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REVIEW

Comparison of robotic right colectomy and laparoscopic right colectomy: a systematic review and meta-analysis

Jianchun Zheng[1] · Shuai Zhao[2] · Wei Chen[1] · Ming Zhang[1] · Jianxiang Wu[1]

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Abstract

Background For right colon surgery, there is an increasing body of literature comparing the safety of robotic right colectomy (RRC) with laparoscopic right colectomy (LRC). The aim of the present systematic review and meta-analysis is to assess the safety and efficacy of RRC versus LRC, including homogeneous subgroup analyses for extracorporeal anastomosis (EA) and intracorporeal anastomosis (IA).

Methods PubMed, Web of Science, Embase, and Cochrane Library databases were searched for studies published between January 2000 and January 2022. Length of hospital stay, operation time, rate of conversion to laparotomy, time to first flatus, number of harvested lymph nodes, estimated blood loss, rate of overall complication, ileus, anastomotic leakage, wound infection, and total costs were measured.

Results Forty-two studies (RRC: 2772 patients; LRC: 12,469 patients) were evaluated. Regardless of the type of anastomosis, RRC showed shorter length of hospital stay, lower rate of conversion to laparotomy, shorter time to first flatus, lower rate of overall complications, and a higher number of harvested lymph nodes compared with LRC, but longer operative time and higher total costs. In the IA subgroup, RRC had a shorter length of hospital stay, longer operative time, and lower rate of conversion to laparotomy compared with LRC, with no difference for the remaining outcomes. In the EA subgroup, RRC had a longer operative time, lower estimated blood loss, lower rate of overall complications, and higher total costs compared with LRC, with the other outcomes being similar.

Conclusion The safety and efficacy of RRC is superior to LRC, especially when an intracorporeal anastomosis is performed. Most included articles were retrospective, offering low-quality evidence and limited conclusions.

Keywords Right colectomy · Robotic · Laparoscopic · Meta-analysis

Introduction

The first laparoscopic right colectomy (LRC) was performed in 1990 [1], and since then it has been increasingly used for benign and malignant disease. This minimally invasive (MI) approach offers faster recovery with earlier return to normal bowel function, less pain, shorter length of hospital stay, and lower postoperative complications compared with open surgery, with similar oncological outcomes [2–5]. The steep learning curve, the ability to provide only a two-dimensional surgical field of view, lens instability due to hand fatigue, and susceptibility to human muscle tremors all limit further development of laparoscopy.

Since 2000, robot-assisted systems have been widely used in various surgical fields [6]. As an emerging technology, the advantages of robots are that they can provide 3D local magnified vision, hand tremor filtering, more flexible

✉ Jianxiang Wu
ss991230@163.com

Jianchun Zheng
sd_zhengjc@163.com

Shuai Zhao
15712433710@163.com

Wei Chen
chenwei0401443@163.com

Ming Zhang
497411076@qq.com

[1] Department of Emergency, The Second Hospital of Jiaxing: The Second Affiliated Hospital of Jiaxing University, Jiaxing, Zhejiang Province, China

[2] Department of General Surgery, Northern Jiangsu People's Hospital Affiliated to Medical School of Nanjing University, Yangzhou, Jiangsu Province, China

and accurate multi-angle moving mechanical arms using Endowrist technology, more stable four arm operation, and their ergonomic design provides surgeons with a better surgical experience [7, 8]. These designs can effectively overcome some of the limitations of laparoscopic surgery.

Since Weber et al.. first reported using robotic colectomy surgery in 2002 [9], some centers have experimented with the technique with satisfactory results. However, these studies are based on single-center experience and non-randomized controlled, the results obtained are insufficient evidence. In addition, the advantages of the robotic surgery system in colectomy are still controversial [10–13, 29, 41]. The learning curve may be shorter with robotic technology compared with laparoscopy [22], and it may facilitate some procedural steps, such as the construction of an intracorporeal anastomosis during right colectomy [10]. Indeed, there is still a debate about the superiority of intracorporeal over extracorporeal anastomosis. Hence, it is of great significance to analyze the safety and effectiveness of robotic right colectomy (RRC), including a comprehensive, systematic, and intuitive homogeneous subgroup analyses for extracorporeal anastomosis (EA) and intracorporeal anastomosis (IA). We conducted this meta-analysis of published literature to compare the length of hospital stay, operation time, rate of conversion to laparotomy, time to first flatus, number of harvested lymph nodes, estimated blood loss, rate of overall complication, ileus, anastomotic leakage, wound infection, and total costs, to assess the safety and efficacy of RRC versus LRC including a homogeneous subgroup analyses for extracorporeal anastomosis (EA) and intracorporeal anastomosis (IA).

Materials and methods

Search strategy

The study was registered on PROSPERO (CRD42022324624), and the findings have been reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) and Assessing the Methodological Quality of Systematic Reviews (AMSTAR) guidelines. The search terms “right colectomy,” “robotic,” and “laparoscopic” were used. Two authors independently searched the PubMed, Web of Science, Embase, and Cochrane Library databases for relevant studies published between January 2000 and January 2022. The search also included all of the Mesh terms. No language restriction was applied, and the search was limited to human studies. The reference lists of all retrieved articles were reviewed for further identification of potentially relevant studies.

Inclusion and exclusion criteria

Any studies that met the following criteria were considered: (1) compared RRC with LRC of intracorporeal anastomosis (IA) and (or) extracorporeal anastomosis (EA) and (2) compared RRC versus LRC on at least one short-term outcome, including operative and postoperative. If there were two or more articles by the same authors or research institutions, the most recent publication was selected. We also manually searched the abstracts published at major international conferences. A manual search of the bibliographies of relevant articles was also carried out to identify trials for possible inclusion. Reference lists of all retrieved articles were manually searched for additional studies.

Articles that met the following criteria were not considered: (1) studies that reported on patients with colorectal surgery but did not contain a independent group of right colectomy, (2) studies in which data could not be extracted from the published results, and (3) articles including abstracts, letters, expert opinions, reviews without raw data, case reports, or studies without control groups.

Data extraction

The data extraction and input of the included literature were completed by two reviewers independently. If there was any disagreement during the selection process, the decision would be made by a third reviewers. The compiled information included author name, geographical region, year of publication, study period, type of study, surgical type, surgical technique, sample size, mean age, gender, body mass index (BMI), length of hospital stay, operation time, rate of conversion to laparotomy, time to first flatus, number of harvested lymph nodes, estimated blood loss, rate of overall complication, ileus, anastomotic leakage, wound infection, and total costs.

Statistical analysis

All data were analyzed using RevMan 5.4 and Stata 17.0. Heterogeneity was detected by the chi-square test. A P-value > 0.10 was considered as homogeneous, otherwise as heterogeneous. Moreover, the I^2 index was used to assess heterogeneity, and $I^2 > 50\%$ was considered as statistically significant. For homogeneous affirmation, the fixed effects model was selected; otherwise, a random effects model was adopted. The odds ratio (OR) and mean difference (MD) were calculated, and publication bias was assessed by Egger’s test. In some publications, the mean values and standard deviation values were unavailable. The methods used to determine these values based on the available median and range data have been described previously by Hozo et al.. As not all patients had colon cancer, the mode of laparoscopic right hemicolectomy, which mainly included D3 and complete mesocolic excision robotically with standard D2/D1 right hemicolectomy, was performed with high heterogeneity in operative time. All costs reported in Euros or CNY were converted into US dollars. The pooled estimates of the mean difference (MD) and 95% CI were calculated using a random effects model because of the expected heterogeneity among the included studies.

Results

Selected studies

The study selection process is summarized in Fig. 1. According to the retrieval strategy and data collection method, a total of 675 related studies were retrieved. From reading the titles and abstracts, we excluded 400 studies and initially included 275 studies. A total of 228 studies were eliminated due to the lack of a right colon resection trial, while the remaining 47 studies met the criteria. After reading the full text according to the criteria and filtering for data integrity, 42 studies [14–55] with a total of 15,241 patients (RRC group, 2772 patients; LRC group, 12,469 patients) were eventually included in this meta-analysis.

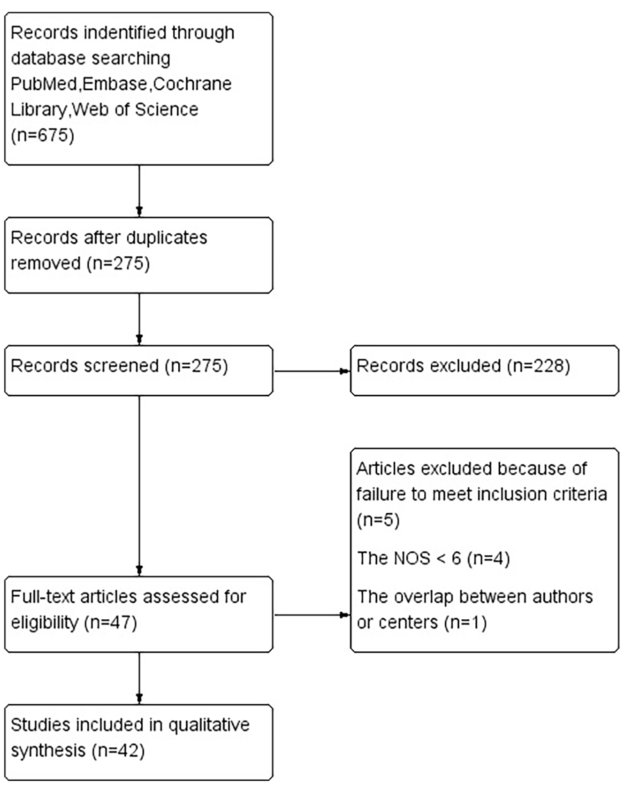

Fig. 1 Flowchart of the search strategy

Study characteristic

The characteristics of the individual trials are presented in Table 1. A total of 2772 patients were included in the RRC group, while 12,469 patients were included in the LRC group. The studies were from Australia (1 study), Italy (14 studies), the UK (1 study), the USA (14 studies), Korea (3 studies), France (2 studies), Denmark (2 studies), Turkey (1 study), Spain (1 study), Singapore (1 study), and China (2 studies).

Study quality

The Newcastle–Ottawa Scale (NOS) was used to assess the quality of the studies. The total NOS score was 9, and papers with a score ≥ 6 were classified as methodologically sound studies. All articles included in this study rated between 6 and 9, indicating that the study quality was sufficient (Table 2).

Comparison between RRC versus LRC

Overall, 42 retrospective studies compared RRC versus LRC on at least the primary outcome or one secondary outcome. Pooled data analysis showed that robotic surgery has a significantly longer operative time and higher total costs but shorter length of hospital stay, lower rate of conversion to laparotomy, shorter time to first flatus, lower rate of overall complication, and higher number of harvested lymph nodes (Fig. 2). All other operative and pathological outcomes, including estimated blood loss, ileus, wound infection, and anastomotic leakage were similar for RRC and LRC (Fig. 3).

Comparison between RRC-IA versus LRC-IA

Overall, ten retrospective studies compared RRC-EA versus LRC-EA on at least the primary outcome or one secondary outcome. Overall, 1534 patients were included: 809 (52.7%) undergoing robotic and 725 (47.3%) undergoing laparoscopic surgery. Pooled data analysis showed a shorter length of hospital stay for RRC-IA than for LRC-IA. Conversely, the overall operative time was longer and the rate of conversion to laparotomy was lower for RRC-IA. All other operative and pathological outcomes were similar between RRC-IA and LRC-IA (Fig. 4).

Comparison between RRC-EA versus LRC-EA

Overall, nine retrospective studies compared RRC-EA versus LRC-EA on at least the primary outcome or one

Table 1 Characteristics of the included studies

Author	Nation	Year	Study period	Type of study	Surgical type	Surgical technique	Sample size	Gender (male/female)	Mean age (years)	BMI
Ahmadi [14]	Australia	2021	2015–2018	CRS	RRC	IA/EA	59	30/29	75	27
					LRC	EA	42	20/22	75	27
Blumberg [15]	USA	2019	2003–2018	CRS	RRC	IA	21	7/14	65	30
					LRC	IA	101	51/50	68	28
Cardinali [16]	Italy	2016	2013–2015	CRS	RRC	IA	30	15/15	68.6	25.4
					LRC	EA	60	35/25	70.7	26.4
Casillas [17]	USA	2014	2005–2012	CRS	RRC	EA	52	25/27	65	26.9
					LRC	EA	110	69/41	71	27
Ceccarelli [18]	Italy	2021	2014–2019	CRS	RRC	IA	26	20/6	69.1	24.4
					LRC	IA	29	15/14	75	24.2
Davis [19]	USA	2014	2009–2011	CRS	RRC	NA	207	NA	NA	NA
					LRC	NA	207	NA	NA	NA
deSouza [20]	USA	2010	2005–2009	CRS	RRC	EA	40	22/18	71.4	27.3
					LRC	EA	135	62/73	65.3	26.6
Deutsch [21]	USA	2012	2004–2009	CRS	RRC	EA	18	12/6	65.2	25
					LRC	EA	47	25/22	70.8	28
de'Angelis [22]	France	2016	2012–2015	CRS	RRC	EA	30	15/15	71	26.4
					LRC	EA	50	19/31	71.1	25.3
Dohrn [23]	Denmark	2021	2015–2018	PNR	RRC	IA/EA	359	181/178	73.3	25.9
					LRC	IA/EA	718	378/340	73.7	25.6
Dolejs [24]	USA	2016	2012–2014	CRS	RRC	NA	259	138/121	65.3	24.5
					LRC	NA	6521	3482/3039	63.7	23.8
Ferrara [25]	Italy	2015	2008–2014	CRS	RRC	EA	13	7/6	NA	NA
					LRC	EA	15	7/8	NA	NA
Ferri [26]	Spain	2021	2013–2017	PNR	RRC	IA	35	23/12	69.6	23
					LRC	EA	35	20/15	68.2	25
Gerbaud [27]	France	2019	2013–2019	CRS	RRC	IA/EA	42	21/21	67	26
					LRC	EA	59	31/28	72	24
Guerrieri [28]	Italy	2015	2013–2014	CRS	RRC	IA/EA	18	9/9	74	26
					LRC	IA/EA	11	9/2	65	26
Haskins [29]	USA	2018	2012–2014	CRS	RRC	NA	89	49/40	68.9	29.3
					LRC	NA	2405	1129/1276	68.3	28.5
Kang [30]	Korea	2016	2007–2011	CRS	RRC	EA	20	9/11	66	23.5
					LRC	EA	43	22/21	65.7	23
Kelley [31]	USA	2018	2012–2017	CRS	RRC	IA	27	17/10	60	28

Table 1 (continued)

Author	Nation	Year	Study period	Type of study	Surgical type	Surgical technique	Sample size	Gender (male/female)	Mean age (years)	BMI
					LRC	EA	87	33/54	60	27
Khan [32]	UK	2021	2007–2017	PNR	RRC	IA	40	19/21	69	26
					LRC	EA	80	37/43	71	28
Lujan [33]	USA	2013	2008–2011	CRS	RRC	IA/EA	22	8/14	71.8	31.4
					LRC	EA	25	10/15	72.6	27.8
Lujan [34]	USA	2018	2009–2015	CRS	RRC	IA	89	48/41	70.9	28.4
					LRC	EA	135	61/74	72.6	27.1
Mégevand [35]	Italy	2019	2010–2015	CRS	RRC	IA	50	28/22	70.3	26.2
					LRC	IA	50	24/26	69.6	25.2
Merola [36]	Italy	2019	2012–2017	M-CRS	RRC	IA	94	60/34	69.4	26.9
					LRC	IA	94	61/33	72.0	27.9
Migliore [37]	Italy	2020	2010–2018	CRS	RRC	IA	46	22/24	68.7	26.0
					LRC	IA	170	96/74	71.9	25.5
Morpurgo [38]	Italy	2013	2008–2012	CRS	RRC	IA	48	27/21	68	25
					LRC	EA	48	16/32	74	28
Ngu [39]	Singapore	2018	2015–2017	CRS	RRC	IA	16	10/6	68.6	23.7
					LRC	IA	16	6/10	69.6	24.7
Nolan [40]	USA	2018	2011–2016	CRS	RRC	NA	10	NA	NA	NA
					LRC	NA	96	NA	NA	NA
Park [41]	Korea	2019	2009–2011	RCT	RRC	IA/EA	35	14/21	62.8	24.4
					LRC	IA/EA	35	16/19	66.5	23.8
Rattenborg [42]	Denmark	2021	2015–2018	PNR	RRC	EA	22	9/13	71	25.5
					LRC	EA	40	15/25	73	25.5
Rawlings [43]	USA	2007	2002–2005	CRS	RRC	IA	17	8/9	64.6	25.7
					LRC	EA	15	6/9	63.1	28.3
Scotton [44]	Italy	2018	1998–2017	CRS	RRC	IA	30	108/98	70.1	26
					LRC	EA	160	80/80	70.3	25.6
Shi [45]	China	2020	2016–2019	CRS	RRC	NA	58	34/24	NA	NA
					LRC	NA	48	27/21	NA	NA
Shin [46]	Korea	2012	2010–2011	PNR	RRC	EA	6	NA	NA	NA
					LRC	EA	6	NA	NA	NA
Solaini [47]	Italy	2019	2007–2017	M-CRS	RRC	IA	305	163/142	NA	NA
					LRC	IA	84	39/45	NA	NA
Sorgato [48]	Italy	2021	2018–2019	CRS	RRC	IA	48	27/21	71	25.6
					LRC	IA	40	28/12	68	26.6

Table 1 (continued)

Author	Nation	Year	Study period	Type of study	Surgical type	Surgical technique	Sample size	Gender (male/female)	Mean age (years)	BMI
Spinoglio [49]	Italy	2018	2005–2015	CRS	RRC	IA	101	57/44	71.2	25.1
					LRC	IA	101	47/54	71.2	25.8
Tagliabue [50]	Italy	2020	2014–2019	CRS	RRC	NA	55	32/23	72	24.3
					LRC	NA	68	40/28	72	24.8
Trastulli [51]	Italy	2015	2005–2014	M-CRS	RRC	IA	102	56/46	68.8	25.6
					LRC	IA	40	25/15	71.5	26.6
Widmar [52]	USA	2016	2009–2014	CRS	RRC	IA/EA	69	33/36	66	NA
					LRC	EA	207	85/122	64	NA
Widmar [53]	USA	2017	2012–2014	CRS	RRC	NA	119	64/55	68	28
					LRC	NA	163	83/80	64	29
Yozgatli [54]	Turkey	2018	2015–2017	CRS	RRC	IA	35	20/15	65	29
					LRC	IA/EA	61	31/30	65	27
Zeng [55]	China	2020	2018–2019	CRS	RRC	EA	10	4/6	57.8	21.4
					LRC	EA	12	3/9	61.3	22.2

LRC laparoscopic right colectomy, *RRC* robotic right colectomy, *CRS* comparative retrospective study, *M* multicenter, *RCT* randomized controlled study, *PNR* prospective not randomized, *NA* not applicable, *IA* intracorporeal anastomosis, *EA* extracorporeal anastomosis

Table 2 The NOS quality of included studies

Study	Selection				Comparability			Outcome		Total	Quality
	REC	SNEC	AE	DO	SC	AF	AO	FU	AFU		
Ahmadi	1	1	1	1	1	1	1	0	0	7	Moderate
Blumberg	1	1	1	1	1	1	1	0	0	7	Moderate
Cardinali	1	1	1	1	1	1	1	0	0	7	Moderate
Casillas	1	1	1	1	1	1	1	0	0	7	Moderate
Ceccarelli	1	1	1	1	1	1	1	0	0	7	Moderate
Davis	1	1	1	1	0	1	1	0	0	6	Low
deSouza	1	1	1	1	1	1	1	0	0	7	Moderate
Deutsch	1	1	1	1	1	1	1	0	0	7	Moderate
de'Angelis	1	1	1	1	1	1	1	0	0	7	Moderate
Dohrn	1	1	1	1	1	1	1	0	0	7	Moderate
Dolejs	1	1	1	1	1	1	1	0	0	7	Moderate
Ferrara	1	1	1	1	1	0	1	0	0	6	Low
Ferri	1	1	1	1	1	1	1	1	1	9	High
Gerbaud	1	1	1	1	1	1	1	0	0	7	Moderate
Guerrieri	1	1	1	1	1	1	1	0	0	7	Moderate
Haskins	1	1	1	1	1	1	1	0	0	7	Moderate
Kang	1	1	1	1	1	1	1	1	1	9	High
Kelley	1	1	1	1	0	1	1	0	0	6	Low
Khan	1	1	1	1	1	1	1	1	1	9	High
Lujan	1	1	1	1	1	1	1	1	0	8	Moderate
Lujan	1	1	1	1	1	1	1	1	0	8	Moderate
Mégevand	1	1	1	1	1	1	1	0	0	7	Moderate
Merola	1	1	1	1	1	1	1	0	0	7	Moderate
Migliore	1	1	1	1	1	1	1	0	0	7	Moderate
Morpurgo	1	1	1	1	1	1	1	0	0	7	Moderate
Ngu	1	1	1	1	1	1	1	0	0	7	Moderate
Nolan	1	1	1	1	0	1	1	0	0	6	Low
Park	1	1	1	1	1	1	1	1	1	9	High
Rattenborg	1	1	1	1	1	1	1	0	0	7	Moderate
Rawlings	1	1	1	1	1	1	1	0	0	7	Moderate
Scotton	1	1	1	1	1	1	1	0	0	7	Moderate
Shi	1	1	1	1	0	1	1	0	0	6	Low
Shin	1	1	1	1	0	1	1	0	0	6	Low
Solaini	1	1	1	1	0	1	1	0	0	6	Low
Sorgato	1	1	1	1	1	1	1	0	0	7	Moderate
Spinoglio	1	1	1	1	1	1	1	1	1	9	High
Tagliabue	1	1	1	1	1	1	1	0	0	7	Moderate
Trastulli	1	1	1	1	1	1	1	0	0	7	Moderate
Widmar	1	1	1	1	1	1	1	0	0	7	Moderate
Widmar	1	1	1	1	1	1	1	0	0	7	Moderate
Yozgatli	1	1	1	1	1	1	1	0	0	7	Moderate
Zeng	1	1	1	1	1	1	1	0	0	7	Moderate

REC representativeness of the exposed cohort, *SNEC* selection of the nonexposed cohort, *AE* ascertainment of exposure, *DO* demonstration that outcome of interest was not present at start of study, *SC* study controls for age and sex, *AF* study controls for any additional factors, *AO* assessment of outcome, *FU* follow-up long enough for outcomes to occur, *AFU* adequacy of follow-up of cohorts (≥ 90%). 1 indicates that the study satisfied the item and 0 means that it did not

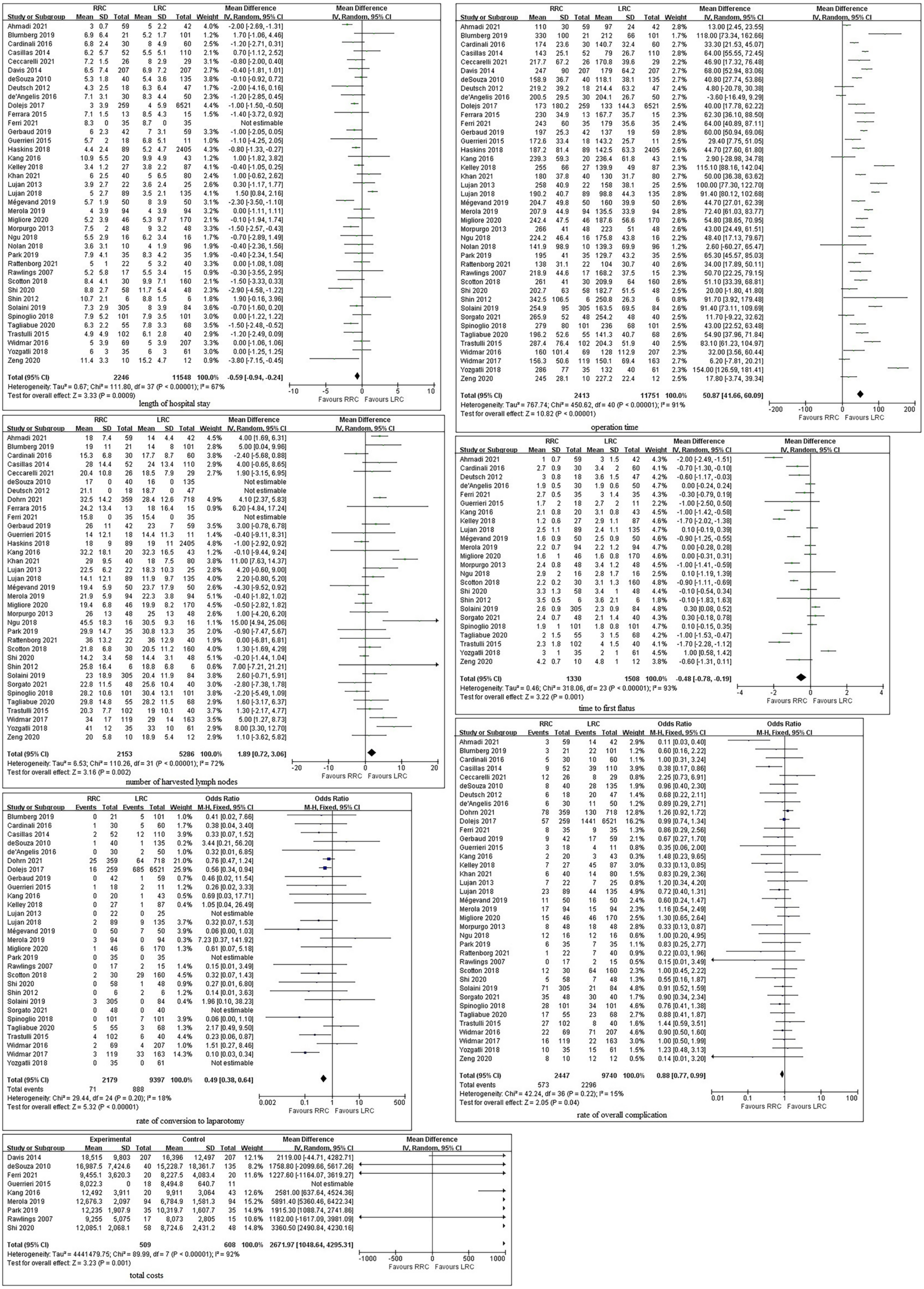

Fig. 2 Forest plots of the comparison of RRC versus LRC (part 1)

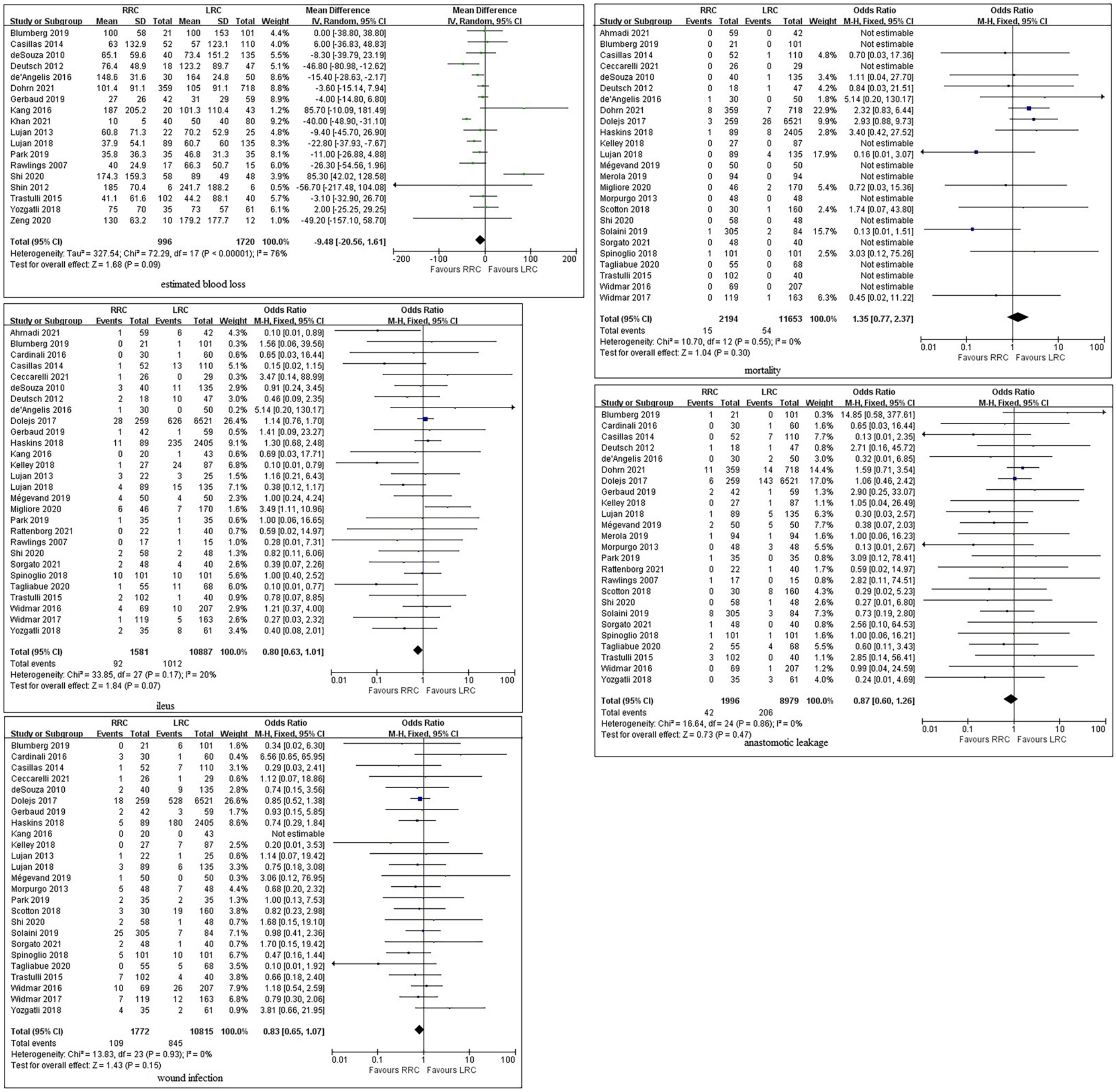

Fig. 3 Forest plots of the comparison of RRC versus LRC (part 2)

secondary outcome. Overall, 669 patients were included: 211 (31.5%) undergoing robotic and 458 (68.5%) undergoing laparoscopy surgery. Pooled data analysis showed the overall operative time was longer, the estimated blood loss was lower, the rate of overall complication was lower, the total costs was higher for RRC-EA than for LRC-EA. For all other comparable outcomes, there was no difference between the two surgical groups. The results of this subgroup analysis are represented in Fig. 5.

Publication bias

A funnel plot was used to assess the presence of publication bias. The absence of asymmetry in the funnel plot indicated no evidence of publication bias. No noticeable publication bias was observed according to the results of Egger's test ($P = 0.06$; Fig. 6).

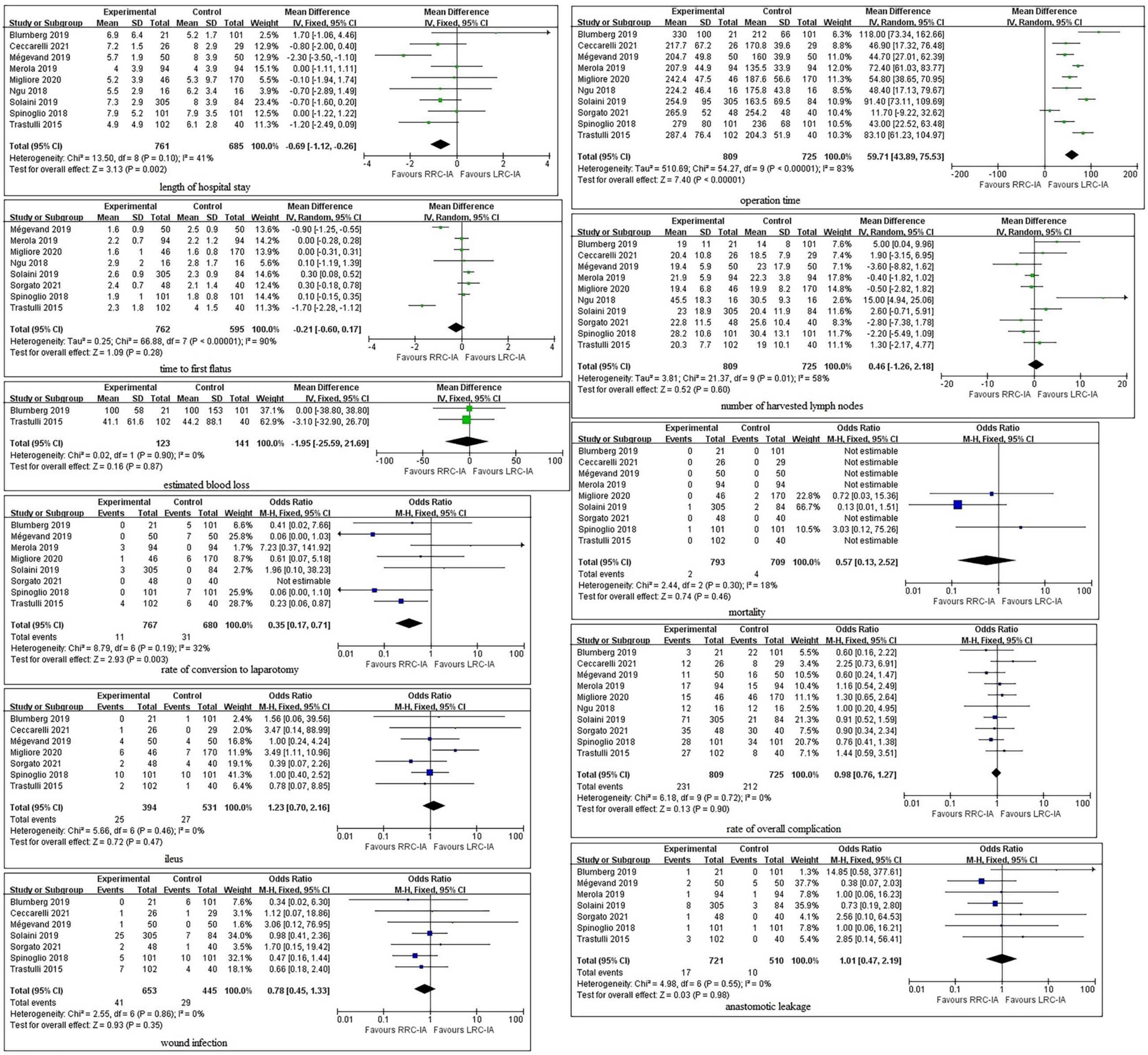

Fig. 4 Forest plots of the comparison of RRC-IA versus LRC-IA

Discussion

Since the first report of laparoscopy surgery for a colorectal operation in 1991, the scope of its influence has gradually expanded and it has become the standard treatment in colorectal operation [1, 56]. However, laparoscopy techniques have inherent limitations, including poor stereoscopic vision and depth perception due to two-dimensional (2D) imaging (despite the rise of 3D platforms), lens instability, poor ergonomics, direct fixation of surgical instrument tips, and operational tremors associated with magnification [57].

With the advent of robotic surgery systems, these problems that plagued surgical operations have been solved, and they have become increasingly popular in various disciplines, especially colorectal operation. The design of robotic surgery systems overcomes some limitations of laparoscopic surgery, such as the stability of the control by the surgeon's 3D view, with seven degrees of freedom and 540° rotating wrist instruments, the remarkable human body engineering design, and tremor filtering functions. Of course, the system also has limitations, such as the loss of haptic feedback, the limited range of movement of the robotic arm, and the fact that it is time consuming and costly [58–60].

There is evidence that robotic right colectomy is a feasible and safe procedure [57, 61–66], with less trauma and faster postoperative recovery, but there are few indicators,

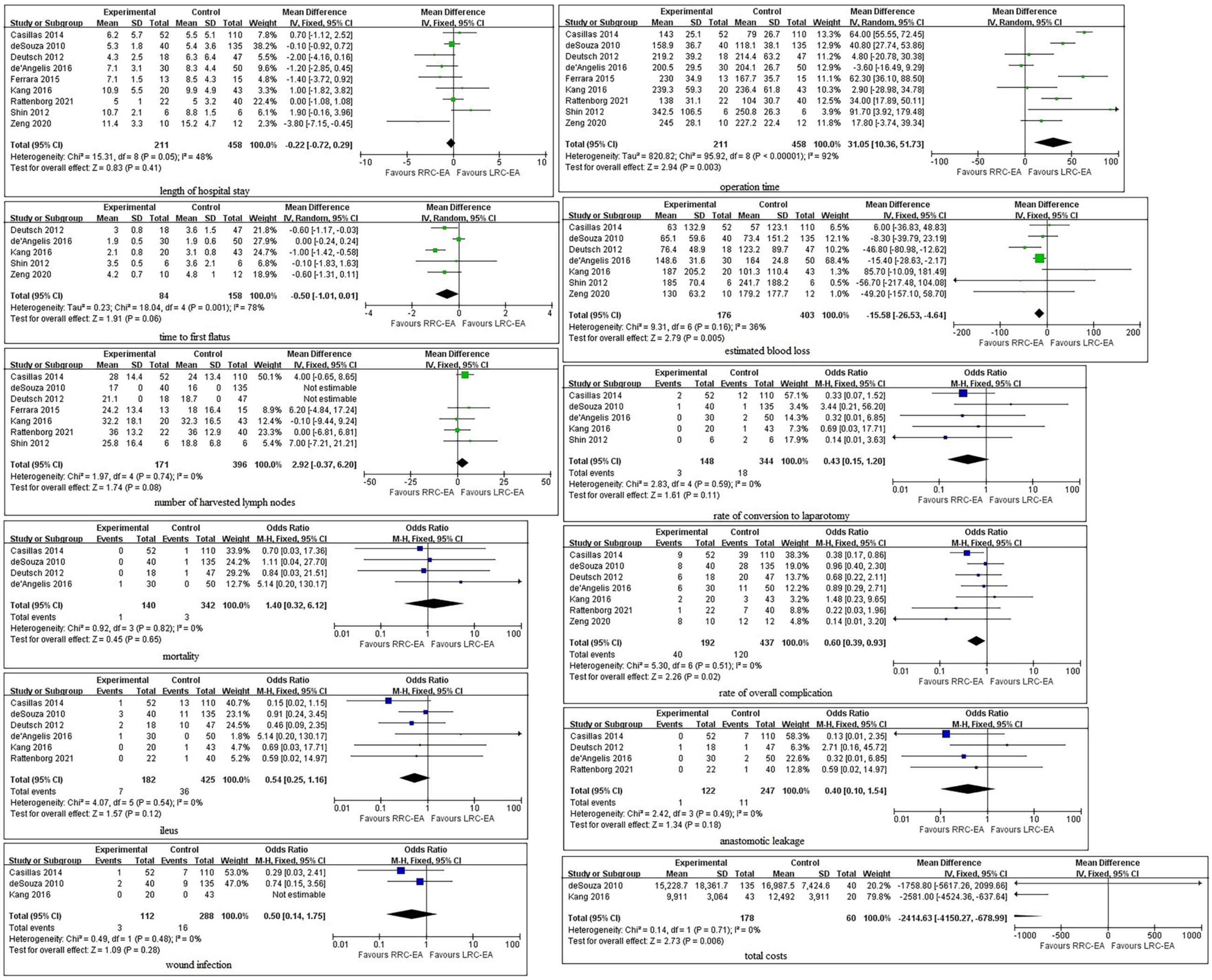

Fig. 5 Forest plots of the comparison of RRC-EA versus LRC-EA

with limited literature and a lack of long-term prognostic indicators. In this meta-analysis, 42 studies involving 15,241 patients were included. We conducted this meta-analysis of published literature to compare the operation related indicators (operation time, estimated blood loss, rate of conversion to laparotomy, and number of harvested lymph nodes) and perioperative related indicators (length of hospital stay, time to first flatus, rate of overall complication, ileus, anastomotic leakage, wound infection, and total costs) to evaluate the safety and efficacy of robotic right colectomy (RRC) (including only homogeneous surgical subgroups).

In terms of operation time, we observed that there was statistically significant difference between the two groups (included subgroups: RRC-IA versus LRC-IA and RRC-EA versus LRC-EA). The operation time in the RRC group was longer than that in the LRC group, which may be related to the unskilled operation of the robotic surgical system in the early stage of surgery, the lack of experience in trocar placement, the long time to install the robot, and the lack of tacit cooperation between doctors and nurses [27]. de'Angelis [22] divided 30 cases of robotic surgery and 50 cases of laparoscopy surgery into three groups according to the operation sequence. Before the two groups of ten cases, LRC group operation time is superior to the RRC group, but after 20 cases, the RRC group is shorter. It should be emphasized that the type of anastomosis in this study was extracorporeal anastomoses (RRC-EA). Therefore, after the training of a certain number of surgical cases, the advantages of the robotic surgery systems accurate and flexible operation can be fully demonstrated, and the operation time can be significantly shortened. The shortening of time is also related to the fact that the robotic surgical system can filter out the natural tremor of the human hand while presenting a magnified 3D field of view, which is more convenient for

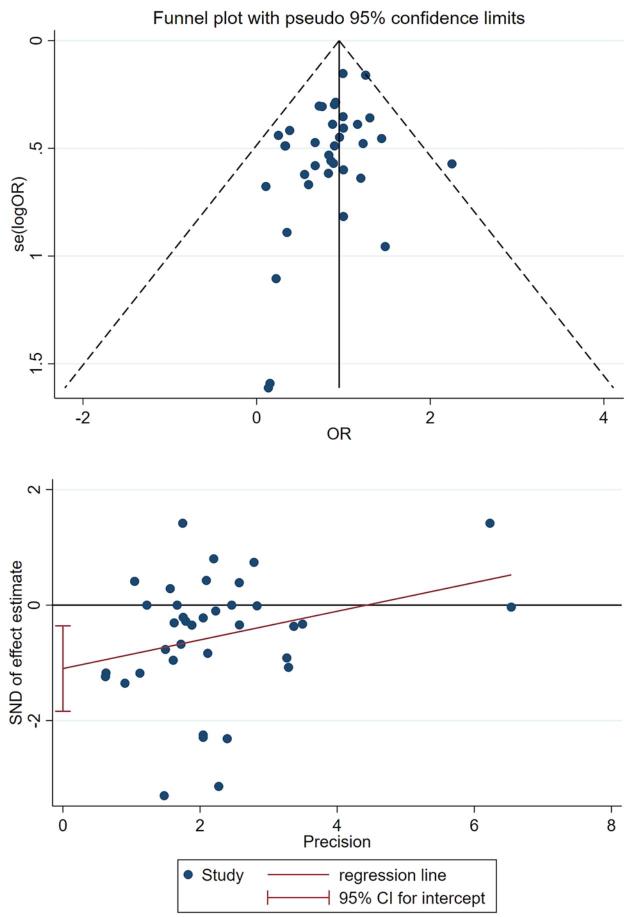

Fig. 6 Funnel plot shows symmetrical distribution of studies and the absence of publication bias, the Egger's test indicates the absence of publication bias

intraoperative tissue positioning and grasping. It is believed that with the popularization and application of robotic surgery systems, the operation time of robots (not only on RRC-EA but also on RRC-IA) will be significantly reduced, even better than laparoscopic surgery in the future. There was no significant difference between the two groups in terms of estimated blood loss. Although robotic surgery is thought to potentially reduce intraoperative bleeding, the chance of intraoperative mishandling is higher relative to laparoscopy surgery due to its lack of force feedback. At the same time, with the popularization of complete mesocolic excision (CME) for tumors of the right colon, the intraoperative bleeding of laparoscopic surgery is reduced, resulting in no obvious advantage of robotic surgery in the control of intraoperative bleeding. However, estimated blood loss was demonstrated to be lower in RRC-EA compared with LRC-EA, possibly because extracorporeal anastomosis is more thorough in hemostasis.

The rate of conversion to laparotomy was significantly lower in the RRC group compared with the LRC group. The robotic surgical system with one lens arm and three robotic arms that can rotate 540°, can perform fine operations in small spaces, improve the ability to deal with more serious adhesions, and reduce the rate of conversion to laparotomy. However, there was no significant difference between RRC-EA and LRC-EA in terms of rate of conversion to laparotomy. This may be due to the lack of included data, and further large prospective series are needed. The number of harvested lymph nodes is an important index to evaluate the radical effect of surgery. This study showed that the number of harvested lymph nodes was higher in the RRC group compared with the LRC group. This demonstrates that robotic methods, which can perform similar radical resection compared with laparoscopic techniques, have potential advantages for tissue dissection.

In terms of perioperative indicators, the length of hospital stay and the time to first flatus in the RRC group were significantly shorter, indicating that the robot had less trauma and faster recovery compared with laparoscopy, which was in line with the minimally invasive concept in the current surgical field. Still, differences in the length of hospital stay were significant only when intracorporeal anastomosis was performed. This confirmed the superiority of intracorporeal anastomosis in improving the recovery of the bowel function. The RRC group showed lower rates of overall complications. There are two possible reasons for this: the average age of patients in the LRC group was older, or the robot itself caused less tissue loss. However, there was no significant difference in ileus, anastomotic leakage, or wound infection between the two groups (including the subgroup analysis). The total cost of robotic surgery is higher than that of laparoscopy surgery, which is mainly related to the use of robotic surgery systems and the high cost of related consumables. As a new type of equipment, the robotic surgery system currently has only one manufacturer, and therefore, the cost is bound to be high. The faster recovery of intestinal functions and shorter hospital stay are counterbalanced by the high general costs of robotic platform use and maintenance. It is believed that with the widespread use of robotic surgery systems and the advent of other robotic surgery systems, the cost of surgical equipment will inevitably drop significantly.

Several limitations exist in the present meta-analysis. Firstly, almost all the articles included in this meta-analysis were retrospective, which limited the strength of the final conclusions. Therefore, the risk of important bias is relevant. Secondly, it is impossible to match patient characteristics in most of the studies, increasing heterogeneity between the two groups. Thirdly, most of the literature presented an intergroup difference in terms of the technique used to perform the anastomosis, which could have significantly biased the comparison between the groups. Due to the differences in equipment resources and the technical level of the implementer among different research institutions, the meta-analysis results have certain heterogeneity. For example, the high heterogeneity in operation time results may be because the robot assistance system is an emerging technology; therefore, each surgical group is affected by experience and surgical level, resulting in the learning curve stage is not consistent, thus having an impact on the surgical results. On the other hand, different definitions of operative time in different surgical groups may also lead to heterogeneity. Finally, data on surgery-related costs are still based on a limited number of surgeries performed in different health systems from different countries, and need to be confirmed by further cost–benefit analyses.

Conclusion

This meta-analysis shows that RRC is superior to LRC in terms of the length of hospital stay. This could be explained by the lower overall complication rate and the shorter time to flatus of the robotic group. This may be due to the fact that intracorporeal anastomosis is more frequently performed in the robotic group than in the laparoscopic group. When an extracorporeal anastomosis is performed, the advantages provided by robotic surgery disappear. Almost all the articles included in this meta-analysis were retrospective, which limited the final conclusions. Therefore, a higher level of evidence achieved by further randomized clinical trials is required.

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Declarations

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval Our study is a systematic review and meta-analysis, so there was no ethical approval required.

Research registration number The name of the registry: RROSPERO; Research Registration Unique Identifying Number. (UIN): CRD42022324624.

Informed consent Our study is a systematic review and meta-analysis, so there was no informed consent required.

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