Cost-comparison of robotic versus laparoscopic colorectal resections: a mapped systematic review and meta-analysis of published studies

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Background: Robotic colorectal resections (RCR) have been gaining popularity recently due to several advantages in addition to oncological safety. The objective of this review is to evaluate the cost comparison of RCR versus laparoscopic colorectal resections (LCR).

Methods: All types of comparative studies reporting the cost of RCR versus LCR were retrieved from the search of standard medical electronic databases and analysis was conducted by using the principles of meta-analysis on the statistical software RevMan version 5.

Results: The search of medical databases yielded 13 studies (one randomised trial and 12 comparative studies) on 16,082 patients undergoing oncological and non-oncological colorectal resections. Eleven studies reported total cost whereas seven studies reported only operative cost. In the random effects model analysis, LCR was associated with the reduced total cost [standardised mean difference −62.34, 95% confidence interval (CI): −75.14 to −49.54, Z=9.55, P<0.001] as well as reduced operative cost (standardised mean difference −4.60, 95% CI: −5.90 to −3.31, Z=6.96, P<0.001) compared to RCR. However, there was significant heterogeneity [Tau^2=346.74, Chi^2=29,559.11, df =11 (P<0.001; I^2=100%); Tau^2=2.73, Chi^2=832.21, df =6 (P<0.001; I^2=99%)] among included studies.

Conclusions: The LCR seems to be more economical as compared to the RCR in terms of operative cost as well as total cost (operative plus in-patient stay). However, due to statistically significant heterogeneity among included studies and paucity of the randomised trials, these findings should be taken cautiously.

Keywords: Laparoscopic colorectal surgery (LCR); robotic colorectal surgery (RCR); cost analysis

Received: 18 September 2023; Accepted: 26 February 2024; Published online: 17 April 2024.
doi: 10.21037/tgh-23-73
View this article at: https://dx.doi.org/10.21037/tgh-23-73

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Introduction

Colorectal cancers are the third most diagnosed cancer worldwide (1). In the UK alone there are 42,000 new cases diagnosed every year (2). Risk factors for these colon cancers can include male sex, advanced age, familial history and lifestyle preferences (3). These patients undergoing colorectal resections for locally advanced tumours have poor survival rate and is also associated with high rates of recurrence in patients undergoing treatment with a curative intent (4,5).

Colorectal resections involve removing the pathological part of the bowel. Sometimes, it may involve removing the entire colon and/or rectum. Laparoscopic colorectal surgeries have shown to be superior when compared to the open approach, especially in emergency scenarios (6,7). The laparoscopic approach has been shown to be superior to the open approach in terms of post-operative pain, faster recovery, shorter hospital stays and better cosmesis (8,9). The laparoscopic approach is also reported to be a feasible and safe option for patients with underlying colorectal cancer (10). In 2006, Pigazzi *et al.* described a robotic approach for colorectal resections which showed to have a better 3D vision, wristed instruments offering better manoeuvrability in the pelvis and tremor abolition (11). Since the advent of robotic assistance in colorectal resections, multiple studies have been done comparing post-operative outcomes of robotic colorectal resections (RCR) versus laparoscopic colorectal resections (LCR). Some have shown that RCR is superior to LCR (12,13). A network meta-analysis done by Seow *et al.* showed that RCR offers better distal resection margin distance and a shorter length of hospital stay (14). But, on the other hand, there have been trials like COLRAR (15), which have shown no significant operative advantage.

In this systematic review, we explored the financial implications of these two approaches. This is important for patients and decreasing the cost of healthcare. This systematic review will compare the total and operative costs of LCR and RCR. We present this article in accordance with the PRISMA reporting checklist (available at https://tgh.amegroups.com/article/view/10.21037/tgh-23-73/rc).

Highlight box

Key findings

- Laparoscopic colorectal resections (LCR) seem to be more economical as compared to robotic colorectal resections (RCR) in terms of operative cost as well as total cost.

What is known and what is new?

- Debate for the superiority of RCR over LCR in terms of perioperative outcomes
- In the random effects model analysis, LCR was associated with reduced total cost as well as reduced operative cost.

What is the implication, and what should change now?

- Concurrent use of this study along with the suitable cohort of the patients and previously published data on the postoperative outcome comparison, can help surgeons make better decisions considering the cost for the hospital and patient.

Methods

Data sources and literature search technique

The literature review was methodically carried out from electronic databases like MEDLINE, EMBASE, PubMed and Cochrane Library using the MeSH search terms. Boolean operators (AND, OR, NOT) were used for extended search results. The titles were carefully screened for study selection. Moreover, references from shortlisted articles were examined to find additional relevant studies.

Trial selection

The trial selection period was limited to between the year 2010–till date. The primary inclusion criteria for the meta-analysis were the cost comparison of LCR versus RCR. The exclusion criteria for this meta-analysis were the studies without available cost data. The availability of the cost incurred for colorectal resections to the hospital was considered the only endpoint for this meta-analysis.

Data collection and management

Reported data were collected from the included trials by independent investigators on a standard data extraction form. The collected dataset was matched and found to be in satisfactory inter-reviewer agreement. The extracted data consisted of a list of the authors, title of the published study, journal of publication, country and year of the publication, sample size, patients in each group and total/operative cost. Following data extraction, the reviewers went through discussing their respective results and a consensus of mutual agreement was reached on likely discrepancies.

Table 1 Quality of included randomised control trial

Variables	Park 2019, (19)
Randomization technique	Computer generated
Concealment	Sealed envelope
Blinding	Single
Intention to treat analysis	Reported
Ethical approval	Reported
Registration number	NCT01423214
Power calculation	Reported, not achieved

Quality of analysis

The methodological quality of the included randomised control trials was assessed using the published guidelines of Jadad *et al.*, Chalmers *et al.* and Rangel *et al.* (16-18). A comprehensive table for the assessment of the quality of the included randomised control trial is given in *Table 1*. The quality of the comparative trials was assessed by the Scottish Intercollegiate Guidelines Network and Rangel *et al.* (18), and shown in *Table 2*.

Statistical analysis

Statistical analysis was performed using RevMan 5.4 (Review Manager 5.4, The Nordic Cochrane Centre, Copenhagen, Denmark). The standard mean difference and a confidence interval (CI) of 95% were used for continuous data and a random-effects model (32,33) was used. Heterogeneity was calculated by inspecting the forest plots and by computing the Chi^2 test, with significance set at $P<0.05$ as well as using the I^2 test with a maximum value of 30 percent identifying low heterogeneity (34). For the sensitivity analysis, in each cell frequency, 0.5 was added in the studies where no event occurred in either the treatment or control group, as per the guidelines recommended by Deeks *et al.* (35). The inverse-variance method was used for the calculation of standard mean difference under the random effect model analysis. If the standard deviation was not available, then the risk of bias was calculated according to the guidelines provided by the Cochrane Collaboration (32). This process assumed that both groups had the same variance, which may not have been true, and variance was either estimated from the range or from the P value. The estimate of the difference between both techniques was pooled, depending upon the effect weights in results determined by each trial estimate variance. A forest plot was used for the graphical display of the results. The square around the estimate stood for the accuracy of the estimation (sample size), and the horizontal line represented the 95% CI.

Results

The initial database search for cost comparison between laparoscopic and RCR generated 21 studies. After excluding duplication and undesirable studies we were left with 13 studies, 11 studies were used in total cost comparison and 7 were used in operative cost comparison. One study was used twice as it had separate comparisons for diverticulitis and colon cancers (27) (*Figure 1*).

Characteristics and demographics of included studies

Twelve comparative trials (20-31) and one randomized controlled trial (RCT) (19) on 16,082 patients were included to conduct this meta-analysis for comparing total cost and operative cost of robotic versus laparoscopic colorectal surgeries, based upon the principles provided by the Cochrane Collaboration. Seven studies were from the USA (20,22,23,26,28,29,31), two were from Korea (19,21), two were from Italy (25,27), one was from Taiwan region (30) and one was from Germany (24). Mean age and gender were also noted in these studies. The PRISMA flow chart for trial selection is given in *Figure 1*. The main characteristics of the included studies are given in *Table 3*. The treatment protocol used in each is given in *Table 4*.

Methodological quality of included studies

The methodological quality of included trials is summarized in *Tables 3,4*. The randomization in RCT was performed through a computer-generated random number, and the concealment was ensured with the help of sealed envelopes. The trial was a single-blind RCT. The quality of the 13 comparative studies (retrospective & prospective) was analysed by using the Scottish Intercollegiate Guidelines Network and Rangel *et al.* (18), and 12 studies were found to have fair quality (20-31).

The outcome of the primary variable

In the analysis, the use of LCR seems to be more

Table 2 Quality of included comparative trials

Quality variables	Al-Mazrou 2018, (20)	Baek 2012, (21)	Ezeokoli 2023, (22)	Hollis 2016, (23)	Gebhardt 2022, (24)	Merola 2020, (25)	Moghadamyeghaneh 2016, (26)	Morelli 2016, (27)	Roskam 2023, (28)	Vasudevan 2016, (29)	Wei 2023, (30)	Wlodarczyk 2023, (31)
Inclusion criteria	1	1	1	0	1	1	1	1	1	1	1	1
Exclusion criteria	0	0	1	0	1	0	0	1	0	1	1	1
Demographics comparable	1	1	0	1	0	1	1	1	1	0	1	0
Can the number of participating centres be determined	1	0	0	0	1	0	0	0	0	1	0	1
Can the number of surgeons who participated be determined	0	0	0	0	1	0	0	0	0	1	0	0
Can the reader determine where the authors are on the learning curve for the reported procedure	0	1	0	1	1	0	0	0	0	1	0	0
Are diagnostic criteria clearly stated for clinical outcomes if required	1	0	0	0	0	0	0	0	1	1	0	0
Is the surgical technique adequately described	1	0	1	1	1	1	1	1	1	1	1	0
Is there any way that they have tried to standardize the operative technique	0	0	1	1	1	1	1	1	1	1	1	1
Is there any way that they have tried to standardize perioperative care	1	0	0	0	1	0	0	0	1	1	0	1
Is the age and range given for patients in the laparoscopic group	1	1	1	1	1	1	1	1	1	1	1	1
Do authors address whether there is any missing data	0	0	0	0	0	1	1	1	1	1	1	1
Is the age and range given for patients in the robotic group	1	1	1	1	1	1	1	1	1	1	1	1
Were patients in each group treated along similar timelines	0	1	1	1	1	1	1	1	0	0	1	1
Did all the patients asked to enter the study take part	0	0	0	0	0	0	0	0	0	0	0	0
Dropout rates stated	0	0	0	0	0	0	0	0	0	0	0	0
Outcomes clearly defined	0	1	1	1	1	0	0	0	1	0	0	0
Blind assessors	0	0	0	0	0	0	0	0	0	0	0	0
Standardised assessment tools	0	1	1	0	1	0	0	0	1	0	0	1
Analysis by intention to treat	0	0	0	0	0	0	0	0	0	0	1	0
Score	8	8	9	8	13	8	8	9	11	12	10	10

economical in terms of total and operative costs. In the random effects model analysis, LCR was associated with the reduced total cost [standardised mean difference −62.34, 95% CI: −75.14 to −49.54, Z=9.55, P<0.001] as well as reduced operative cost [standardised mean difference −4.60, 95% CI: −5.90 to −3.31, Z=6.96, P<0.001] compared to RCR. However, there was significant heterogeneity (Tau^2=346.74; Chi^2=29,559.11, df=11; (P<0.001; I^2=100%) (Tau^2=2.73; Chi^2=832.21, df=6; (P<0.001; I^2=99%) among included studies (*Figures 2,3*).

Discussion

Key findings

The review of medical databases resulted in thirteen studies (one RCT and 12 retrospective studies) on 16,082 patients undergoing oncological and non-oncological colorectal resections. Eleven studies reported total cost whereas seven studies reported only operative cost. The LCR seems to be more economical compared to RCR in terms of operative cost as well as total cost (operative plus in-patient stay).

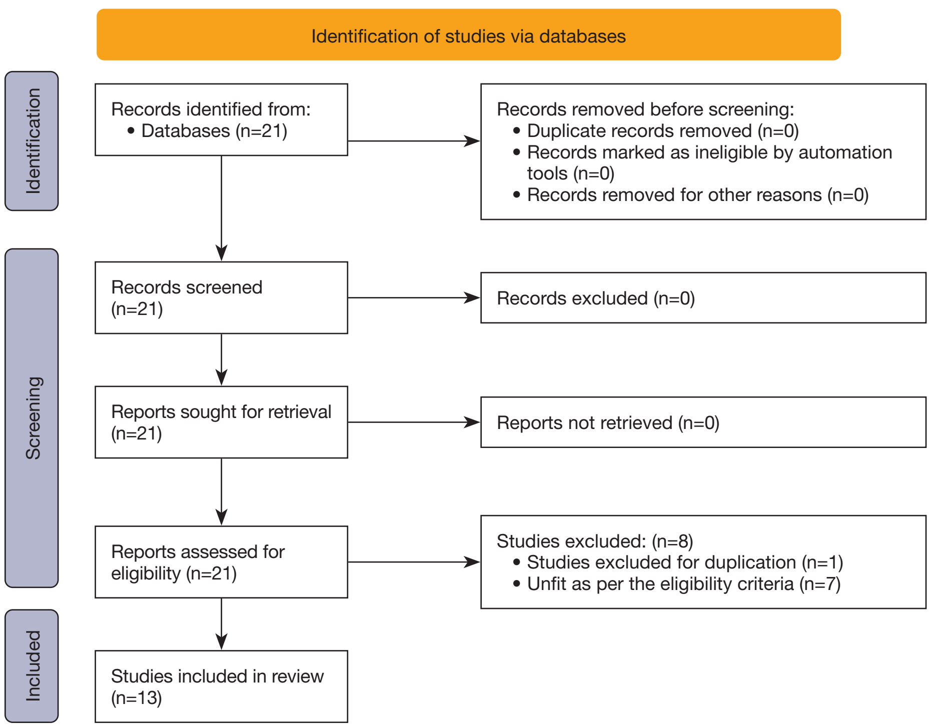

Figure 1 PRISMA flowchart.

Table 3 Characteristics of included studies

Study	Country/region	Study type	N	Age (years), mean ± SD	Gender (men) (%)
Al-Mazrou 2018, (20)	USA	Retrospective study			
Laparoscopic			2,219	63±16.6	55
Robotic			2,219	64±16.6	54.4
Baek 2012, (21)	Korea	Prospective study			
Laparoscopic			150	62.3±10.9	72.7
Robotic			154	59.1±12.2	68.2

Table 3 *(continued)*

Table 3 *(continued)*

Study	Country/region	Study type	N	Age (years), mean ± SD	Gender (men) (%)
Ezeokoli 2023, (22)	USA	Retrospective study			
Laparoscopic			258	66.4±15.5	42
Robotic			240	64.9±12.4	53
Gebhardt 2022, (24)	Germany	Retrospective study			
Laparoscopic			38	37±12	52.6
Robotic			29	39±15	44.8
Hollis 2016, (23)	USA	Retrospective study			
Laparoscopic			67	57.9*	50.8
Robotic			45	58.4*	42.2
Merola 2020, (25)	Italy	Retrospective study			
Laparoscopic			94	72.09±9.54	64.89
Robotic			94	69.41±10.31	63.82
Moghadamyeghaneh 2016, (26)	USA	Retrospective study			
Laparoscopic			9,614	48±17	46.1
Robotic			326	46±18	51.1
Morelli 2016, (27)	Italy	Retrospective study			
Laparoscopic			25	68.9±11.5	60
Robotic			50	68.8±10.7	66
Park 2019, (19)	South Korea	Randomized control trial			
Laparoscopic			36	67.2±10.1	68.8
Robotic			35	65.5±11.4	64.2
Roskam, (a) 2023, (28)	USA	Retrospective study			
Laparoscopic			8	58.8±5.7	NR
Robotic			14	63.4±11.5	NR
Roskam, (b) 2023, (28)	USA	Retrospective study			
Laparoscopic			8	60.2±9.8	NR
Robotic			14	58.8±5.7	NR
Vasudevan 2016, (29)	USA	Retrospective study			
Laparoscopic			131	70.9±13.4	49
Robotic			96	63.6±12.7	51
Wei 2023, (30)	Taiwan	Retrospective study			
Laparoscopic			49	66.2±12.5	38.77
Robotic			17	63.4±12.0	41.17
Wlodarczyk 2023, (31)	USA	Retrospective study			
Laparoscopic			33	66.5±15.5	18.2
Robotic			19	66.8±16.0	10.5

*, average age from the data available using Microsoft Bing AI. N, number; SD, standard deviation; NR, not reported.

Table 4 Treatment protocol for included trial

Study	Laparoscopic [%]	Robotic [%]
Al-Mazrou 2018, (20)	Diagnosis—neoplasm [91.3], diverticular disease [6.9] and others [1.8]	Diagnosis—neoplasm [91.5], diverticular disease [6.8] and others [1.7]
	Procedures—colectomy [52.8], sigmoidectomy [17.9], AR [28.6], APR [13.3], rectal procedures [4.2] and other [1.1]	Procedures—colectomy [53], sigmoidectomy [16.7], AR [28.9], APR [12.5], rectal procedures [4.4] and other [1.2]
Baek 2012, (21)	Diagnosis—neoplasm [100]	Diagnosis—neoplasm [100]
	Procedures—AR [86.7], APR [2.7] and others [10.6]	Procedures—AR [69.4], APR [7.1] and others [23.5]
Ezeokoli 2023, (22)	Diagnosis—neoplasm [100]	Diagnosis—neoplasm [100]
	Procedures—colectomy [82], rectal procedures [16] and others [4]	Procedures—colectomy [63], rectal procedures [34] and others [3]
Gebhardt 2022, (24)	Diagnosis—IBD [100]	Diagnosis—IBD [100]
	Procedures—colectomy [100]	Procedures—colectomy [100]
Hollis 2016, (23)	Diagnosis—neoplasm [52.2], IBD [11.9], diverticular disease [14.9] and others [20.9]	Diagnosis—neoplasm [75.6], IBD [15.6] and diverticular disease [8.9]
	Procedures—colectomy [79.1], AR [17.9], APR [1.5] and others [1.5]	Procedures—colectomy [17.8], AR [60], APR [15.6] and others [6.6]
Merola 2020, (25)	Diagnosis—neoplasm [100]	Diagnosis—neoplasm [100]
	Procedures—colectomy [100]	Procedures—colectomy [100]
Moghadamyeghaneh 2016, (26)	Diagnosis—neoplasm [31.2], IBD [38.9], diverticular disease [3.8] and others [26.1]	Diagnosis—neoplasm [39.9], IBD [46.4], and others [13.7]
	Procedures—colectomy [100]	Procedures—colectomy [100]
Morelli 2016, (27)	Diagnosis—neoplasm [100]	Diagnosis—neoplasm [100]
	Procedures—AR [84], APR [8] and others [8]	Procedures—AR [64], APR [14] and others [22]
Park 2019, (19)	Diagnosis—neoplasm [100]	Diagnosis—neoplasm [100]
	Procedures—AR [81.5], APR [2.1] and others [16.4]	Procedures—AR [73.5], APR [3.3] and others [23.2]
Roskam (a) 2023, (28)	Diagnosis—neoplasm [100]	Diagnosis—neoplasm [100]
	Procedures—sigmoidectomy [100]	Procedures—sigmoidectomy [100]
Roskam (b) 2023, (28)	Diagnosis—diverticular disease [100]	Diagnosis—diverticular disease [100]
	Procedures—sigmoidectomy [100]	Procedures—sigmoidectomy [100]
Vasudevan 2016, (29)	Diagnosis—neoplasm [61.8] and others [38.2]	Diagnosis—neoplasm [62.5] and others [37.5]
	Procedures—colectomy [92.4] and others [7.7]	Procedures—colectomy [99] and others [1]
Wei 2023, (30)	Diagnosis—neoplasm [61.8] and others [38.2]	Diagnosis—neoplasm [61.8] and others [38.2]
	Procedures—colectomy [27.66] and AR [72.34]	Procedures—colectomy [17.64] and AR [82.36]
Wlodarczyk 2023, (31)	Diagnosis—rectal prolapse [100]	Diagnosis—rectal prolapse [100]
	Procedures—rectal procedures [100]	Procedures—rectal procedures [100]

AR, anterior resection; APR, abdominoperineal resection; IBD, inflammatory bowel disease.

Study or subgroup	Laparoscopic colorectal sx Mean	SD	Total	Robotic colorectal sx Mean	SD	Total	Weight	Std. mean difference IV, Random, 95% CI
Al-Mazrou 2018	4,645	3,144	2,219	6,585	4,202	2,219	16.0%	−0.52 [−0.58, −0.46]
Baek SJ 2012	2,829	587	156	8,849	1,593	154	15.7%	−4.98 [−5.43, −4.52]
Ezeokoli 2023	7,776	4,457	258	8,756	3,694	240	16.0%	−0.24[−0.41, −0.06]
Gebhardt 2022	6,812.81	3,228.67	38	10,569.07	4,184.5	29	15.6%	−1.01 [−1.53, −0.50]
Merola 2020	2,933.3	327.96	94	8,615	484.81	94	13.4%	−13.67 [−15.10, −12.25]
Morelli 2016	2,162.5	43.5	25	4,666.7	147.78	50	7.8%	−20.05 [−23.38, −16.72]
Wlodarczyk 2023	33,090	15,395	33	46,118	9,329	19	15.5%	−0.95 [−1.54, −0.35]
Total (95% CI)			**2871**			**2805**	**100.0%**	**−4.60 [−5.90, −3.31]**

Heterogeneity: Tau^2=2.73; Chi^2=832.21, df=6 (P<0.00001); I^2=99%

Test for overall effect: Z=6.96 (P<0.00001)

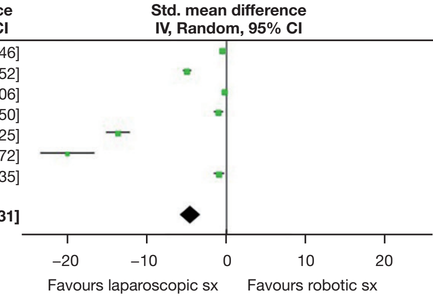

Figure 2 Forest plot showing the operative cost among laparoscopic *vs.* robotic colorectal resections. The outcome is presented as the standard mean difference with a 95% CI. Sx, surgery; Std, standard; SD, standard deviation; IV, inverse variance; CI, confidence interval.

Study or subgroup	Laparoscopic colorectal sx Mean	SD	Total	Robotic colorectal sx Mean	SD	Total	Weight	Std. mean difference IV, Random, 95% CI
AL-Mazrou 2018	16,994	0.5	2,219	20,822	0.5	2,219	0.6%	−7654.71 [−7814.02, −7495.39]
Baek 2012	9,978	3,549	150	14,647	3,822	154	12.3%	−1.26 [−1.51, −1.02]
Hollis 2016	13,778	0.5	67	13,319	0.5	45	1.0%	911.73 [790.17, 1033.28]
Merola 2020	6,310	1,470	94	11,790	1,950	94	12.3%	−3.16 [−3.59, −2.73]
Moghadamyeghaneh 2016	55,037	0.5	9614	73,489	0.5	326	0.1%	−36901.21 [−37414.27, −36388.16]
Morelli 2016	7,760	889.32	25	12,510.8	325.97	50	12.3%	−8.17 [−9.59, −6.74]
Park 2019	10,319.7	1,607.7	36	12,235	1,907.9	35	12.3%	−1.08 [−1.57, −0.58]
Roskam (a) 2023	73,411	3,703	8	80,829	4,418	14	12.3%	−1.71 [−2.74, −0.67]
Roskam (b) 2023	68,277	1,168	8	86,003	3,250	14	12.3%	−6.29 [−8.52, −4.06]
Vasudevan 2016	114,853	0.5	131	107,220	0.5	96	0.0%	15215.06 [13803.18, 16626.93]
Wei 2023	8,556.3	2,056.7	49	13,779.6	3,114.8	17	12.3%	−2.18 [−2.85, −1.51]
Wlodarczyk 2023	73,888	28,129	33	106,841	25,513	19	12.3%	−1.19 [−1.81, −0.58]
Total (95% CI)			**12434**			**3083**	**100.0%**	**−62.34 [−75.14, −49.54]**

Heterogeneity: Tau^2=346.74; Chi^2=29559.11, df=11 (P<0.00001); I^2=100%

Test for overall effect: Z=9.55 (P<0.00001)

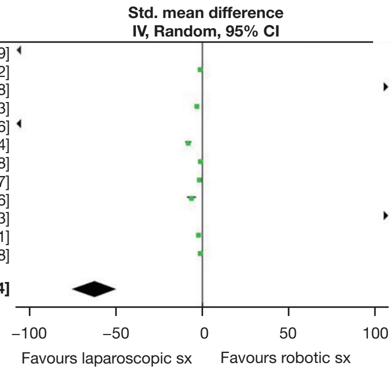

Figure 3 Forest plot showing the total cost among laparoscopic *vs.* robotic colorectal resections. The outcome is presented as the standard mean difference with a 95% CI. Sx, surgery; Std., standard; SD, standard deviation; IV, inverse variance; CI, confidence interval.

Comparison with existing literature

According to the review of the literature, this is the only meta-analysis comparing the costs of laparoscopic versus RCR. There have been multiple studies comparing the perioperative outcomes of LCR versus RCR. Zhang *et al.* have shown that the safety and efficacy of RCR are comparable to LCR (36). Similarly, Safiejko *et al.* and Wang *et al.* have also shown that RCR provides several advantages lower conversion rate, decreased hospital stay, improved overall survival and decreased infection rates (37,38).

Strength and limitations

The RCT used in the analysis was strong in strength, randomization was computer generated, concealment was sealed, ethical approval was taken, it was a blinded trial and intention to treat analysis was reported. The rest of the thirteen comparative trials used in this study were also of adequate strength. Therefore, in total the evidence provided is of high quality.

Nonetheless, this meta-analysis also has multiple limitations. There was a statistically significant heterogeneity among included studies and paucity of the RCT, these findings should be taken cautiously. Also, the procedures used in this meta-analysis were of wide range and although most of the studies were centred around colon cancers there were a significant number of patients with other pathology as well.

Implications

Multiple studies have been done comparing the post-operative outcomes of RCR versus LCR. Concurrent use of this study along with the suitable cohort of the patients and previously published data on the post-operative outcome comparison, can help surgeons make better decisions considering the cost for the hospital and patient.

Conclusions

The LCR seems to be more economical compared to RCR in terms of operative cost as well as total cost (operative plus in-patient stay). However, due to statistically significant heterogeneity among included studies and paucity of the RCT, these findings should be taken cautiously. A major multi-centric large-scale RCT comparing the post-operative outcomes along with the cost is imperative to confirm the findings of our meta-analysis.

Acknowledgments

The provisional abstract of this systematic review has been presented at the annual conference of "The Association of Surgeons of Great Britain and Ireland" on 17th–19th May 2023 at Harrogate, United Kingdom and it is now available in the *British Journal of Surgery*.
Funding: None.

Footnote

Reporting Checklist: The authors have completed the PRISMA reporting checklist. Available at https://tgh.amegroups.com/article/view/10.21037/tgh-23-73/rc

Peer Review File: Available at https://tgh.amegroups.com/article/view/10.21037/tgh-23-73/prf

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://tgh.amegroups.com/article/view/10.21037/tgh-23-73/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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doi: 10.21037/tgh-23-73
Cite this article as: Singh A, Kaur M, Baig MK, Swaminathan C, Subramanian A, Sajid MS. Cost-comparison of robotic versus laparoscopic colorectal resections: a mapped systematic review and meta-analysis of published studies. Transl Gastroenterol Hepatol 2024;9:21.

