence gap justifies a focused synthesis restricted to studies explicitly reporting CME-verified resections, ensuring comparable surgical intent and oncological standards.

This systematic review and meta-analysis aimed to synthesize the existing evidence comparing RCME and LCME in the treatment of right-sided colon cancer, focusing exclusively on CME and evaluating surgical, pathological, and oncological outcomes.

Methods

This systematic review and meta-analysis were structured according to the PRISMA 2020 guidelines (Preferred Reporting Items for Systematic Review and Meta-analysis) [7] and checked according to the AMSTAR 2 guidelines (assessing the methodological quality of systematic reviews) [8]. The protocol of this study was registered in PROSPERO under the number CRD420251006360.

Electronics searches

Searches were conducted in PubMed/MEDLINE, Embase, Cochrane Central Register of Controlled Trials (CENTRAL), and Scopus from January 1st, 2005, to March 6th, 2025. Google Scholar was used for gray literature screening only; duplicates were removed using EndNote X9 and manually verified for relevance and quality. No language restrictions were applied to find the highest possible number of articles in the literature. Keywords used were "robotic surgery"; "laparoscopic surgery"; "complete mesocolon excision"; "colon cancer", "colectomy", "outcome", "morbidity"," mortality", and "oncological outcomes". We selected the titles and abstracts of the relevant studies. The reference lists of all included studies and relevant systematic reviews were screened manually for additional citations. The different research strategies used for these databases are reported in *Supplementary File 1*.

Study selection

Randomized controlled trials (RCTs) and controlled clinical trials (CCTs) comparing RCME and LCME for right colon cancer. Trials that compared robotic and laparoscopic right colectomies without complete mesocolon excision were excluded. Articles published in peer-reviewed journals were included in this study. Data from non-comparative studies, review articles, editorial letters, abstracts only, comments, video vignettes, and case series (fewer than ten cases) were excluded.

Participants

Patients of either sex who underwent surgery for right colon cancer and right colectomy with CME using a robotic or laparoscopic approach with or without neoadjuvant treatment.

Intervention group (RCME group)

CME for surgery for right colon cancer using the robotic approach.

Control group (LCME group)

CME for surgery for right colon cancer using the laparoscopic approach.

Endpoints measures primary endpoints were operative outcomes (morbidity, operative time, bleeding, blood loss, and conversion rate). The secondary endpoints were postoperative recovery (ileus, hospital stay, time to first flatus, and time to oral intake), pathological outcomes (the number of lymph nodes harvested and the number of positive lymph nodes), and oncological outcomes (disease-free survival (DFS), and overall survival (OS)).

Study selection

Two authors independently reviewed all the abstracts. All studies with full text that met the inclusion criteria were retained. Disagreements were resolved through discussion after consulting a third member of the review team. Only studies that explicitly verified CME were included. Verification requires at least one of the following:

1. Description of CME and central vascular ligation (CVL) or D3 lymphadenectomy in the operative technique.
2. Confirmation by intraoperative or pathological photo-documentation of intact mesocolic planes; or reference to a previously validated CME protocol (Hohenberger et al. [2] or equivalent).

Studies that did not specify CME criteria or lacked documentation of CVL/D3 dissection were excluded.

Evaluation of study quality and risk of bias

All studies that met the selection criteria were independently evaluated by two authors using the MINORS scale [9] and Newcastle-Ottawa scale [10] for CCT and CONSORT for RCTs [11]. The Cochrane risk of bias assessment tool for bias (RoB2) [6] was used for bias assessment.

Data extraction

Two authors independently extracted data using a standardized data-extraction sheet. Extracted items included study design, country, patient demographics, CME verification method, operative outcomes, pathological variables, and survival data (DFS, OS). Each included propensity-matched cohort was reviewed to confirm unique patient populations and eliminate any overlap. No duplicated or overlapping cohorts were detected. When odds ratios (OR) and 95% confidence intervals were not reported, they were estimated from Kaplan–Meier curves using the PlotDigitilizer Online App method or by contacting the study authors. DFS and OS were synthesized using pooled ORs under a random-effects model.

Assessment of heterogeneity

Heterogeneity was assessed using three strategies: the Cochran Chi² test (Q test) and Tau² [12], which estimates the variance of true effects; graphical exploration through funnel plots [13]; and sensitivity analysis, including subgroup analysis when applicable.

Summary of findings

Two authors independently evaluated the evidence of the primary outcomes. We evaluated, developed, and assessed the recommendations (GRADE) [14]. We used the methods and recommendations described in Sect. 8.5 and 8.7 and Chaps. 11 and 12 of the Cochrane Handbook for systematic reviews of interventions. We used GRADEpro GDT software to prepare a Summary of Findings table. Using footnotes and comments, we explained the reasons for downgrading or upgrading the included studies.

Evaluation of effect size

The Review Manager 5.3.5 statistical package from the Cochrane Collaboration was used for the meta-analysis [15]. We selected the mean difference (MD) as an effective measure of continuous data. Odds ratios (OR) with 95% confidence intervals (95% CI) were calculated for dichotomous variables. A random-effects model was used. The significance threshold was set at $P < 0.05$. We tested the interaction between relevant factors and effect size estimates. Between-study variance (τ^2) was estimated using the DerSimonian–Laird method, with sensitivity analyses using Paule–Mandel and REML estimators to test robustness. Continuity corrections of 0.5 were applied for zero-event studies in both arms, and the Peto method was used for sensitivity analyses when applicable.

Results

Bibliographic research

The literature search yielded 20 eligible studies. Seven comparative studies were included [16–22]. The PRISMA flow diagram of bibliographic research is shown in Fig. 1. Five studies were excluded for the following reasons: one study presented duplicated data from the retained studies [23], one systematic review and meta-analysis comparing RCME with LCME or CME-free laparoscopic colectomies in right and left colon cancers [3], one systematic review of robotic CME [24], one review article of CME in mini-invasive surgery [25], and one study comparing robotic and laparoscopic procedures without CME [26]. Table 1 summarizes the demographic data of the seven included studies. These studies were published between 2012 and 2024, and originated in Turkey, Singapore, South Korea, Italy, and China. Most studies were retrospective, with only one RCT [19]. The sample size varied significantly, ranging from 18 patients to 284 patients. A

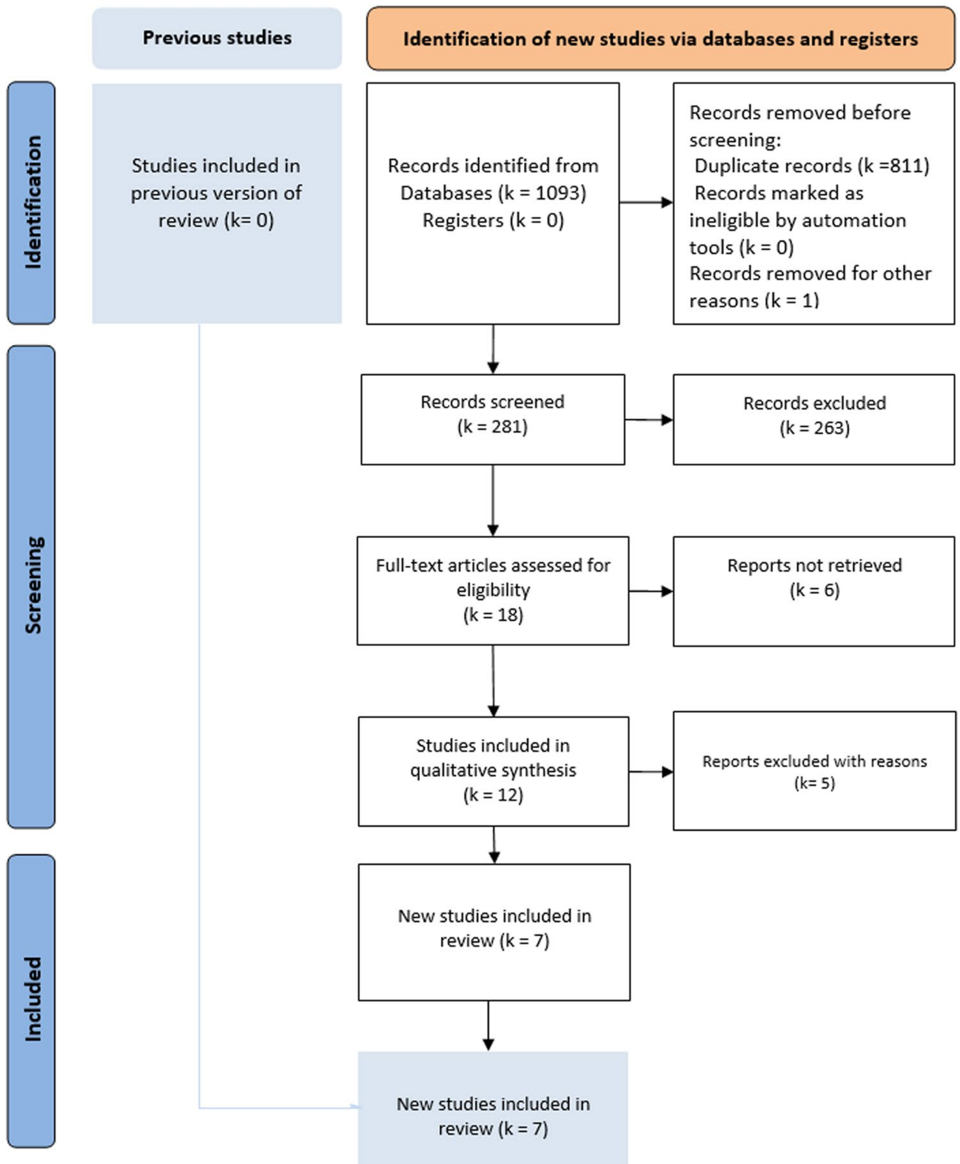

Fig. 1 PRISMA 2020 flow diagram for search strategy

total of 733 patients were included in all the studies, with 364 in the RCME group and 369 in the LCME group, ensuring a nearly balanced comparison between the two surgical approaches. The demographics across studies showed that the mean age ranged from 47.7 to 74.6 years, with a balanced gender distribution between male and female participants in both groups. The BMI values were generally similar across the RCME and LCME groups, mostly falling between 22.5 and 26.2 kg/m^2. The American Society of Anesthesiologists (ASA) score has been reported in most studies, ranging from 1 to 3, indicating varying levels of preoperative health status between patients. Regarding surgical techniques, all studies used the Da Vinci robotic system (Intuitive Surgical, LTD., Sunnyvale, USA), with different versions, including the Da Vinci Si and Da Vinci Xi. Tumor sizes have been reported in some studies, with values ranging from 4 to 4.7 cm. The follow-up period varied between studies, ranging from 60 months to shorter durations in a few studies.

Operative outcomes

Morbidity

Postoperative morbidity was reported in seven studies [16–22]. It occurred in 76 of the 353 patients in the RCME group and 80 of the 356 patients in the LCME group. The OR was 0.95 (95% CI [0.66, 1.37], p = 0.79), indicating no statistically significant differences between the two groups in terms of postoperative morbidity risk.

Table 1 Demographic and data of the retained studies

First author name	Year of publication	Journal	Country of origin of the study	Study type or design	Sample size	RCME group	LCME group	Inclusion period	Age (years) RCME/LCME	Gender (M: F) RCME/LCME	BMI (mean, kg/m2) RCME/LCME	ASA score RCME/LCME	Type of the robot	Tumour size	CME approach	Follow up (months) RCME/LCME	MINORS	CONSORT
Aghayeva	2024	Journal of Laparoendoscopic & Advanced Surgical Techniques	Turkey	Single-center retrospective study with a propensity score	74	37	37	March 2014 - December 2021	66/61	22:15/22:15	26.2/25.5	1 10/13 2 23/17 3 4/7	Da Vinci Xi	-	Medial to lateral	60/60	18/25	-
Ceccarelli*	2020	Surgical Endoscopy	Turkey	Retrospective clinical study with a propensity score matching	55	26	29	January 2014 - June 2019	70.6/74.6	14:6/13:7	23/24.1	1 2/4 2 11/10 3 7/6	Da Vinci Si/Da Vinci Xi	4/4.1	Medial to lateral	1	14/25	-
Ngu	2018	Journal of Robotic Surgery	Singapore	Retrospective study	32	16	16	July 2015 - June 2017	68.6/69.6	10:6/6:10	23.7/24.7	2 8/4 3 8/12	Da Vinci Xi	4/4.5	Inferior to superior	1	14/25	-
Park	2012	British Journal of Surgery	South Korea	Randomized clinical trial	70	35.	35	September 2009 - July 2011	62.8/66.5	14:21/16:19	24.4/23.8	1 15/21 2 16/12 3 4/2	Da Vinci Si	4.1/4.7	Inferior to superior	1	-	24.5/27
Pişkin	2021	Comprehensive Medicine	Turkey	Retrospective study	18	8	10	March 2019 - December 2020	47.7/53.2	5:3/5:5	-	1 4/2 2 4/2 3 0/3	Da Vinci Xi	-	Medial to lateral	1	12/25	-
Spinoglio	2018	Annals of Surgical Oncology	Italy	Retrospective study	200	100	100	October 2005 - November 2013	71.2/71.2	44:54/54:47	25.1/25.8	1 13/10 2 40/36 3 38/43 4 10/12	Da Vinci Si	-	Medial to lateral	60/60	19/25	-
Tian	2023	Frontiers in Oncology	China	Retrospective multi-centerpropensity scores matching study	284	142	142	July 2016 - July 2021.	63.2/63.4	74:68/79:63	22.5/22.5	1 21/12 2 66/76 3 55/54	Da Vinci Si	-	Medial to lateral	60/60	19/25	-

3D laparoscopy,*BMI* Body mass index, *ASA*American Society of Anesthesiologists, *RCME* Robotic complete mesocolon excision, *M* male, *F* female, *CME* complete mesocolon excision

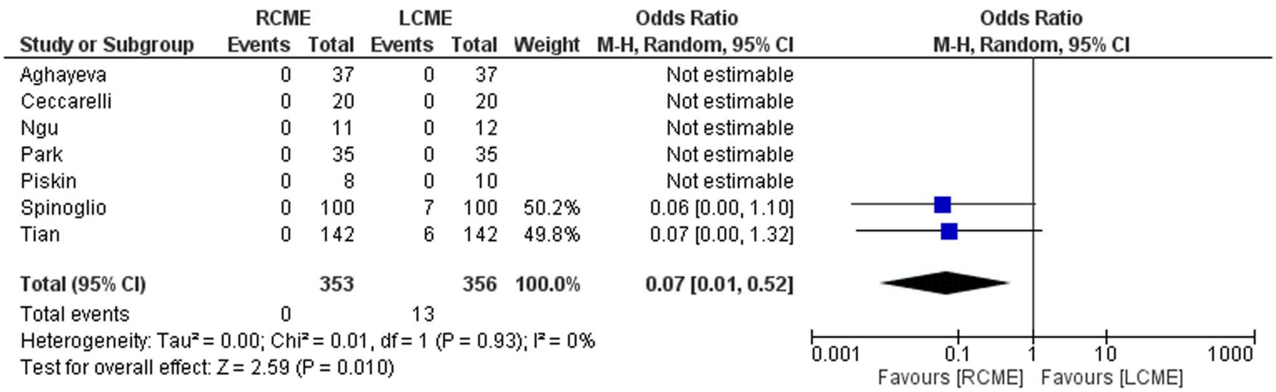

Fig. 2 Forest plot of the conversion rate

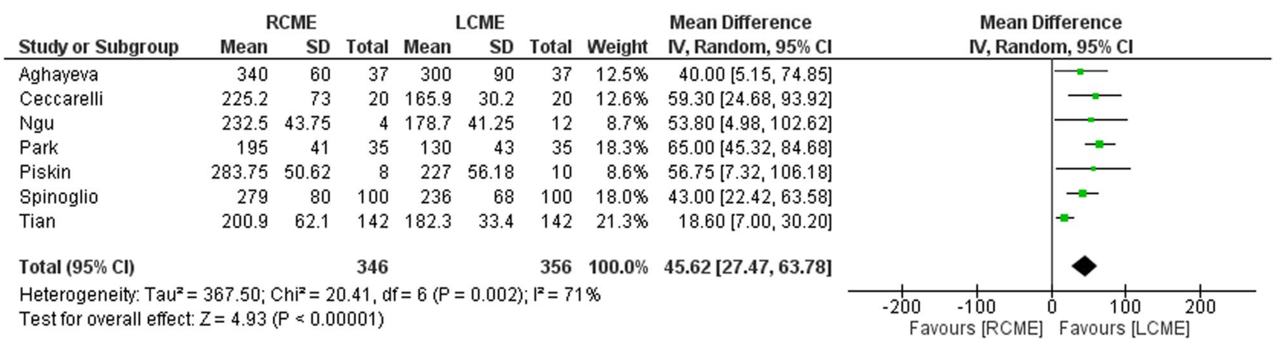

Fig. 3 Forest plot of the operative time

Bleeding

Overall postoperative morbidity was recorded in five studies [16, 17, 19, 21, 22], with two of 334 patients in the RCME group and seven of 334 patients in the LCME group experiencing bleeding. The OR was 0.38 (95% CI [0.10, 1.53]; p = 0.17), indicating that there were no statistically significant differences in bleeding between RCME and LCME.

Blood loss

Blood loss was evaluated in four studies [15, 18, 19, 21], with 356 patients in the RCME group and 356 patients in the LCME group, respectively. The mean difference was – 4.60 (95% CI [−27.73, 18.53], p = 0.70), which showed no significant difference in intraoperative blood loss between the two groups. There was heterogeneity among the studies with Tau²=470.

Conversion to open surgery

Conversion to open surgery was recorded in seven studies [16–22]. None of the 353 patients in the RCME group required conversion, whereas 13 of the 356 patients in the LCME group required conversion. The OR was 0.07 (95% CI [0.01, 0.52], p = 0.01), demonstrating a significantly lower conversion rate in the RCME group than in the LCME group (Fig. 2**).**

Operative time

Operative time was compared in seven studies [16–22], with 346 and 356 patients in the RCME and LCME groups, respectively. The mean difference was 45.6 min (95% CI [27.47, 63.78], p < 0.00001), indicating that RCME required a significantly longer operative time than LCME. There was heterogeneity among the studies, with Tau² = 367.5 (Fig. 3).

Post-operative recovery

Postoperative ileus

Postoperative ileus was reported in four studies [16, 19, 21, 22], occurring in 13 of 314 patients in the RCME group and 15 of 314 patients in the LCME group. The OR was 0.88 (95% CI [0.40, 1.92], p = 0.74), indicating no significant differences between the two groups regarding the occurrence of postoperative ileus.

Time to oral intake

Time to oral intake was reported in six studies [16, 17, 19–22], evaluated in 333 patients in the RCME group and 336 patients in the LCME group. The MD was – 0.05 (95% CI [−0.34, 0.24], p = 0.72), indicating no significant differences between the two groups regarding the time of oral intake. There was a low heterogeneity rate among the studies (Tau²=0.04).

Time to first flatus

Time to first flatus was reported in six studies [16, 17, 19–22], evaluated in 316 patients in the RCME group and 319 patients in the LCME group. The MD was − 0.03 (95% CI [−0.33, 0.26], p = 0.83), indicating no significant differences between the two groups regarding the time of first flatus. There was a low heterogeneity rate among the studies (Tau^2=0.06).

Hospital stay

Seven studies [15–21] evaluated hospital stays, with 353 patients in the RCME group and 356 in the LCME group. The mean difference was − 0.10 (95% CI [−0.61, 0.40], p = 0.69), suggesting that there were no significant differences in hospitalization duration between RCME and LCME.

Pathological outcomes

Harvested lymph nodes

The number of lymph nodes was analyzed in seven studies [16–22], with a total of 353 patients in the RCME group and 356 in the LCME group. The mean difference between the two groups was 2.05 (95% CI [−1.53, 5.63], p = 0.26), indicating that there was no significant difference in the number of lymph nodes between RCME and LCME. There was heterogeneity among the studies, with Tau^2=11.57.

Number of positive lymph nodes

The number of positive lymph nodes was analyzed in two studies [17, 18], with a total of 31 patients in the RCME group and 32 in the LCME group. The MD between the two groups was 0.43 (95% CI [−0.81, 1.67], p = 0.50), indicating that there was no significant difference in the number of positive lymph nodes between RCME and LCME.

Oncological outcomes

Disease-free survival

Two studies reported the rate of DFS [16, 22]. There was no difference between the RCME group and the LCME group in terms of 1-year DFS, 3-year DFS, and 5-year DFS. The OR was 1.25 (95% CI [0.48, 3.30], p = 0.65), 0.69 (95% CI [0.35, 1.33], p = 0.26), and 1.15 (95% CI [0.25, 5.27], p = 0.86), respectively.

Overall survival

Two studies reported the rate of OS [16, 22]. There was no difference between the RCME group and the LCME group in terms of 1-year OS, 3-year OS, and 5-year OS. The OR was 1 (95% CI [0.14, 7.20], p = 1), 0.52 (95% CI [0.07, 3.87], p = 0.52), and 1.2 (95% CI [0.67, 2.15], p = 0.55), respectively.

Quality assessment of the included studies and reporting the effects of RCME.

The quality assessment and risk of bias for the retained clinical trials are reported in Tables 1 and 2, respectively. The different outcomes after the pooled analysis were summarized in Table 3**.** A summary of findings for RCME versus LCME in right-sided colon cancer is reported in Table 4. This review shows that when the right complete mesocolon is performed robotically, compared with laparoscopy:

- It probably increases the operating time.
- It may lead to a lower conversion rate to open surgery.
- It may provide a similar hospital stay.
- We do not know if it causes additional morbidity, lymph node harvest, positive lymph nodes, bleeding, ileus, time to first flatus, time to oral intake, DFS, and OS.

Table 2 Quality assessment and risk of bias assessment of the retained clinical trial

First author	RoB2 for Randomized controlled trials					
	Bias due to Randomization Process	**Bias due to Deviations from Intended Interventions**	**Bias due to Missing Outcome Data**	**Bias in Measurement of the Outcome**	**Bias in Selection of the Reported Result**	**Overall Risk of Bias Judgment**
Park	low Risk	some concerns	Low Risk	some concerns	Low Risk	some concerns
	NOS for non-randomized controlled trials					
	Selection (0–4)	**Comparability (0–2)**	**Outcome (0–3)**	**Total Score (/9)**		
Aghayeva	4	2	3	9		
Ceccarelli*	3	1	2	6		
Ngu	3	1	2	6		
Pişkin	2	1	2	5		
Spinoglio	4	2	3	9		
Tian	4	2	3	9		

Table 3 The pooled analysis of the different outcomes

Outcomes	Number of studies	RCME group	LCME group	OR/MD	IC 95%	I^2 (%)	Tau^2	*p*
Operative outcomes								
Morbidity	7	76/353	80/356	0.95	0.66 to 1.37	0	0	0.79
Bleeding	5	2/334	7/334	0.38	0.10 to 1.53	0	0	0.17
Blood loss	4	356	356	−4.60	−27.73 to 18.53	89	470.28	0.7
Conversion	7	0/353	13/356	0.07	0.01 to 0.52	0	0	0.01
Operative time	7	346	356	45.62	27.47 to 63.78	71	367.5	< 0.01
Postoperative recovery								
Ileus	4	13/314	15/314	0.88	0.40 to 1.92	0	0	0.74
Time to oral intake	6	333	336	−0.05	−0.34 to 0.24	29	0.04	0.72
Time to first flatus	6	316	319	−0.03	−0.33 to 0.26	54	10.91	0.83
Hospital stay	7	353	356	−10	−0.61 to 0.40	0	0	0.69
Pathological outcomes								
Number of harvested LN	7	353	356	2.05	−1.53 to 5.63	57	11.57	0.26
Number of positive LN	2	31	32	0.43	−0.81 to 1.67	0	0	0.50
Oncological outcomes								
1-year OS	2	177/179	177/179	1	0.14 to 7.20	0	0	1
3-year OS	2	156/179	171/179	0.52	0.07 to 3.87	61	1.41	0.52
5-year OS	2	154/179	150/179	1.2	0.67 to 2.15	0	0	0.55
1-year DFS	2	171/179	169/179	1.25	0.48 to 3.30	0	0	0.65
3-year DFS	2	148/179	157/179	0.69	0.35 to 1.33	10	0.03	0.26
5-year DFS	2	148/179	152/179	1.15	0.25 to5.27	80	0.99	0.86

RCME Robotic Complete Mesocolic Excision, *LCME* Laparoscopic Complete Mesocolic Excision, *OR* Odds Ratio, *MD* Mean Difference *IC 95%* 95% Confidence Interval, I^2 Heterogeneity Tau^2 Between-study variance *LN* Lymph Nodes *OS* Overall Survival *DFS* Disease-Free Survival.

Discussion

This systematic review and meta-analysis found that RCME for right-sided colon cancer is associated with a significantly lower conversion rate to open surgery compared to LCME. However, RCME was also linked to longer operative time. No significant differences were observed between the two approaches regarding postoperative morbidity, blood loss, ileus, hospital stay, lymph node yield, or long-term oncological outcomes, including disease-free and overall survival.

Our study found two differences in the efficacy of RCME and LCME. RCME significantly reduced the conversion rate to open surgery compared with LCME (0% vs. 3.5%). However, this was associated with significantly longer operating time.

The lower observed conversion rate in RCME may be related to the improved visualization and instrument articulation of robotic systems [27]. However, these inferences remain speculative as no included study quantitatively assessed ergonomics or surgeon workload [6].

Further prospective analyses are required to validate whether these technical features directly influence conversion outcomes [28]. Additionally, robotic surgery provides better access to difficult anatomical areas, particularly in patients with obesity or previous surgeries where laparoscopic mobility with straight instruments is limited [21]. In the study by Spinoglio et al. [21], laparoscopic conversions occurred in seven out of 100 patients (7% of cases). This was due to adhesions in two cases, technical difficulties in three cases, and inability to perform an intracorporeal anastomosis in two cases. Tian et al. [22] reported a statistically lower conversion rate in the RCME group (0% vs. 4.2%, p = 0.03). These conversions were due to severe adhesions in four cases and massive bleeding in two cases. It seems that these difficulties can be resolved by robotic dexterity [13, 14]. Furthermore, the absence of conversion in the RCME group across included studies highlights a consistent benefit, which may support broader implementation in high-risk populations. We should highlight the impact of conversions to open surgery when evaluating the cost-effectiveness. While reduced conversion could theoretically influence hospital costs, none of the included studies provided formal cost analyses. Therefore, the economic implications of RCME remain uncertain, and future cost-effectiveness studies are needed to assess whether potential clinical advantages translate into economic benefit. However, it is important to recognize that the absence of conversions in the RCME group across our included studies may also be influenced by publication bias, small overall sample size, and inter-study heterogeneity, and should therefore not be interpreted as definitive evidence of superiority. On the other hand, the longer operative time associated with RCME may be influenced by learning-curve effects and differences in robotic platform generations. Earlier studies using the Da Vinci Si platform generally reported longer docking and setup times, whereas more recent Xi-based series showed reduced operative duration. A

Table 4 Summary of findings table of RCME versus LCME

Outcomes	№ of participants (studies) Follow-up	Certainty of the evidence (GRADE)	Relative effect (95% CI)	Anticipated absolute effects	
				Risk with LCME	Risk difference with RCME
Morbidity	709 (7 studies)	⨁◯◯◯ Very low[a]	OR 0.95 (0.66 to 1.37)	225 per 1 000	9 fewer per 1 000 (64 fewer to 60 more)
Conversion	709 (7 studies)	⨁⨁◯◯ Low	OR 0.07 (0.01 to 0.52)	37 per 1 000	34 fewer per 1 000 (36 fewer to 17 fewer)
Harvested lymph nodes	709 (7 studies)	⨁◯◯◯ Very low[b]	-	-	MD 2.05 higher (1.53 lower to 5.63 higher)
Operative time	702 (7 studies)	⨁⨁⨁◯ Moderate[b]	-	-	MD 45.62 higher (27.47 higher to 63.78 higher)
Bleeding	668 (5 studies)	⨁◯◯◯ Very low[a, b]	OR 0.38 (0.10 to 1.53)	21 per 1 000	13 fewer per 1 000 (19 fewer to 11 more)
Ileus	628 (4 studies)	⨁◯◯◯ Very low[a]	OR 0.88 (0.40 to 1.92)	48 per 1 000	5 fewer per 1 000 (28 fewer to 40 more)
Blood loss	712 (4 studies)	⨁◯◯◯ Very low[b]	-	-	MD 4.6 lower (27.73 lower to 18.53 higher)
Hospital stay	709 (7 studies)	⨁⨁◯◯ Low	-	-	MD 0.1 lower (0.61 lower to 0.4 higher)

*The risk in the intervention group (and its 95% confidence interval) is based on the assumed risk in the comparison group and the relative effect of the intervention (and its 95% CI). *CI* confidence interval, *MD* mean difference, *OR* odds ratio

GRADE Working Group grades of evidence

High certainty: we are very confident that the true effect lies close to that of the effect estimate. Moderate certainty: we are moderately confident in the effect estimate: the true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different. Low certainty: our confidence in the effect estimate is limited: the true effect may be substantially different from the estimate of the effect. Very low certainty: we have very little confidence in the effect estimate: the true effect is likely to be substantially different from the estimate of effect.

recently published European multicenter analysis on the implementation of RCME on 551 patients demonstrated the safety of RCME and good lymph nodes retrieval following a stepwise training program [29]. Piozzi et al. [30] emphasized that RCME, despite being promising, requires a structured learning approach, significant case volume, and mentorship to ensure safety and effectiveness. A case volume for proficiency is required. Studies suggest that proficiency in LCME is achieved in 24–33 cases [31], while RCME requires approximately 27 cases after extensive laparoscopic experience [32]. However, some studies have indicated that the transition from open CME to RCME can be achieved safely without prior LCME experience [33]. This could encourage the wider adoption of minimally invasive CME techniques and highlight the interest of a structured training program. In addition, the operation can be reduced in CME using preoperative navigation with CT angiography reconstruction, which could help better delineate the complex vascular anatomy of the right colon [34], using virtual reality simulators and robotic platforms that can provide hands-on experience in a controlled environment, and proctoring or mentoring.

Regarding the safety of RCME and LCME, our study concluded that these two surgical approaches were feasible and safe. We observed comparable overall morbidity, blood loss, and bleeding rates. In different retained studies, there was no high incidence of major complications. In the pooled analysis, there were no differences between the two groups in terms of bleeding or blood loss. The heterogeneity among different studies on blood loss could be explained by the absence of standardized measurement tools for this outcome. In a study by Tian et al. [22], vascular injury caused conversion to open surgery in two cases in the LCME group: one for a superior mesenteric artery lesion and one for middle colic artery injury. Furthermore, we highlight for the second time the interest in preoperative CT angiography navigation or reconstruction to reduce blood loss before right colectomy with CME [34].

Postoperative recovery is a critical factor in evaluating the effectiveness of RCME compared to LCME.

Although prior studies in other robotic procedures have suggested potential reductions in ileus rates due to more stable dissection and limited bowel handling [35]. This is because of more precise dissection and reduced tissue trauma, which minimizes intestinal handling. The improved stability of robotic instruments and improved visualization contribute to less mechanical irritation of the bowel, potentially accelerating the return of intestinal function [36]. However, our pooled analysis found no significant difference in ileus between RCME and LCME. Therefore, any presumed physiological mechanism remains unproven within CME-specific right colectomy cohorts. Differences in postoperative recovery between RCME and LCME may be partly influenced by institutional perioperative protocols, particularly ERAS implementation. Enhanced recovery pathways can shorten hospital stay, accelerate return of bowel function, and standardize analgesia and mobilization regimens, potentially diminishing measurable differences between surgical approaches. While RCME offers ergonomic and technical advantages, these must be weighed against higher acquisition, maintenance, and consumable costs, particularly in resource-limited settings. Cost-effectiveness may be more favorable in high-volume centers, complex cases, or where reduced conversion rates translate into measurable savings. Similar considerations have been reported in other colorectal procedures. A recent comparative study on robotic versus laparoscopic extended total mesorectal excision for rectal cancer [37] found that while robotics may enhance technical precision, its added value must be evaluated alongside costs, learning curves, and institutional resource availability.

Regarding hospital stay, data from a recent meta-analysis published by Negrut et al. [38] suggest slightly shorter hospitalization for robotic right colectomy than for laparoscopic right colectomy (MD = 0.42 days, p = 0.003). Similarly, another systematic review and meta-analysis by Oweira et al. [3] compared RCME with laparoscopic colectomy with or without CME. The pooled analysis concluded that there was no significant difference in hospital stay between the two groups. However, while the robotic approach may offer advantages in recovery, the difference in hospital stay is often influenced by institutionally enhanced recovery protocols rather than by surgical techniques. Compared to these two meta-analysis [3, 38], our study offers several distinct advantages. First, unlike Negrut et al. [38], who broadly compared robotic and laparoscopic colectomies without consistently isolating cases of CME, our review exclusively included studies that performed CME in both arms, ensuring a more homogeneous and oncologically relevant comparison. Second, while Oweira et al. [3] included a mixed cohort of right and left colectomies, with or without CME, we focused solely on right-sided colon cancer treated with CME, which allows for greater surgical consistency, outcome specificity, and a homogeneous study population. Third, our meta-analysis incorporates the most recent studies, capturing contemporary surgical techniques and robotic platforms such as the Da Vinci Xi, which were underrepresented in earlier reviews. Finally, our detailed evaluation of both operative and long-term oncological outcomes, including DFS and OS, provides a more comprehensive assessment of the relative performance of robotic versus laparoscopic CME.

The oncological safety of RCME versus LCME remains an important point of discussion, particularly concerning the number of lymph nodes harvested and adherence to principles of CME. The robotic approach provides greater dexterity and improved visualization, allowing for more meticulous lymphadenectomy, especially in difficult anatomical regions [39]. Studies comparing RCME and LCME have reported comparable lymph node yields with robotic procedures [16, 21]. This validates the oncological safety of the two approaches for CME, confirmed in our study by the absence of difference between the two groups in terms of DFS and OS. While RCME showed a slight trend toward higher lymph node yield, the difference did not reach statistical significance, indicating that both approaches achieve adequate oncological resection when performed by experienced teams.

Some limitations must be acknowledged. Owing to the availability of only one RCT, we included additional CCTs with variable degrees of risk of bias. The relatively small sample size, variability in surgeon experience, robotic platforms, and perioperative protocols can influence the outcomes and reduce the generalizability of these findings.

The observed 0% conversion rate in RCME should be interpreted cautiously, as this could reflect selection bias, publication bias, or statistical anomaly given the small number of events and heterogeneity across studies. It is worth noting that some outcomes, such as blood loss and lymph node harvest, showed high inter-study heterogeneity. Even more, subgroup analyses or meta-regression to explore heterogeneity (e.g., by robotic platform, surgeon experience, or publication year) were not feasible. This could reflect differences in measurement methods, surgeon experience, or CME technique across institutions. The CME differences between the East and West could impact on the quality of the comparison between papers. Then, a need for standardized reporting and CME protocols in future studies, like the RRoC-STAR Delphi consensus [40], is mandatory. Another limitation is the extensive period of the papers included. Since RCME has been standardized relatively recently and is better with the most modern platforms. Finally, long-term outcomes such as quality of life and nutritional status were not evaluated.

Conclusion

This study systematically assessed the existing evidence comparing RCME and LCME for right-sided colon cancer, with a focus on surgical outcomes, evidence, and postoperative morbidity. RCME is a safe and feasible alternative to LCME for right-sided colon cancer, showing an observed lower conversion rate in the available studies. Given the small sample size and the heterogeneity of the included studies, this finding should be interpreted with caution. Multicenter RCTs, with long-term followup, p are expected to provide high-quality evidence in the future.

Abbreviations

CRC	Colorectal Cancer
CME	Complete Mesocolic Excision
LCME	Laparoscopic Complete Mesocolic Excision
RCME	Robotic Complete Mesocolic Excision
RCT	Randomized Controlled Trial
CCT	Controlled Clinical Trial
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
AMSTAR	A MeaSurement Tool to Assess Systematic Reviews
MINORS	Methodological Index for Non-Randomized Studies
CONSORT	Consolidated Standards of Reporting Trials
ASA	American Society of Anesthesiologists
GRADE	Grading of Recommendations, Assessment, Development and Evaluations

Supplementary Information

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Supplementary Material 1.

Supplementary Material 2.

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Authors' contributions
M.A.C. conceived and designed the study, conducted the formal analysis, interpreted the data, and drafted the manuscript. A.G. contributed to data collection, validation, and manuscript editing. B.K. performed the literature review, managed data curation, and prepared figures and tables. M.A.D. assisted with methodology development and critically reviewed the manuscript. P.P.B. provided validation, supervision, and clinical insights. G.N.P. handled statistical analysis and data visualization. J.S.K. contributed to supervision and critical manuscript revision. W.F. supported methodological guidance and resource provision. C.R. offered senior supervision and manuscript review. H.O. oversaw the project, contributed to study conception, and approved the final version of the manuscript.

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Data availability
All data generated or analyzed during this study are included in this published article.

Declarations

Ethics approval and consent to participate
This study involved only human participants. This was a retrospective analysis of published cases that did not require informed consent. Ethical approval and consent to participate were not included in this review.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

Author details
[1]Department of Visceral and Digestive Surgery, Fattouma Bourguiba University Hospital, University of Monastir, Monastir, Tunisia
[2]Department of Visceral Surgery, Perpignan Hospital, Perpignan, France
[3]Department of Anesthesiology, Montreuil Hospital Center, Montreuil, France
[4]Department of Surgery, Dipartimento di Scienze della Salute, Asst Santi Paolo e Carlo, University of Milan, Milan, Italy
[5]Department of Colorectal Surgery, Portsmouth Hospitals University NHS Trust, Portsmouth, UK
[6]Department of Surgery, Universitätsmedizin Mannheim, Heidelberg University, Mannheim, Germany

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