REVIEW ARTICLE

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Operative and oncological outcomes after robotic rectal resection compared with laparoscopy: a systematic review and meta-analysis

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Abstract

Background: Most studies comparing robotic and laparoscopic surgery, show little difference in clinical outcomes to justify the expense. We systematically reviewed and pooled evidence from studies comparing robotic and laparoscopic rectal resection.
Method: Medical Literature Analysis and Retrieval System Online (MEDLINE), Excerpta Medica (EMBASE), and Cochrane databases were searched for studies between 1996 and 2021 comparing clinical outcomes between laparoscopic and robotic rectal surgeries involving total mesorectal excision. Outcome measures included operative times, conversions to open, complications, recurrence and survival rates.
Results: Fifty eligible studies compared outcomes between robotic and laparoscopic rectal resections; three were randomized trials. Pooled results showed significantly longer operating times for robotic surgery but lower conversion and complications rates, shorter lengths of stay in hospital, better rates of complete mesorectal resection and better three-year overall survival. However, the low number of randomized studies makes most data subject to bias.
Conclusion: Available evidence supports the safety and ongoing use of robotic rectal cancer surgery, while further high-quality evidence is sought to justify the expense.

Introduction

Minimally invasive surgery is increasingly preferred for rectal cancer treatment.[1] Although there is ongoing concern about oncological equivalence of laparoscopic resections compared to open[1,2] this has been combated by the faster, less painful recovery with better cosmesis and reduced intra-abdominal adhesions.[3–5]

Robotic-assisted laparoscopic surgery enables magnified, three-dimensional views and wristed instruments which promise to facilitate pelvic surgery, theoretically improving the quality of the dissection. This has spurred uptake of the platform for rectal cancer,[6] despite ongoing questions regarding the cost-benefits. Most studies show outcomes after robotic rectal resections to be equivalent, but not necessarily better than laparoscopy, with additional costs and longer operating times.[7] The aim of this study was to systematically review and pool all available data comparing post-operative and oncological outcomes between robotic and laparoscopic rectal resections.

Methods

Medical Literature Analysis and Retrieval System Online (MEDLINE), Excerpta Medica (EMBASE), and Cochrane databases were searched for studies between 1996 and 2020. MeSH search headings and keywords used included 'rectal' or 'rectum anterior resection', or 'rectum tumour', combined using 'AND' with 'robotic surgery' or 'robotic surgical procedures'. Reference lists of relevant studies were searched for relevant

Table 1 Summary characteristics of included studies

Authors (year)	Country	Study design	Total number of patients	Number or RS patients	Number of LS patients	Number of OS patients	Quality assessment†
Patriti *et al.* (2009)	Italy	CM	66	29	37	0	7/9
Bianchi *et al.* (2010)	Italy	PC	50	25	25	0	7/9
Popescu *et al.* (2010)	Romania	RC	122	38	84	0	6/9
Baek *et al.* (2011)	USA	CM	82	41	41	0	7/9
D'Annibale *et al.* (2013)	Italy	RC	100	50	50	0	6/9
Erguner *et al.* (2013)	Turkey	RC	64	27	37	0	7/9
Fernandez *et al.* (2013)	USA	RC	72	13	59	0	6/9
Kang *et al.* (2013)	Korea	CM	495	165	165	165	8/9
Barnajian *et al.* (2014)	USA	CM	60	20	20	20	8/9
Tam *et al.* (2014)	USA	RC	42	21	21	0	8/9
Young *et al.* (2014)	USA	RC	83	45	38	0	7/9
Cho *et al.* (2015)	Korea	CM	556	278	278	0	8/9
Park, JS (2015)	Korea	CM	212	106	106	0	8/9
Serin *et al.* (2015)	Turkey	RC	79	14	65	0	7/9
Allemann *et al.* (2015)	Switzerland	CM	60	20	40	0	8/9
Bedirli *et al.* (2016)	Turkey	RC	63	35	28	0	7/9
Corbellini *et al.* (2016)	Italy	PC	160	65	40	55	7/9
de Jesus *et al.* (2016)	Brazil	RC	300	59	41	200	6/9
Feroci *et al.* (2016)	Italy	RC	111	53	58	0	7/9
Kim, JC *et al.* (2016)	Korea	RC	2114	533	486	1095	6/9
Kim, YS *et al.* (2016)	Korea	CM	99	33	66	0	8/9
Morelli *et al.* (2016)	Italy	RC	75	50	25	0	6/9
Ramji *et al.* (2016)	Canada	RC	79	26	27	26	6/9
Yamaguchi *et al.* (2016)	Japan	RC	442	203	239	0	7/9
Huang *et al.* (2017)	Taiwan	CM	78	40	38	0	7/9
Ielpo *et al.* (2017)	Spain	RC	198	86	112	0	6/9
Kamali *et al.* (2017)	UK	RC	36	18	18	0	7/9
Kim, J *et al.* (2017)	Korea	CM	448	224	224	0	8/9
Law & Foo (2017)	Hong Kong	RC	391	220	171	0	6/9
Lim *et al.* (2017)	Korea	RC	138	74	64	0	7/9
Silva-Velazco *et al.* (2017)	USA	RC	488	66	118	304	6/9
Valverde *et al.* (2017)	France	RC	130	65	65	0	6/9
Wang *et al.* (2017)	China	RCT	137	71	66	0	3/5
Aselmann *et al.* (2018)	Germany	RC	85	44	41	0	7/9
Crolla *et al.* (2018)	Netherlands	RC	352	168	184	0	7/9
Esen *et al.* (2018)	Turkey	RC	178	100	78	0	6/9
Kim, MJ *et al.* (2018)	Korea	RCT	139	66	73	0	3/5
Panteleimonitis *et al.* (2017)	UK/Portugal	CM	124	63	61	0	8/9
Rouanet *et al.* (2018)	France	RC	400	200	200	0	8/9
Yang *et al.* (2018)	China	RC	300	91	102	107	7/9
Asklid *et al.* (2019)	Sweden	RC	119	72	47	0	7/9
Bo *et al.* (2019)	China	RC	1695	556	1139	0	8/9
Galata *et al.* (2019)	Germany	PC	51	18	33	0	8/9
Jayne *et al.* (2019)	Multi-centre	RCT	471	237	234	0	3/5
Liu *et al.* (2019)	China	RC	196	80	116	0	7/9
Megevand *et al.* (2019)	Italy	RC	70	35	35	0	7/9
Sugoor *et al.* (2019)	India	CM	168	84	84	0	8/9
Tejedor *et al.* (2019)	UK	CM	272	136	136	0	7/9
Asoglu *et al.* (2020)	Turkey	RC	79	14	65	0	6/9

Table 1 Continued

Authors (year)	Country	Study design	Total number of patients	Number or RS patients	Number of LS patients	Number of OS patients	Quality assessment†
Numata *et al.* (2020)	Japan	RC	88	32	56	0	8/9

†Quality assessment: Newcastle Ottawa Scale for non-randomized studies, Jadad scale for randomized studies.

CM, case-matched; LS, laparoscopic surgery; OS, open surgery; PC, prospective cohort; RC, retrospective cohort; RCT, Randomized controlled trial; RS, robotic surgery.

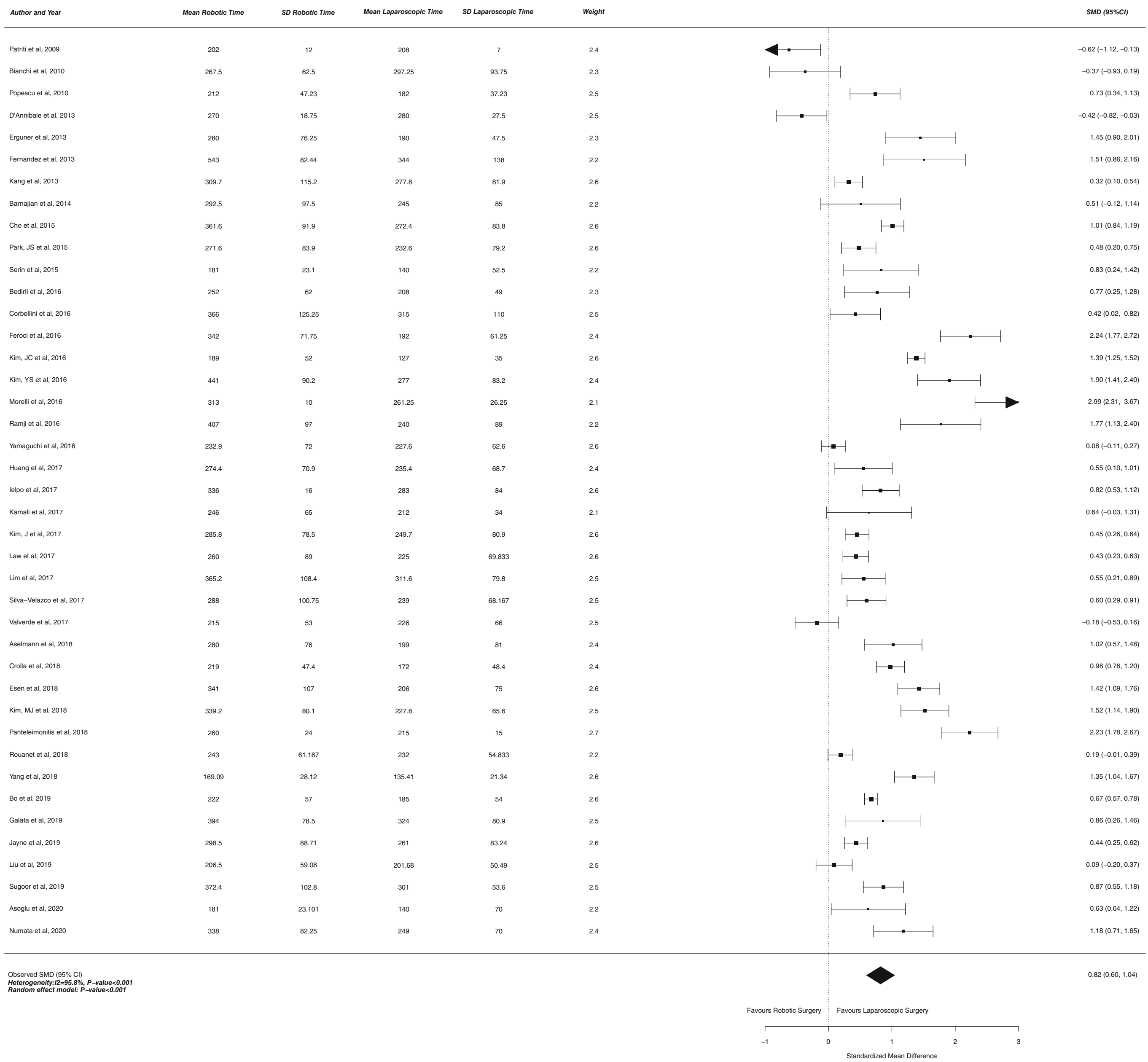

Fig. 1. Operative times. Pooled analysis of operative times. SD, standard deviation; SMD, standardized mean difference.

studies (full search strategy in Appendix S1). The last search was undertaken on 8 February 2021; by the primary investigators (JF, JL).

Included studies compared laparoscopic and robotic rectal mesorectal excision (TME), namely anterior resection or abdominoperineal resection. Adult studies reporting at least one outcome of

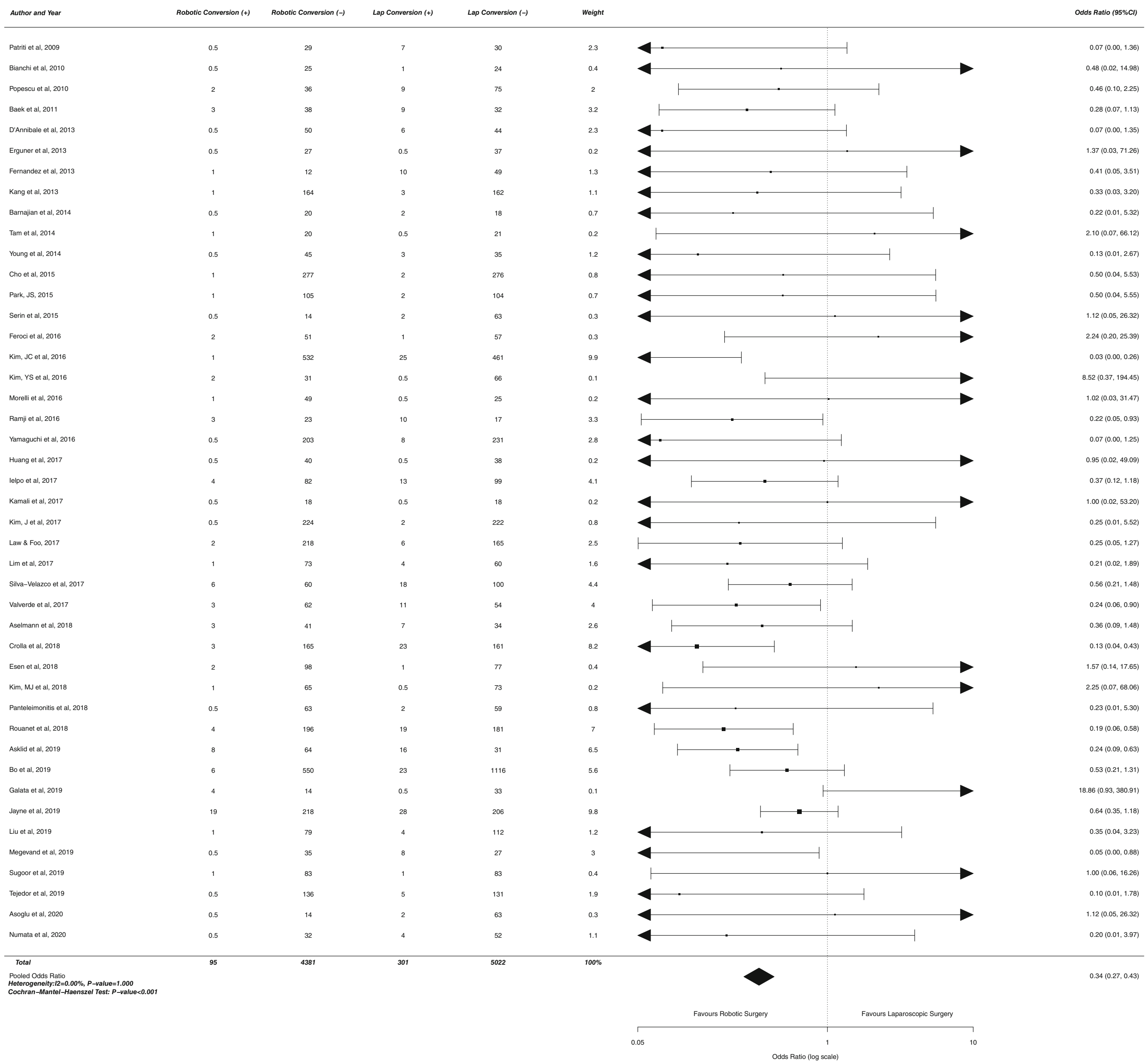

Fig. 2. Conversion to open surgery. Pooled analysis of rates of conversion to open surgery.

interest were included. Outcomes of interest included operating times, blood loss, conversion to open, time to return of bowel function and oral intake, complications, length of hospital stay and unplanned readmission. Pathological and oncological outcomes of interest included number of lymph nodes harvested, rates of incomplete resection (circumferential resection margin (CRM) less than 1 mm or incomplete TME graded by pathologist as involving the muscularis propria or intramesorectal plane), and survival. Only studies published in the English language were included. Case reports, case series or trials published only in abstract form were excluded. Study quality was assessed by two authors (JF, JL) using the Newcastle Ottawa Scale for non-randomized studies[8] or the Jadad scale[9] for randomized studies, with any discrepancies resolved on discussion with senior authors (AH and SW).

Statistical analysis

Categorical data were collected as absolute numbers and continuous data as means with standard deviation. Cochran–Mantel–Haenszel test was performed to pool categorical data as odds ratio (OR) with 95% confidence interval (CI) whereas a random effect model pooled continuous data to generate standard mean difference between the two groups. I^2 statistic assessed study heterogeneity. A P-value of <0.05 was considered significant. All data analysis was

Author and Year	Robotic Complications (+)	Robotic Complications (−)	Lap Complications (+)	Lap Complications (−)	Weight	Odds Ratio (95%CI)
Patriti et al, 2009	9	20	7	30	0.5	1.93 (0.62, 6.02)
Bianchi et al, 2010	4	21	6	19	0.5	0.60 (0.15, 2.47)
Popescu et al, 2010	6	32	13	71	0.8	1.02 (0.36, 2.94)
Baek et al, 2011	9	32	11	30	1	0.77 (0.28, 2.11)
D'Annibale et al, 2013	5	45	11	39	1.2	0.39 (0.13, 1.23)
Erguner et al, 2013	3	24	8	29	0.7	0.45 (0.11, 1.90)
Fernandez et al, 2013	13	0.5	37	22	0.1	15.46 (0.87, 273.61)
Kang et al, 2013	34	131	46	119	4.3	0.67 (0.40, 1.12)
Barnajian et al, 2014	8	12	2	18	0.1	6.00 (1.08, 33.27)
Tam et al, 2014	9	12	7	14	0.4	1.50 (0.43, 5.25)
Young et al, 2014	13	32	13	25	1.2	0.78 (0.31, 1.98)
Cho et al, 2015	72	206	66	212	5.7	1.12 (0.76, 1.65)
Park, JS, 2015	20	86	32	74	3	0.54 (0.28, 1.02)
Serin et al, 2015	2	12	16	49	0.6	0.51 (0.10, 2.53)
Allemann et al, 2016	8	12	14	26	0.7	1.24 (0.41, 3.74)
Bedirli et al, 2016	9	26	11	17	1.1	0.53 (0.18, 1.56)
Corbellini et al, 2016	19	46	12	28	1.2	0.96 (0.41, 2.28)
Feroci et al, 2016	17	36	26	32	2	0.58 (0.27, 1.26)
Kim, JC et al, 2016	65	468	63	423	6.8	0.93 (0.64, 1.35)
Kim, YS et al, 2016	15	18	26	40	1.1	1.28 (0.55, 2.98)
Morelli et al, 2016	28	22	16	9	1.1	0.72 (0.27, 1.93)
Ramji et al, 2016	26	0.5	24	3	0.1	6.50 (0.31, 136.55)
Yamaguchi et al, 2016	18	185	54	185	5.3	0.33 (0.19, 0.59)
Huang et al, 2017	6	34	7	31	0.7	0.78 (0.24, 2.58)
Ielpo et al, 2017	20	66	25	87	1.9	1.05 (0.54, 2.06)
Kim, J et al, 2017	77	147	56	168	4.3	1.57 (1.04, 2.37)
Law & Foo, 2017	44	176	38	133	4	0.88 (0.54, 1.43)
Silva–Velazco et al, 2017	26	40	52	66	2.6	0.83 (0.45, 1.52)
Valverde et al, 2017	27	38	32	33	2.2	0.73 (0.37, 1.46)
Aselmann et al, 2018	18	26	30	11	2.1	0.25 (0.10, 0.63)
Crolla et al, 2018	71	97	111	73	7.2	0.48 (0.31, 0.74)
Esen et al, 2018	23	77	19	59	1.9	0.93 (0.46, 1.86)
Kim, MJ et al, 2018	23	43	17	56	1.2	1.76 (0.84, 3.70)
Rouanet et al, 2018	51	149	48	152	4.2	1.08 (0.69, 1.71)
Yang et al, 2018	7	84	13	89	1.3	0.57 (0.22, 1.50)
Bo et al, 2019	83	473	195	944	12.7	0.85 (0.64, 1.12)
Galata et al, 2019	6	12	12	21	0.7	0.87 (0.26, 2.93)
Jayne et al, 2019	78	159	73	161	5.8	1.08 (0.73, 1.59)
Liu et al, 2019	6	74	24	92	2.1	0.31 (0.12, 0.80)
Megevand et al, 2019	12	23	20	15	1.5	0.39 (0.15, 1.03)
Sugoor et al, 2019	16	68	16	68	1.5	1.00 (0.46, 2.16)
Asoglu et al, 2020	2	12	16	49	0.6	0.51 (0.10, 2.53)
Numata et al, 2020	7	25	30	26	2	0.24 (0.09, 0.65)
Total	***1015***	***3302***	***1355***	***3848***	***100%***	
Pooled Odds Ratio						0.84 (0.76, 0.92)

Heterogeneity:I2=46.5%, P–value<0.001

Cochran–Mantel–Haenszel Test: P–value<0.001

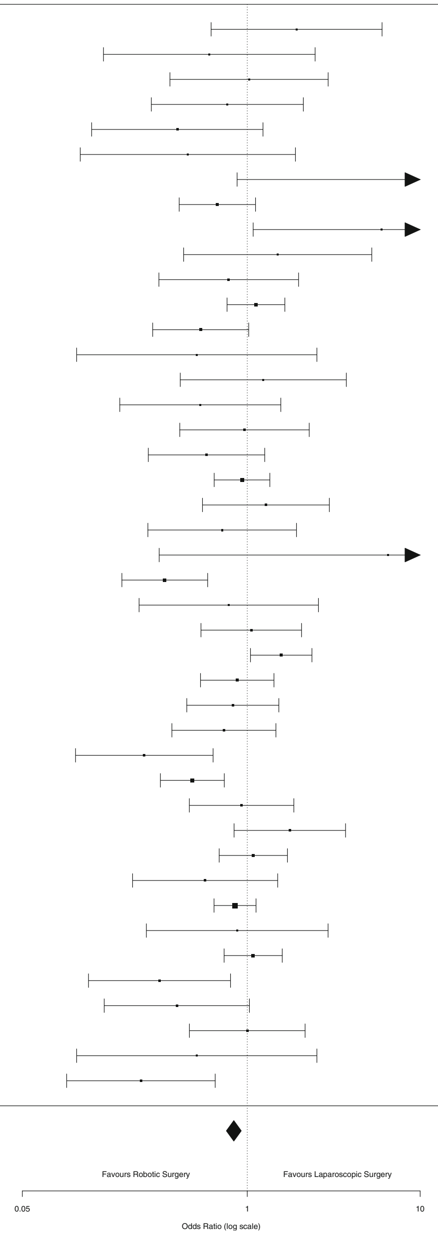

Fig. 3. Complications. Pooled analysis of rates of complications.

performed (by JK with design and analysis contribution by PW) in R Studio Team (2015) and using the metaphor package for meta-analysis.[10] Ethical review board approval was not required.

Results

The initial search identified 1777 studies. Review of titles and/or abstracts reduced this to 101 papers which were assessed for eligibility, with 50 papers included in the final analysis[7,11–59] (Appendix S2 PRISMA flow chart). Thirty-one studies were retrospective cohort studies, with three randomized trials, 13 case-matched studies and three prospective cohort studies. This incorporated a total of 4809 robotic and 5636 laparoscopic procedures. Study characteristics are summarized in Table 1.

Demographics of study participants such as mean age, gender, BMI and ASA between robotic and laparoscopic procedures were similar in most studies (Appendix S3). However, the distance of the tumour from the anal verge varied across the studies; and in four, tumours were statistically significantly more distal in robotic procedures.

Intra-operative and post-operative outcomes

Operative times were significantly shorter for laparoscopic surgery (SMD 0.82, $P < 0.001$) (Fig. 1). Conversion and complication rates were significantly lower for robotic surgery (OR 0.34, $P < 0.001$)

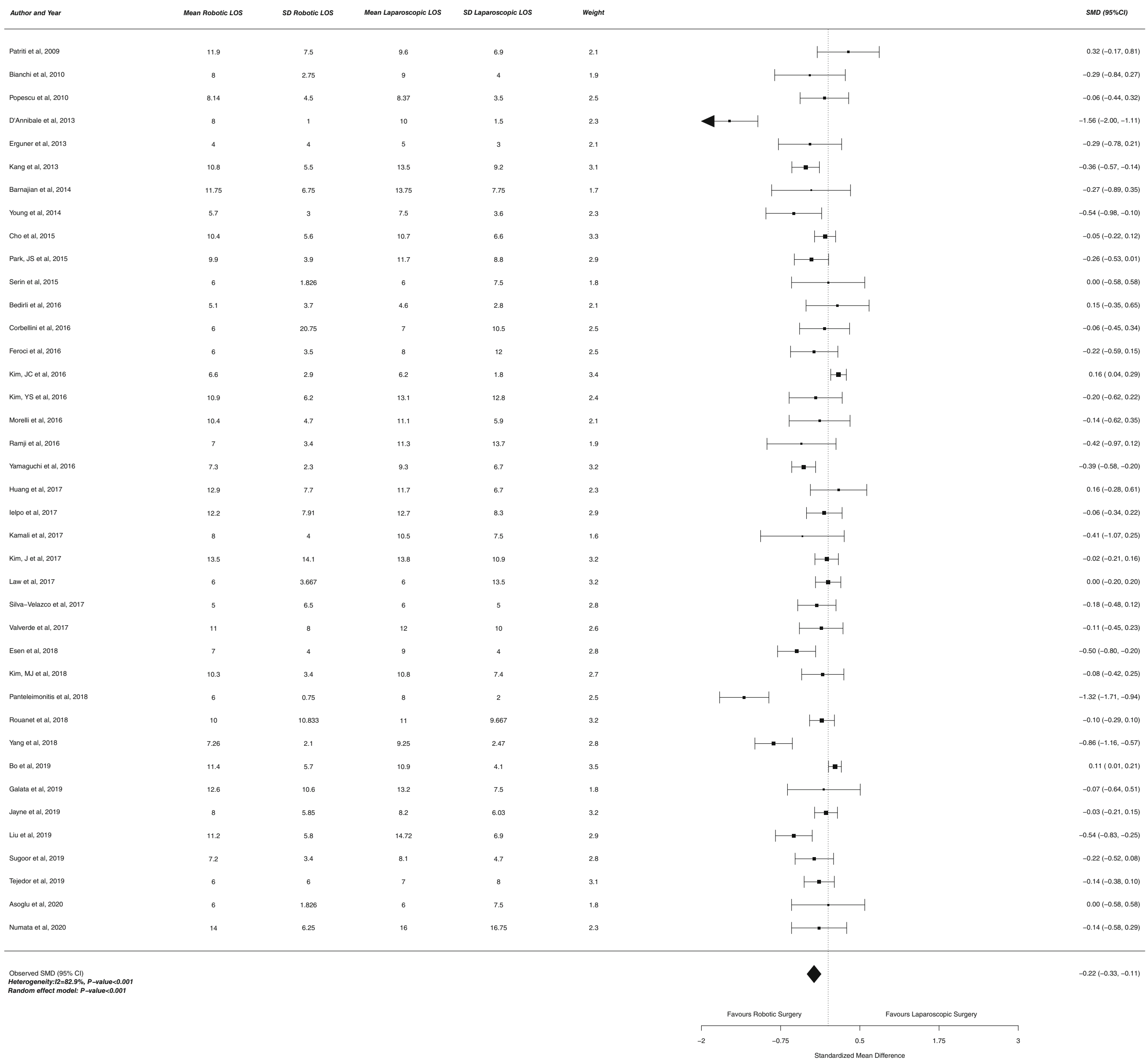

Fig. 4. Length of stay in hospital. Pooled analysis of mean length of stay in hospital, in days. LOS, length of stay; SD, standard deviation; SMD, standardized mean difference.

(Fig. 2) and (OR 0.84, $P < 0.001$) (Fig. 3) and length of hospital stay was shorter (SMD 0.22, $P < 0.001$) (Fig. 4). Robotic surgery was associated with lower rates of anastomotic leak, surgical site infection and post-operative urinary retention, but no significant differences in estimated intra-operative blood loss, post-operative ileus, intra-abdominal abscess or 90-day reoperation (see Appendices S4–S10). There was no difference in time to flatus (Appendix S11).

Oncological and long-term clinical outcomes

Rates of complete TME were higher in robotic surgery (OR 0.51, $P < 0.001$) (Fig. 5) but there was no significant differences in number of lymph nodes harvested, rates of intact CRM or rates of adequate distal margin resection (Appendices S12–S14).

There was no significant difference local recurrence (Appendix S15) or 3-year disease-free survival (RR 0.94, $P = 0.386$) (Fig. 6) but slightly higher overall survival after robotic surgery (RR 0.79, $P = 0.023$) (Fig. 7).

Discussion

This is the largest study of its kind, pooling all available data comparing robotic and laparoscopic outcomes for rectal resections.

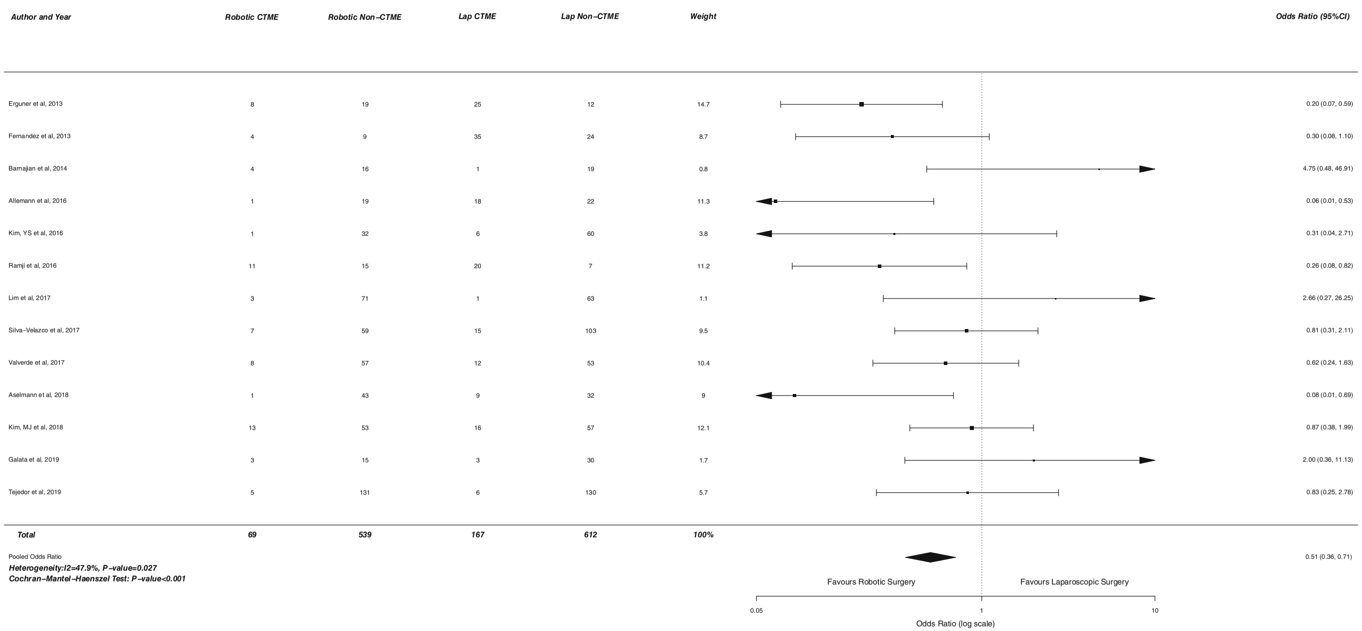

Fig. 5. Complete mesorectal excision. Pooled analysis of rates of complete mesorectal excision. CTME, complete total mesorectal excision.

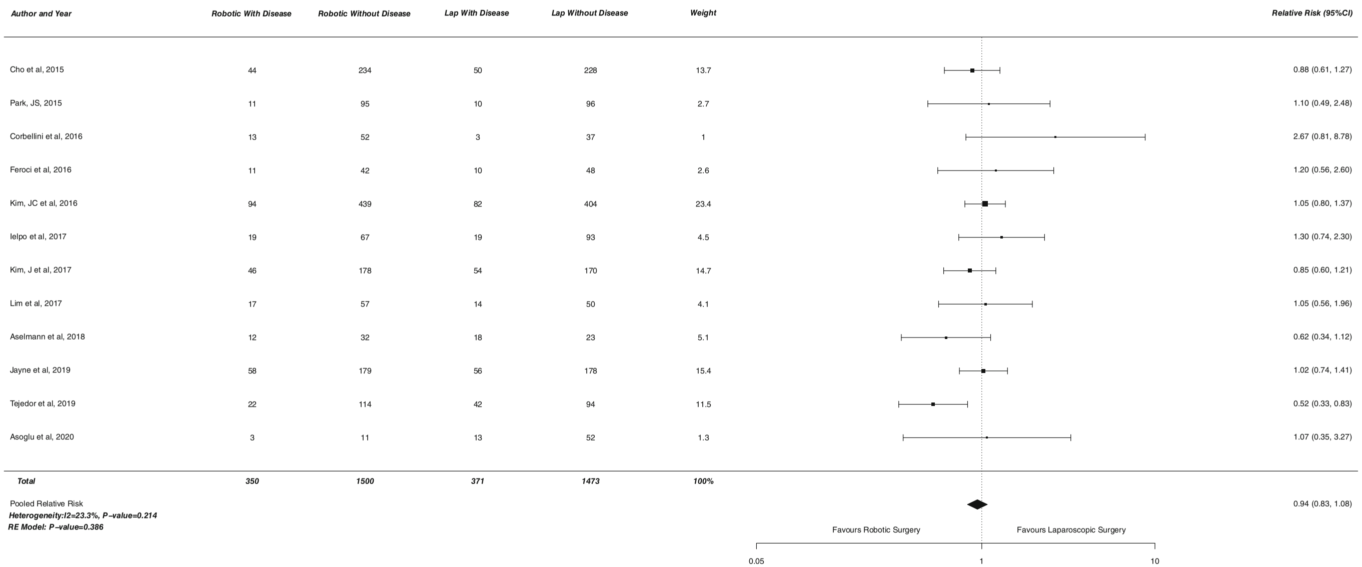

Fig. 6. Three-year disease-free survival. Pooled analysis of three-year disease-free survival.

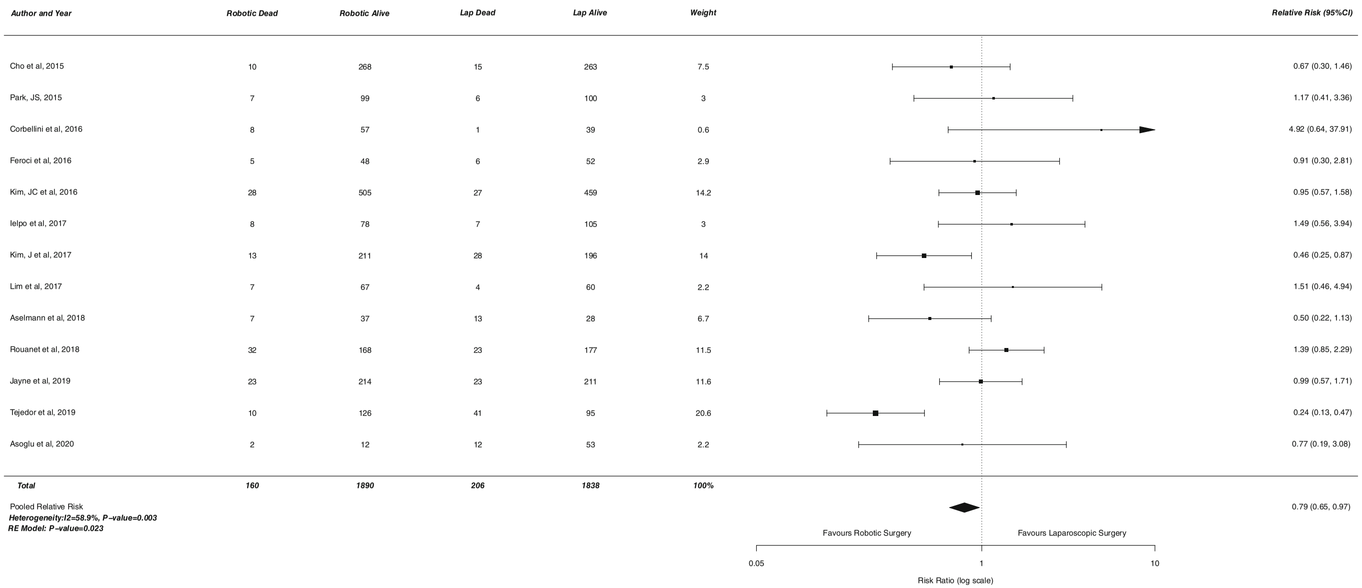

Fig. 7. Three-year overall survival. Pooled analysis of three-year overall survival.

Unsurprisingly, laparoscopic surgery is faster than robotic. All other significant differences were in favour of robotic surgery, with lower rates of conversion to open, and complications as well as shorter length of stay in hospital, better rates of complete mesorectal excision and better overall 3-year survival.

Longer operating time has been an almost universal finding[7,56,58] carrying increased risk of anaesthetic complications as well as reducing case numbers and therefore cost-effectiveness. The impact of additional steps required for robotic surgery such as docking is minimized with experience[60] and improvements to the platform.[61]

The increased costs of robotic surgery may be offset to some extent by fewer conversions to open surgery, reductions in length of stay in hospital and lower complication rates, but remains a key barrier to uptake. Greater clinical benefits are needed to justify the robotic platform as the modality of choice for rectal cancer surgery.

Limitations

The small number of randomized studies comparing robotic and laparoscopic rectal surgery renders data susceptible to selection bias. One might expect surgeons to choose easier cases for a newer technique; however baseline characteristics in these studies appeared equal aside from three studies with more males in the robotic arm,[21,39,41] one study with more males in the laparoscopic arm[29]; two studies[21,41] with significantly higher BMIs in the robotic arm; and four studies[11,20,30,51] with lower average tumour heights in the robotic arm, mostly suggesting the robotic platform was favoured for more difficult cases (see Appendix S3).

Conclusion

This meta-analysis comparing robotic to laparoscopic rectal cancer resections supports the safety of ongoing use of the robotic platform for rectal cancer surgery, though it remains unclear whether the modest clinical advantages justify the additional expense of robotic surgery at this point in the evolution of this technology.

Author contributions

Flynn & Larach: Study design, literature search, data consolidation, data interpretation and writing of manuscript. **Kong & Waters**: Study design, statistical analysis, data interpretation, editing of manuscript. **Rahme**: Study design, literature review, writing of manuscript. **Warrier & Heriot**: Study design, resolution of discrepancies in study inclusion and qualities, editing of manuscript.

Conflict of interest

Julie Flynn has no conflicts of interest or financial ties to disclose. Jose T. Larach educational grant funded by Intuitive Surgical. Joseph C. H. Kong has no conflicts of interest or financial ties to disclose. Peadar S. Waters has no conflicts of interest or financial ties to disclose. Satish K. Warrier honorarium for proctoring robotic cases. Alexander Heriot has no conflicts of interest or financial ties to disclose.

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Supporting information

Additional Supporting Information may be found in the online version of this article at the publisher's web-site:

Appendix S1: Full search strategy
Appendix S2: PRISMA flow chart of studies selection
Appendix S3: Demographics. LS: laparoscopic surgery; OS: open surgery; NS: not statistically significant; NR: not reported; SD: standard deviation; RS: robotic surgery. * Mean (SD) or median (range). **Interquartile range
Appendix S4: Anastomotic leak
Appendix S5: Surgical site infection. SSI: Surgical Site Infection
Appendix S6: Post-operative urinary retention. UR: Urinary Retention
Appendix S7: Estimated blood loss. SD: Standard Deviation; SMD: Standardized Mean Difference; EBL: Estimated Blood Loss
Appendix S8: Post-operative ileus
Appendix S9: Intra-abdominal abscess. IA: Intra-Abdominal Abscess
Appendix S10: Reoperation within 90 days. RTT: Return to Theatre/Reoperation
Appendix S11: Time to flatus after surgery. SD: Standard Deviation. SMD: Standardized Mean Difference
Appendix S12: Number of lymph nodes harvested. SD: Standard Deviation. SMD: Standardized Mean Difference. LN: Lymph nodes
Appendix S13: Adequate (>1 mm) circumferential resection margin. CRM: Circumferential Resection Margin
Appendix S14: Length of distal resection margin. SD: Standard Deviation
SMD: Standardized Mean Difference. DM: Distal Resection Margin
Appendix S15: Local tumour recurrence. LR: Local Tumour Recurrence