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REVIEW ARTICLE

Robotic versus laparoscopic surgery for rectal cancer: an overview of systematic reviews with quality assessment of current evidence

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Abstract

Purpose The clinical benefits of robotic surgery for patients with rectal cancer have been reported and many systematic reviews have been published. However, they have investigated a variety of outcomes and differ remarkably in quality. In this overview, we summarize the findings of these reviews and evaluate their quality.

Methods The PubMed, Scopus, and Cochrane Central Register of Controlled Trials databases were comprehensively searched to identify systematic reviews and meta-analyses that compared robotic and laparoscopic surgery. We assessed the quality of the reviews using the AMSTAR-2 tool.

Results The literature search identified 17 eligible reviews, all of which reported that the incidence of conversion to open surgery was lower for robotic surgery than for laparoscopic surgery. Most of the reviews reported no difference in the other outcomes between robotic surgery and laparoscopic surgery. However, the quality of the reviews was judged to be low or critically low.

Conclusions Critically low quality evidence suggests that robotic surgery for rectal cancer decreases the likelihood of conversion to open surgery, but other clinical benefits remain unclear. High-quality systematic reviews in which selection of high-quality studies is combined with adequate methodology are needed to clarify the true efficacy of robotic surgery for rectal cancer.

Keywords Rectal neoplasms · Robot · Systematic review · Meta-analysis · Overview

Introduction

Traditionally, rectal cancer was treated with open surgery, which is invasive and traumatic for the patients. Laparoscopic surgery was introduced in 1991 [1] and is now widely performed for rectal cancer because it is minimally invasive and has better short-term outcomes such as early recovery and a short hospital stay [2]. Moreover, several studies have suggested that the long-term outcomes of laparoscopic surgery are non-inferior to those of open surgery [3, 4]; however, there are some problems inherent to laparoscopic surgery, including the technical difficulty of negotiating a narrow space and the level of assistant skill required [5].

The first report on robotic surgery for benign colonic disease was published in 2002 [6] and by 2006, its use had extended to include total mesorectal excision for rectal cancer [7]. The advantages of robotic surgery for rectal cancer were reported to be its dexterity when working in the narrow pelvic space and a stable view. Robotic surgery is expected to overcome the limitations of laparoscopic surgery with clinical benefits for patients with rectal cancer [5, 8]. Many systematic reviews of the efficacy and safety of robotic surgery for rectal cancer have been published. However, these reviews have reported a variety of outcomes and their methodological quality has not been investigated in depth. Thus, we summarized the current systematic reviews and meta-analyses and assessed their methodological quality using a new tool: AMSTAR-2 [9]. To the best of our knowledge, this is first overview to evaluate the quality of systematic reviews on robotic surgery for rectal cancer.

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Methods

Inclusion criteria

All systematic reviews were eligible for this overview if robotic surgery was compared with laparoscopic surgery for rectal cancer. Any systematic review without a meta-analysis was excluded.

Outcome measures

Surgical outcomes

Operative time, estimated blood loss, and the incidence of conversion to open surgery were evaluated.

Postoperative outcomes

Length of hospital stay, time to recovery of bowel movement, and time to resumption of oral intake were evaluated.

Safety outcomes (postoperative complications)

The incidences of overall complications, anastomotic leakage, postoperative ileus, urinary retention, postoperative bleeding, wound infection, pelvic abscess, and overall mortality were evaluated.

Oncologic outcomes

The incidences of a positive circumferential resected margin (CRM), a distal resected margin (DRM), and the number of lymph nodes retrieved (NLNR) were evaluated.

Quality of life outcomes

Quality of life after surgery was assessed using the International Prostate Symptom Scale scores and the International Index of Erectile Function.

Long-term outcomes

Local recurrence, overall survival, and disease-free survival were evaluated.

Study search and selection

A systematic literature search of PubMed, Scopus, and the Cochrane Central Register of Controlled Trials (CENTRAL) was conducted on August 8, 2018. Two authors (N.H. and T.S.) screened the titles and abstracts of identified articles independently and assessed the full texts of the articles after the screening. Disagreement between the authors was resolved by discussion. Duplicate publications were identified by checking the review authors' names and institutions, and the content, and were then removed.

Data extraction

Two authors (N.H. and T.S.) extracted data from the included reviews independently. The extracted data included the method used for the literature search and data extraction, the assessment of the risk of bias, publication bias, and outcomes data. Discrepancies in the extracted data were resolved by cross-checking of the included reviews by the authors.

Quality assessment of the included reviews

The same authors (N.H. and T.S.) assessed the quality of included reviews independently, using the AMSTAR-2 tool [9]. AMSTAR-2 classifies the quality of a systematic review as high, moderate, low, or critically low, based on 16 domains, 7 of which are critical (protocol registration, adequacy of the literature search, justification for excluding studies, assessment of risk of bias from included studies, appropriateness of meta-analysis methods, consideration of risk of bias, and assessment of publication bias) and 9 of which are non-critical (PICO [population, intervention, control, outcome] description, explanation for selection of the study design, adequacy of study selection, adequacy of data extraction, adequate details in the description of the included studies, reporting of sources of funding, assessment of potential impact of risk of bias, assessment of heterogeneity, and reporting of conflicts of interest). A review without a critical flaw is classified as being of high or moderate quality according to the number of non-critical weaknesses; a review with no or one non-critical weakness is classified as being of high quality, and others, as being of moderate quality. A review with one critical flaw is classified as being of low quality and one with more than one critical flaw is classified as being of critically low quality. The overall quality of each outcome was judged according to the summary of the quality of the included reviews. Discrepancies between the authors were resolved by discussion.

Heterogeneity

The heterogeneity of each outcome was judged based on the summary of I^2 values across the included reviews. An I^2 value of 0–40% was interpreted as low heterogeneity, an I^2 value of 30–60% as moderate heterogeneity, and an I^2 value of 50–90% as substantial heterogeneity. An I^2 value

of 75–100% was regarded as considerable heterogeneity in accordance with the Cochrane Handbook of Systematic Reviews [10].

Descriptive analysis

A descriptive analysis was performed for each outcome. Continuous valuables were evaluated as the mean difference (MD) or standardized mean difference (SMD) and the 95% confidence interval (CI). Categorical valuables were evaluated as the odds ratio (OR), risk ratio (RR), or risk difference (RD) with a 95% CI.

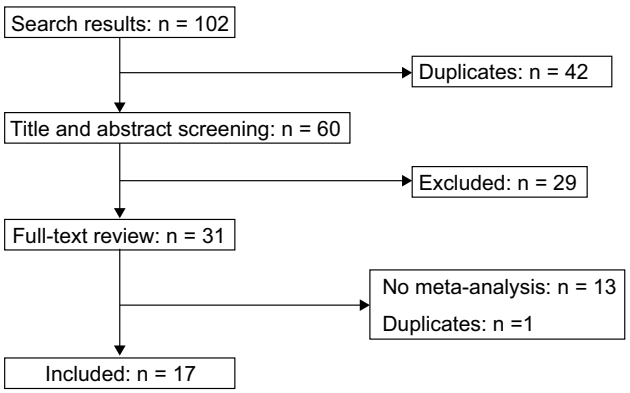

Fig. 1 Flow diagram demonstrating the process used to select reviews for inclusion in this overview

Results

Selection of reviews

The systematic literature search of the three databases identified 102 articles, 42 of which were removed after being confirmed as duplicate publications. The titles and abstracts of the remaining 60 articles were screened and a further 29 were excluded. After screening, 31 full-text articles were retrieved to establish whether they met the eligibility criterion for the overview. 18 articles were judged to be eligible for inclusion, but 2 of these were found to be identical except for the titles. Thus, 17 reviews were included in the final analysis (Fig. 1) [11–27]. Tables 1 and 2 summarize the characteristics of these reviews.

Quality of included reviews

Based on AMSTAR-2, one domain of critical flaw was identified in one review, and the quality of this review was judged to be low. Two and more domains of critical flaw were identified in the other reviews, and the quality of these reviews were judged to be critically low (Table 2).

Table 1 Clinical characteristics of the participants in the included reviews

Review	Year	Disease	Operation	Participants, *n*
Broholm [11]	2015	Rectal cancer	NR	689
Cui [12]	2017	Rectal cancer	ISR, LAR, TME	949
Huang [13]	2016	Colorectal cancer	NR	2071
Lee [14]	2015	Rectal cancer	APR, ISR, LAR, PRO, TME	2224
Li [15]	2017	Rectal cancer	TME	3601
Lin [16]	2011	Rectal cancer	NR	661
Lorenzon [17]	2016	Colorectal disease	NR	2772
Memon [18]	2012	Rectal cancer	APR, TME	754
Ohtani [19]	2018	Rectal cancer	APR, AR, CAA, IPAA, ISR, SPP	4348
Ortiz-Oshiro [20]	2012	Rectal cancer	APR, CAA, LAR, PME, SPP, TME	486
Prete [21]	2018	Rectal cancer	APR, AR, LAR	681
Sun [22]	2016	Rectal cancer	LAR	592
Trastulli [23]	2011	Rectal cancer	APR, AR, CAA, LAR, TME, TSME	854
Wang [24]	2016	Rectal cancer	TME	1229
Wilder [25]	2016	Colorectal cancer	NR	685
Xiong [26]	2015	Rectal cancer	TME	1229
Yang [27]	2012	Colorectal disease	NR	1493

APR abdominoperineal resection, *AR* anterior resection, *CAA* coloanal anastomosis, *IPAA* ileal pouch–anal anastomosis, *ISR* intersphincteric resection, *LAR* low anterior resection, *PME* partial mesorectal excision, *PRO* proctectomy, *NR* not reported, *SPP* sphincter-preserving procedure, *TME* total mesorectal excision, *TSME* tumor-specific mesorectal excision

Table 2 Characteristics of the included reviews

Review	Year	Databases searched, *n*	Studies included, *n*		Risk of bias assessment	Domains of critical flaw	Quality
			RCT	Non-RCT			
Broholm	2015	3	0	10	NOS	1,2,3,5,7	Critically low
Cui	2017	3	0	9	MINORS	1,2,3,5	Critically low
Huang	2016	3	0	10	QUADAS	1,2,3,5,6,7	Critically low
Lee	2015	3 (+5 LD)	2	15	Cochrane RoB, MINORS	1,3,5,6	Critically low
Li	2017	3 (+1 LD)	0	17	NOS	1,2,3,5,7	Critically low
Lin	2011	4	2	6	NR	1,2,3,4,5,7	Critically low
Lorenzon	2016	3	1	6	NR	1,2,4,5,6,7	Critically low
Memon	2012	2	0	7	NR	1,2,3,4,7	Critically low
Ohtani	2018	4	0	23	MINORS	1,2,3,5,7	Critically low
Ortiz-Oshiro	2012	5	0	5	STROBE	1,3,5,7	Critically low
Prete	2018	3	5	0	Cochrane RoB	7	Low
Sun	2016	3	1	6	Jadad scale, MINORS	1,2,3,4,5,7	Critically low
Trastulli	2011	6	0	8	NOS	1,5,6	Critically low
Wang	2016	3	1	7	Jadad scale, NOS	1,2,3,4,5,7	Critically low
Wilder	2016	4	0	5	NR	1,2,3,4,5,7	Critically low
Xiong	2015	4	1	7	Cochrane RoB, NOS	1,5	Critically low
Yang	2012	2	1	6	NR	1,2,3,4,5,7	Critically low

Domain 1, protocol registration; 2, adequacy of the literature search; 3, justification for excluding studies; 4, assessment of risk of bias from included studies; 5, appropriateness of meta-analysis methods; 6, consideration of risk of bias; 7, assessment of publication bias

LD local database, *MINORS* methodological index for non-randomized studies, *NOS* Newcastle–Ottawa scale, *QUADAS* quality assessment of diagnostic accuracy studies, *NR* not reported, *RCT* randomized controlled trial, *RoB* risk of bias, *STROBE* strengthening of the reporting of observational studies in epidemiology

Table 3 Operative times

Review	Year	Studies included, *n*	Participants, *n*		Estimation measure	Estimation	95% CI	*P* value	Favors	I^2
			Robot group	Laparoscopy group						
Cui	2017	9	354	451	MD	33.73	8.48 to 58.99	< 0.01	Laparoscopy	96
Huang	2016	5	697	628	MD	34.29	− 6.85 to 75.43	0.10	NS	93
Lee	2015	10	821	844	MD	49.97	20.43 to 79.52	< 0.01	Laparoscopy	97
Li	2017	16	NR	NR	MD	57.43	36.70 to 78.15	< 0.01	Laparoscopy	96
Lin	2011	4	137	262	MD	27.92	− 13.43 to 69.27	0.19	NS	97
Lorenzon	2016	8	518	595	SMD	0.53	0.14 to 0.92	NR	Laparoscopy	NR
Ohtani	2018	23	2068	2274	MD	44.80	28.44 to 61.15	< 0.01	Laparoscopy	97
Ortiz-Oshiro	2012	5	203	283	MD	7.08	− 32.30 to 46.46	0.72	NS	0
Prete	2018	5	344	337	MD	38.43	31.84 to 45.01	< 0.01	Laparoscopy	4
Sun	2016	7	324	268	MD	28.40	− 3.48 to 60.27	0.08	NS	93
Trastulli	2011	7	341	461	MD	21.26	− 11.09 to 53.62	0.20	NS	96
Wang	2016	8	554	675	MD	17.34	− 18.11 to 52.79	> 0.05	NS	94
Xiong	2015	8	554	675	MD	17.34	− 18.11 to 52.79	0.34	NS	96
Yang	2012	7	300	420	MD	15.61	v10.73 to 41.94	0.25	NS	97

CI confidence interval, *MD* mean difference, *NR* not reported, *NS* not significant, *SMD* standardized mean difference

Surgical outcomes

Operative time

15 reviews reported on operative times, but one was excluded because it contained apparently incorrect data. Table 3 summarizes the data for the remaining 14 reviews. Operative time was reported as the MD with 95% CI by 13 reviews and as the SMD with 95% CI by 1 review. The operative time was significantly longer for robotic surgery than for laparoscopic surgery in six reviews, but the times did not differ significantly in eight reviews. Most of the included meta-analyses had very high I^2 values, indicating considerable heterogeneity. The overall quality of the evidence for this outcome was judged to be critically low.

Estimated blood loss

Ten reviews reported on the estimated blood loss, nine of which reported it as the MD with 95% CI and one reported it as the SMD with 95% CI (Table 4). Estimated blood loss was significantly less for robotic surgery than for laparoscopic surgery in three reviews, significantly more for robotic surgery than for laparoscopic surgery in one review, and not significantly different in six reviews. Most of the included meta-analyses had high I^2 values, indicating substantial heterogeneity. The overall quality of the evidence for this outcome was judged to be critically low.

Conversion to open surgery

14 reviews reported on conversion to open surgery, 8 of which reported the OR with 95% CI, 3 reported the RR with 95% CI, and 3 reported the RD with 95% CI (Table 5). The conversion rate was significantly lower for robotic surgery than for laparoscopic surgery in all the reviews. Most of the included meta-analyses had low I^2 values, indicating low heterogeneity. The overall quality of the evidence for this outcome was judged to be critically low.

Postoperative outcomes

Length of hospital stay

13 of the 14 reviews reported the length of hospital stay as the MD with 95% CI and 1 reported it as the SMD with 95% CI (Table 6). The length of hospital stay was significantly shorter after robotic surgery than after laparoscopic surgery in 3 reviews and not significantly different in 11 reviews. Most of the included meta-analyses had high I^2 values, indicating substantial heterogeneity. The overall quality of the evidence for this outcome was judged to be critically low.

Time to recovery of bowel function

Ten reviews reported on time to recovery of bowel function and all reported the MD with 95% CI (Table 7). Two reviews reported that the time to recovery of bowel function was significantly shorter after robotic surgery than after laparoscopic surgery and eight reviews found no significant difference. The I^2 values varied widely across the included meta-analyses, indicating low to substantial heterogeneity. The overall quality of the evidence for this outcome was judged to be critically low.

Time to resumption of oral intake

Four reviews reported on time to resumption of oral intake and all reported the MD with 95% CI (Table 8). None of these reviews found a significant difference in time to

Table 4 Estimated blood loss

Review	Year	Studies included, *n*	Participants, *n*		Estimation measure	Estimation	95% CI	*P* value	Favors	I^2
			Robot group	Laparoscopy group						
Cui	2017	5	253	204	MD	−41.15	−77.51 to −4.79	0.03	Robot	84
Huang	2016	7	837	880	MD	−19.50	−34.47 to −4.54	0.01	Robot	55
Lee	2015	8	751	796	MD	−9.03	−33.11 to 15.05	0.46	NS	71
Li	2017	11	NR	NR	MD	−12.45	−48.66 to 23.76	0.50	NS	76
Lin	2011	2	67	121	MD	−32.35	−86.19 to 21.50	0.24	NS	53
Lorenzon	2016	6	421	456	SMD	0.34	0.01 to 0.67	NR	Laparoscopy	NR
Ohtani	2018	15	1143	1355	MD	−9.29	−32.82 to 14.24	0.44	NS	85
Wang	2016	5	427	477	MD	−22.20	−87.23 to 42.82	>0.05	NS	97
Xiong	2015	5	427	477	MD	−22.20	−87.23 to 42.82	0.50	NS	98
Yang	2012	3	108	162	MD	−47.26	−65.76 to −28.75	<0.01	Robot	20

CI confidence interval, *MD* mean difference, *NR* not reported, *NS* not significant, *SMD* standardized mean difference

Table 5 Conversion to open surgery

Review	Year	Studies included, *n*	Participants, *n*		Estimation measure	Estimation	95% CI	*P* value	Favors	I^2
			Robot group	Laparoscopy group						
Cui	2017	8	467	443	RD	−0.05	−0.09 to −0.01	0.02	Robot	63
Huang	2016	5	697	628	OR	0.17	0.06 to 0.46	<0.01	Robot	0
Lee	2015	10	674	769	RR	0.28	0.15 to 0.54	<0.01	Robot	0
Li	2017	12	NR	NR	OR	0.35	0.19 to 0.62	<0.01	Robot	0
Lin	2011	8	268	393	OR	0.25	0.11 to 0.58	<0.01	Robot	0
Memon	2012	7	351	401	RD	−0.07	−0.12 to −0.01	0.03	Robot	80
Ohtani	2018	21	1864	2105	OR	0.30	0.19 to 0.46	<0.01	Robot	0
Ortiz-Oshiro	2012	5	204	284	RR	0.31	0.12 to 0.78	0.01	Robot	0
Prete	2018	4	273	271	RR	0.58	0.35 to 0.97	0.04	Robot	0
Sun	2016	6	290	252	OR	0.07	0.02 to 0.31	<0.01	Robot	0
Trastulli	2011	7	341	467	OR	0.26	0.12 to 0.57	<0.01	Robot	0
Wang	2016	8	554	675	OR	0.23	0.10 to 0.52	<0.01	Robot	0
Xiong	2015	8	554	675	OR	0.23	0.10 to 0.52	<0.01	Robot	0
Yang	2012	7	300	426	RD	−0.07	−0.13 to 0.00	0.04	Robot	80

CI confidence interval, *NR* not reported, *NS* not significant, *OR* odds ratio, *RD* risk difference, *RR* risk ratio

Table 6 Length of hospital stay

Review	Year	Studies included, *n*	Participants, *n*		Estimation measure	Estimation	95% CI	*P* value	Favors	I^2
			Robot group	Laparoscopy group						
Cui	2017	8	423	420	MD	−1.07	−1.80 to −0.33	<0.01	Robot	75
Huang	2016	5	697	628	MD	−1.25	−2.03 to −0.47	<0.01	Robot	65
Lee	2015	10	821	917	MD	−0.53	−1.26 to 0.21	0.16	NS	61
Li	2017	16	NR	NR	MD	−0.69	−1.48 to 0.10	0.09	NS	82
Lin	2011	3	99	178	MD	−0.04	−2.28 to 2.20	0.97	NS	83
Lorenzon	2016	8	518	595	SMD	0.11	−0.26 to 0.48	NR	NS	NR
Memon	2012	NR	NR	NR	MD	−0.57	−1.83 to 0.69	0.38	NS	68
Ortiz-Oshiro	2012	5	203	283	MD	−0.06	−2.38 to 2.26	0.96	NS	84
Prete	2018	4	260	262	MD	−0.61	−2.23 to 1.02	0.46	NS	66
Sun	2016	7	324	268	MD	−1.03	−1.78 to −0.28	<0.01	Robot	78
Trastulli	2011	7	341	461	MD	−0.66	−1.76 to 0.43	0.23	NS	61
Wang	2016	8	554	675	MD	−0.37	−1.28 to 0.54	>0.05	NS	>75
Xiong	2015	8	554	675	MD	−0.37	−1.28 to 0.54	0.43	NS	76
Yang	2012	6	241	361	MD	−0.40	−1.55 to 0.76	0.50	NS	63

CI confidence interval, *MD* mean difference, *NR* not reported, *NS* not significant, *SMD* standardized mean difference

resumption of oral intake between robotic surgery and laparoscopic surgery. Most of the included meta-analyses had high I^2 values, indicating substantial heterogeneity. The overall quality of the evidence for this outcome was judged to be critically low.

Safety outcomes

Overall complications

12 reviews reported on the incidence of overall complications

Table 7 Time to recovery of bowel function

Review	Year	Studies included, *n*	Participants, n		Estimation measure	Estimation	95% CI	*P* value	Favors	I^2
			Robot group	Laparoscopy group						
Cui	2017	6	390	377	MD	−0.03	−0.40 to 0.34	0.89	NS	73
Lee	2015	8	762	850	MD	−0.13	−0.25 to −0.01	0.03	Robot	0
Li	2017	8	NR	NR	MD	−0.11	−0.26 to 0.03	0.13	NS	46
Lin	2011	2	70	141	MD	−0.18	−0.96 to 0.60	0.65	NS	73
Ortiz-Oshiro	2012	4	174	246	MD	0.15	−0.27 to 0.57	0.48	NS	0
Prete	2018	2	89	84	MD	−0.59	−0.95 to −0.23	<0.01	Robot	0
Sun	2016	3	207	159	MD	−0.15	−0.37 to 0.06	0.17	NS	23
Wang	2016	5	434	547	MD	−0.29	−0.71 to 0.13	>0.05	NS	86
Xiong	2015	5	434	547	MD	−0.25	−0.60 to 0.11	0.17	NS	82
Yang	2012	4	171	281	MD	0.09	−0.16 to 0.35	0.47	NS	1

CI confidence interval, *MD* mean difference, *NR* not reported, *NS* not significant

Table 8 Time to resumption of oral intake

Review	Year	Studies included, *n*	Participants, *n*		Estimation measure	Estimation	95% CI	*P* value	Favors	I^2
			Robot group	Laparoscopy group						
Lee	2015	6	727	805	MD	−0.18	−0.36 to 0.00	0.05	NS	36
Trastulli	2011	4	246	364	MD	−0.43	−1.06 to 0.20	0.18	NS	79
Xiong	2015	6	500	613	MD	−0.42	−1.07 to 0.22	0.20	NS	94
Yang	2012	4	187	299	MD	−0.23	−0.73 to 0.28	0.38	NS	62

CI confidence interval, *MD* mean difference, *NS* not significant

Table 9 Overall complications

Review	Year	Studies included, *n*	Participants, *n*		Estimation measure	Estimation	95% CI	*P* value	Favors	I^2
			Robot group	Laparoscopy group						
Cui	2017	9	473	476	OR	0.58	0.41–0.83	<0.01	Robot	0
Huang	2016	6	770	862	OR	0.84	0.66–1.07	0.16	NS	18
Li	2017	16	1673	1875	OR	1.02	0.82–1.25	0.88	NS	24
Lin	2011	8	268	393	OR	1.05	0.71–1.55	0.82	NS	0
Memon	2012	7	NR	NR	RR	0.93	0.67–1.29	0.67	NS	29
Ohtani	2018	21	2005	2196	OR	0.93	0.77–1.14	0.49	NS	27
Prete	2018	5	344	337	OR	1.02	0.80–1.31	0.85	NS	0
Sun	2016	7	324	276	OR	0.65	0.43–0.99	0.04	Robot	0
Trastulli	2011	2	152	223	OR	0.94	0.55–1.58	0.95	NS	64
Wang	2016	8	554	675	OR	0.95	0.73–1.25	>0.05	NS	25
Xiong	2015	8	554	675	OR	0.95	0.73–1.25	0.73	NS	25
Yang	2012	7	300	426	OR	1.07	0.73–1.56	0.74	NS	0

CI confidence interval, *NR* not reported, *NS* not significant, *OR* odds ratio, *RR* risk ratio

(Table 9). 11 reported the OR with 95% CI and one reported the RR with 95% CI. The overall incidence of complications from robotic surgery was significantly lower than that from laparoscopic surgery in two reviews but was not significantly different in 10 reviews. Most of the included meta-analyses had low I^2 values, indicating low heterogeneity. The overall

quality of the evidence for this outcome was judged to be critically low.

Anastomotic leakage

Eight reviews reported on the incidence of anastomotic leakage (Table 10). Four reviews reported the OR with 95% CI, three reported the RR with 95% CI, and one reported the RD with 95% CI. None of the reviews found a significant difference in the incidence of anastomotic leakage between robotic surgery and laparoscopic surgery. All the meta-analyses had low I^2 values, indicating low heterogeneity. The overall quality of evidence for this outcome was judged to be critically low.

Postoperative ileus

Five reviews reported on the incidence of postoperative ileus (Table 11). Four reviews reported the OR with 95% CI and one reported the RD with 95% CI. The incidence

Table 10 Anastomotic leakage

Review	Year	Studies included, *n*	Participants, *n*		Estimation measure	Estimation	95% CI	*P* value	Favors	I^2
			Robot group	Laparoscopy group						
Lee	2015	10	819	925	RR	0.87	0.65 to 1.17	0.36	NS	0
Li	2017	13	1475	1620	OR	0.80	0.61 to 1.06	0.12	NS	0
Ohtani	2018	22	2018	2255	OR	0.82	0.64 to 1.05	0.11	NS	0
Ortiz-Oshiro	2012	5	186	236	RR	1.12	0.49 to 2.56	0.78	NS	0
Prete	2018	3	88	86	RR	1.26	0.39 to 4.10	0.70	NS	0
Trastulli	2011	7	316	424	OR	0.94	0.52 to 1.69	0.83	NS	0
Xiong	2015	8	554	675	OR	0.91	0.61 to 1.37	0.66	NS	0
Yang	2012	7	300	426	RD	0.01	−0.03 to 0.05	0.62	NS	0

CI confidence interval, *NS* not significant, *OR* odds ratio, *RD* risk difference, *RR* risk ratio

Table 11 Postoperative ileus

Review	Year	Studies included, *n*	Participants, *n*		Estimation measure	Estimation	95% CI	*P* value	Favors	I^2
			Robot group	Laparoscopy group						
Li	2017	11	1255	1437	OR	1.48	1.02 to 2.15	0.04	Laparoscopy	3
Ohtani	2018	18	1907	2040	OR	1.20	0.89 to 1.62	0.23	NS	0
Trastulli	2011	5	278	358	OR	1.34	0.51 to 3.50	0.55	NS	0
Xiong	2015	5	427	477	OR	1.71	0.96 to 3.06	0.07	NS	25
Yang	2012	5	237	317	RD	0.01	−0.02 to 0.04	0.58	NS	0

CI confidence interval, *NS* not significant, *OR* odds ratio, *RD* risk difference

Table 12 Urinary retention

Review	Year	Studies included, *n*	Participants, *n*		Estimation measure	Estimation	95% CI	*P* value	Favors	I^2
			Robot group	Laparoscopy group						
Lee	2015	5	299	389	RR	0.87	0.47–1.61	0.65	NS	0
Li	2017	5	243	287	OR	0.41	0.18–0.89	0.03	Robot	0
Ohtani	2018	9	1141	1266	OR	0.85	0.57–1.26	0.41	NS	4
Prete	2018	5	344	337	RR	0.97	0.54–1.72	0.81	NS	0
Wang	2016	2	81	160	OR	1.37	0.27–6.89	> 0.05	NS	0
Xiong	2015	2	81	160	OR	1.94	0.38–9.84	0.43	NS	0

CI confidence interval, *NS* not significant, *OR* odds ratio, *RR* risk ratio

of postoperative ileus was found to be significantly higher after robotic surgery than after laparoscopic surgery in one review but there was no significant difference in incidence in the other four reviews. All the meta-analyses had low I^2 values, indicating low heterogeneity. The overall quality of the evidence for this outcome was judged to be critically low.

Urinary retention

Six reviews reported on the incidence of urinary retention (Table 12). Four reviews reported the OR with 95% CI and two reported the RR with 95% CI. One review found that the incidence of urinary retention was significantly lower after robotic surgery than after laparoscopic surgery and five found no significant difference. All the meta-analyses had low I^2 values, indicating low heterogeneity. The overall quality of the evidence for this outcome was judged to be critically low.

Postoperative bleeding

Three reviews reported on the incidence of postoperative bleeding (Table 13). Two of these reported the OR with 95% CI and one reported the RR with 95% CI. None of the reviews found any significant difference in the incidence of postoperative bleeding between robotic surgery and laparoscopic surgery. All three meta-analyses had low I^2 values, indicating low heterogeneity. The overall quality of the evidence for this outcome was judged to be critically low.

Wound infection

Six reviews assessed the incidence of wound infection (Table 14). Four reviews reported the OR with 95% CI, one reported the RR with 95% CI, and one reported the RD with 95% CI. None of the reviews found a significant difference in the incidence of wound infection between robotic surgery and laparoscopic surgery. Most of these meta-analyses had low I^2 values, indicating low heterogeneity. The overall

Table 13 Postoperative bleeding

Review	Year	Studies included, *n*	Participants, *n*		Estimation measure	Estimation	95% CI	*P* value	Favors	I^2
			Robot group	Laparoscopy group						
Lee	2015	6	680	676	RR	1.23	0.51–2.94	0.64	NS	0
Li	2017	8	810	926	OR	1.58	0.77–3.26	0.21	NS	0
Xiong	2015	6	463	584	OR	1.93	0.74–5.00	0.18	NS	0

CI confidence interval, *NS* not significant, *OR* odds ratio, *RR* risk ratio

Table 14 Wound infection

Review	Year	Studies included, n	Participants, *n*		Estimation measure	Estimation	95% CI	*P* value	Favors	I^2
			Robot group	Laparoscopy group						
Lee	2015	7	625	717	RR	0.76	0.32 to 1.81	0.54	NS	0
Li	2017	8	1126	1171	OR	0.91	0.41 to 2.02	0.81	NS	0
Prete	2018	5	344	337	OR	0.94	0.52 to 1.71	0.95	NS	0
Trastulli	2011	4	192	246	OR	0.81	0.26 to 2.50	0.72	NS	0
Xiong	2015	5	309	434	OR	0.71	0.25 to 2.00	0.52	NS	0
Yang	2012	5	192	246	RD	0.00	−0.03 to 0.04	0.87	NS	0

CI confidence interval, *NS* not significant, *OR* odds ratio, *RD* risk difference, *RR* risk ratio

Table 15 Pelvic abscess

Review	Year	Studies included, *n*	Participants, *n*		Estimation measure	Estimation	95% CI	*P* value	Favors	I^2
			Robot group	Laparoscopy group						
Lee	2015	5	566	602	RR	1.21	0.57–2.60	0.62	NS	0

CI confidence interval, *NS* not significant, *RR* risk ratio

quality of the evidence for this outcome was judged to be critically low.

Pelvic abscess

Only one review investigated the incidence of pelvic abscess (Table 15) and presented the data as the OR with 95% CI. This review found no significant difference in the incidence of pelvic abscess between robotic surgery and laparoscopic surgery. The meta-analysis had a low I^2 value, indicating low heterogeneity. The overall quality of the evidence for this outcome was judged to be critically low.

Mortality

Two reviews reported on mortality rates (Table 16). One of these presented the data as the OR with 95% CI and the other reported the RR with 95% CI. There was no significant difference in the mortality rate between robotic surgery and laparoscopic surgery in either review. Both meta-analyses had a low I^2 value, indicating low heterogeneity. The overall quality of the evidence for this outcome was judged to be critically low.

Oncologic outcomes

Positive CRM

11 reviews reported the incidence of positive CRM (Table 17). Seven of these reported the OR with 95% CI, one reported the RR with 95% CI, and three reported the RD with 95% CI. The incidence of a positive CRM was significantly lower for robotic surgery than for laparoscopic surgery in two reviews but was not significantly different in nine reviews. Most of these meta-analyses had low I^2 values, indicating low heterogeneity. The overall quality of the evidence for this outcome was judged to be critically low.

DRM

Seven reviews reported the incidence of DRM (Table 18) and all presented the data as the MD with 95% CI. The incidence of DRM was significantly lower for robotic surgery than for laparoscopic surgery in one review, but was not significantly different in six reviews. Most of these meta-analyses had moderate I^2 values, indicating moderate heterogeneity. The overall quality of the evidence for this outcome was judged to be critically low.

Table 16 Mortality

Review	Year	Studies included, *n*	Participants, *n*		Estimation measure	Estimation	95% CI	*P* value	Favors	I^2
			Robot group	Laparoscopy group						
Prete	2018	5	344	337	RR	0.97	0.14–6.86	0.96	NS	NR
Trastulli	2011	4	147	226	OR	1.29	0.08–21.47	0.86	NS	NR

CI confidence interval, *NR* not reported, *NS* not significant, *OR* odds ratio, *RR* risk ratio

Table 17 Positive circumferential resected margin

Review	Year	Studies included, *n*	Participants, *n*		Estimation measure	Estimation	95% CI	*P* value	Favors	I^2
			Robot group	Laparoscopy group						
Cui	2017	6	426	368	RD	−0.02	−0.05 to 0.01	0.23	NS	34
Li	2017	13	NR	NR	OR	0.80	0.55 to 1.17	0.26	NS	0
Lin	2011	3	118	189	OR	0.54	0.12 to 2.39	0.42	NS	0
Memon	2012	7	351	401	RD	0.00	−0.02 to 0.03	0.77	NS	0
Prete	2018	2	248	241	RR	0.82	0.39 to 1.73	0.60	NS	NR
Sun	2016	4	273	215	OR	0.50	0.25 to 1.01	0.05	NS	39
Trastulli	2011	6	312	430	OR	0.81	0.34 to 1.90	0.64	NS	0
Wang	2016	2	292	363	OR	0.44	0.20 to 0.96	<0.05	Robot	0
Wilder	2016	4	222	280	OR	1.08	0.45 to 2.59	0.86	NS	0
Xiong	2015	2	292	363	OR	0.44	0.20 to 0.96	0.04	Robot	0
Yang	2012	7	300	420	RD	−0.01	−0.03 to 0.02	0.53	NS	0

CI confidence interval, *NR* not reported, *NS* not significant, *OR* odds ratio, *RD* risk difference, *RR* risk ratio

Table 18 Distal resected margin

Review	Year	Studies included, n	Participants, *n*		Estimation measure	Estimation	95% CI	*P* value	Favors	I^2
			Robot group	Laparoscopy group						
Li	2017	8	NR	NR	MD	1.98	−1.25 to 5.22	0.23	NS	68
Lin	2011	3	99	178	MD	−0.35	−1.27 to 0.58	0.46	NS	64
Memon	2012	7	351	401	MD	−0.03	−0.30 to 0.24	0.84	NS	NR
Trastulli	2011	6	303	383	MD	0.03	−0.31 to 0.36	0.88	NS	40
Wilder	2016	5	NR	NR	MD	−0.32	−0.62 to −0.01	0.04	Laparoscopy	36
Xiong	2015	4	271	350	MD	−0.09	−0.30 to 0.11	0.36	NS	41
Yang	2012	7	290	364	MD	0.12	−0.22 to 0.46	0.48	NS	64

CI confidence interval, *MD* mean difference, *NR* not reported, *NS* not significant

Table 19 Number of lymph nodes retrieved

Review	Year	Studies included, *n*	Participants, *n*		Estimation measure	Estimation	95% CI	*P* value	Favors	I^2
			Robot group	Laparoscopy group						
Lee	2015	8	647	732	MD	0.20	−0.54 to 0.94	0.60	NS	48
Li	2017	12	NR	NR	MD	0.49	−0.98 to 1.96	0.52	NS	64
Lin	2011	4	137	262	MD	0.41	−0.67 to 1.50	0.46	NS	43
Lorenzon	2016	6	360	487	SMD	−0.21	−0.62 to 0.20	NR	NS	NR
Memon	2012	NR	NR	NR	MD	−0.90	−1.94 to 1.80	0.94	NS	57
Ortiz-Oshiro	2012	5	203	283	MD	−0.06	−2.27 to 2.16	0.96	NS	40
Prete	2018	5	344	330	MD	−0.35	−1.83 to 1.12	0.54	NS	0
Sun	2016	7	324	274	MD	0.63	−0.78 to 2.05	0.38	NS	0
Trastulli	2011	7	341	467	MD	−0.38	−1.71 to 0.94	0.57	NS	40
Wang	2016	7	400	525	MD	0.16	−1.41 to 1.74	>0.05	NS	76
Wilder	2016	5	NR	NR	MD	−2.17	−3.51 to −0.83	<0.01	Laparoscopy	37
Xiong	2015	7	400	525	MD	0.16	−1.41 to 1.74	0.84	NS	75
Yang	2012	7	300	420	MD	−0.37	−1.16 to 0.41	0.35	NS	38

CI confidence interval, *MD* mean difference, *NR* not reported, *NS* not significant, *SMD* standardized mean difference

NLNR

13 reviews reported on NLNR (Table 19). 12 of these presented the data as the MD with 95% CI and 1 reported the SMD with 95% CI. The number of NLNRs was significantly smaller for robotic surgery than for laparoscopic surgery in one review, but was not significantly different in 12 reviews. Most of these meta-analyses had moderate I^2 values, indicating moderate heterogeneity. The overall quality of evidence for this outcome was judged to be critically low.

Quality of life outcomes

International prostate symptom scores

Two reviews reported the International Prostate Symptom Scale scores 3, 6, and 12 months after surgery (Table 20). Both reviews presented the data as the MD with 95% CI. In both reviews, the scores were significantly lower 3 months after robotic surgery than 3 months after laparoscopic surgery, but they were not significantly different at 6 and 12 months. Both these meta-analyses had low I^2 values (low heterogeneity). The overall quality of the results was judged to be critically low.

International index of erectile function scores

Two reviews reported the International Index of Erectile Function scores 3 and 6 months after surgery (Table 21) and both presented the data as the MD with 95% CI. Both reviews demonstrated that the decline in this score was significantly smaller after robotic surgery than after laparoscopic surgery at 3 and 6 months. Both these meta-analyses

had low I^2 values, indicating low heterogeneity. The overall quality of the results was judged to be critically low.

Long-term outcomes

Local recurrence

Four reviews reported on the incidence of local recurrence, including one by Huang et al. [13], which reported the results of two meta-analyses. Therefore, the data for five reviews are summarized in Table 22. All reviews reported the data as the MD with 95% CI. No between-group differences in the incidence of local recurrence were found in any of the meta-analyses, most of which had low I^2 values, indicating low heterogeneity. The overall quality of the evidence for this outcome was judged to be critically low.

Overall survival

Three reviews reported on overall survival, including the one by Huang et al. [13], which reported the results of two meta-analyses. Therefore, the data for four meta-analyses are summarized in Table 23. There was no between-group difference in overall survival in any of these meta-analyses, all of which had low I^2 values, indicating low heterogeneity.

Table 20 International prostate symptom score

Review	Year	Time, months	Studies included, *n*	Participants, *n*		Estimation measure	Estimation	95% CI	*P* value	Favors	I^2
				Robot group	Laparoscopy group						
Broholm	2015	3	3	76	86	MD	−1.58	−3.10 to −0.05	0.04	Robot	9
		6	3	76	86	MD	−0.59	−2.00 to 0.82	0.41	NS	0
		12	3	92	101	MD	−0.90	−1.81 to 0.02	0.05	NS	0
Lee	2015	3	2	44	54	MD	−2.90	−5.31 to −0.48	0.02	Robot	0
		6	2	44	54	MD	−0.45	−2.58 to 1.68	0.68	NS	0
		12	2	60	69	MD	−0.90	−1.93 to 0.14	0.06	NS	0

CI confidence interval, *MD* mean difference, *NS* not significant

Table 21 International index of erectile function score

Review	Year	Time, months	Studies included, *n*	Participants, *n*		Estimation measure	Estimation	95% CI	*P* value	Favors	I^2
				Robot group	Laparoscopy group						
Broholm	2015	3	3	64	64	MD	−2.59	−4.25 to −0.94	< 0.01	Robot	0
		6	3	64	61	MD	−3.06	−4.53 to −1.59	< 0.01	Robot	1
Lee	2015	3	2	32	32	MD	−2.82	−4.78 to −0.87	< 0.01	Robot	37
		6	2	32	29	MD	−2.15	−4.08 to −0.22	0.03	Robot	0

CI confidence interval, *MD* mean difference

Table 22 Local recurrence

Review	Year	Time, years	Studies included, *n*	Participants, *n*		Estimation measure	Estimation	95% CI	*P* value	Favors	I^2
				Robot group	Laparoscopy group						
Huang	2016	NR	5	638	569	OR	1.23	0.70–2.18	0.47	NS	0
		5	3	470	509	OR	1.41	0.81–2.44	0.22	NS	0
Li	2017	3	4	NR	NR	OR	0.68	0.36–1.26	0.22	NS	0
Wang	2016	NR	2	67	121	OR	0.61	0.14–2.59	> 0.05	NS	0
Xiong	2015	NR	2	67	121	OR	0.61	0.14–2.59	0.50	NS	0

CI confidence interval, *NR* not reported, *NS* not significant, *OR* odds ratio

Table 23 Overall survival

Review	Year	Time, years	Studies included, *n*	Participants, *n*		Estimation measure	Estimation	95% CI	*P* value	Favors	I^2
				Robot group	Laparoscopy group						
Huang	2016	3	4	261	353	OR	0.75	0.40–1.41	0.37	NS	0
		5	4	514	548	OR	0.97	0.62–1.51	0.88	NS	0
Li	2017	3	3	NR	NR	OR	0.71	0.44–1.12	NR	NS	0
Ohtani	2018	3	3	654	587	OR	0.92	0.58–1.46	0.71	NS	0

CI confidence interval, *NR* not reported, *NS* not significant, *OR* odds ratio

Table 24 Disease-free survival

Review	Year	Time, years	Included studies, *n*	Participants, *n*		Estimation measure	Estimation	95% CI	*P* value	Favors	I^2
				Robot group	Laparoscopy group						
Huang	2016	3	5	426	518	OR	0.99	0.69–1.44	0.97	NS	0
		5	5	620	654	OR	1.02	0.77–1.35	0.91	NS	25

CI confidence interval, *NS* not significant, *OR* odds ratio

The overall quality of the evidence for overall survival was judged to be critically low.

Disease-free survival

The review by Huang et al. [13] that reported the results of two meta-analyses was the only one that reported data for disease-free survival (Table 24). There was no between-group difference in disease-free survival in either of these meta-analyses, both of which had low I^2 values, indicating low heterogeneity. The overall quality of the evidence for this outcome was judged to be critically low.

Discussion

Summary of findings

This overview summarizes 22 outcomes of robotic surgery for rectal cancer: 3 surgical, 3 postoperative, 8 safety, 3 oncologic, 2 quality of life, and 3 long-term outcomes. Conversion to open surgery was less common with robotic surgery than with laparoscopic surgery, but at the expense of a longer operative time. There was no marked between-group difference in estimated blood loss. Some of the reviews reported earlier postoperative recovery after robotic surgery, but most reported no significant between-group difference. Robotic surgery might enhance postoperative recovery, but the evidence for this outcome was unclear. There were no differences between robotic surgery and laparoscopic surgery in most of the reviews that reported on postoperative complications. Therefore, it remains unclear whether robotic surgery can decrease the incidence of these complications.

The surgical and pathological findings were not significantly different between robotic surgery and laparoscopic surgery in most of the reviews, so whether robotic surgery improves the oncologic quality of surgery remains to be clarified. Two reviews reported on quality of life outcomes, some of which showed improved quality of life after robotic surgery. However, whether robotic surgery improves quality of life to a greater degree than laparoscopic surgery could not be established because of the small number of studies that addressed this issue. In terms of long-term outcomes, there were no between-group differences in survival or cancer recurrence in any of the reviews. Therefore, it is still unclear whether robotic surgery can improve the prognosis of patients with rectal cancer.

Future research and implications for clinical benefits

Robotic surgery has been reported to have several advantages [5, 8]. However, its clinical usefulness was not demonstrated definitively in this overview. While the included reviews consistently showed that the conversion rate to open surgery was significantly lower for robotic surgery than for laparoscopic surgery, robotic surgery required a longer operative time, which is inevitable because of the additional setup time. Almost all the reviews included in our overview found no significant between-group difference in postoperative complications or in prognosis. Some reviews indicated that robotic surgery enhanced postoperative recovery and improved quality of life, which suggests that it might have

clinical benefits in patients with rectal cancer. However, the quality of evidence to support robotic surgery for rectal cancer is low or critically low in the current systematic reviews, which likely reflects that most of the studies included in these meta-analyses did not have a randomized controlled design and that the methods used to perform a systematic review and meta-analysis potentially had shortcomings. High-quality reviews of high-quality studies that use appropriate methodology are needed to clarify the efficacy of robotic surgery for rectal cancer.

Strengths and limitations

This overview summarized all systematic reviews and meta-analyses identified by a comprehensive literature search of multiple electronic databases in an effort to present the most reliable evidence of the benefits of robotic surgery for patients with rectal cancer. Although we assessed the quality of the included reviews, we did not evaluate the quality of the studies included in each review; however, the quality of those studies would have depended on the quality of the review itself. Furthermore, there was a degree of overlap in some of the studies in the reviews included in this overview.

Conclusions

Critically low quality evidence suggests that the likelihood of conversion to an open procedure is lower for robotic surgery than for laparoscopic surgery when used to treat rectal cancer. Whether robotic surgery has additional clinical benefits remains unclear. Further high-quality studies are needed to clarify the efficacy of robotic surgery because the quality of a systematic review depends, to a large extent, on the number and quality of included studies. The quality of the evidence yielded by a systematic review can also be improved by appropriate methodology.

Compliance with ethical standards

Conflict of interest We have no conflicts of interest to declare.

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