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REVIEW

Robotic rectal surgery: State of the art

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Abstract

Laparoscopic rectal surgery has demonstrated its superiority over the open approach, however it still has some technical limitations that lead to the development of robotic platforms. Nevertheless the literature on this topic is rapidly expanding there is still no consensus about benefits of robotic rectal cancer surgery over the laparoscopic one. For this reason a review of all the literature examining robotic surgery for rectal cancer was performed. Two reviewers independently conducted a search of electronic databases (PubMed and EMBASE) using the key words "rectum", "rectal", "cancer", "laparoscopy", "robot". After the initial screen of 266 articles, 43 papers were selected for review. A total of 3013 patients were included in the review. The most commonly performed intervention was low anterior resection (1450 patients, 48.1%), followed by anterior resections (997 patients, 33%), ultra-low anterior resections (393 patients, 13%) and abdominoperineal resections (173 patients, 5.7%). Robotic rectal surgery seems to offer potential advantages especially in low anterior resections with lower conversions rates and better preservation of the autonomic function. Quality of mesorectum and status of and circumferential resection margins are similar to those obtained with conventional laparoscopy even if robotic rectal surgery is undoubtedly associated with longer operative times. This review demonstrated that robotic rectal surgery is both safe and feasible but there is no evidence of its superiority over laparoscopy in terms of postoperative, clinical outcomes and incidence of complications. In conclusion robotic rectal surgery seems to overcome some of technical limitations of conventional laparoscopic surgery especially for tumors requiring low and ultra-low anterior resections but this technical improvement seems not to provide, until now, any significant clinical advantages to the patients.

Key words: Robotic surgery; Robotic rectal surgery; DaVinci rectal surgery; Robotic rectal cancer; Robotics for rectal cancer; Robotic rectal resection

Core tip: Laparoscopic rectal surgery has progressively expanded. However it has some technical limitations. The need to overcome these limitations leads to the development of robotic platforms. Although the positive feedback is by the surgeons, there is still no evidence in literature about the superiority of robotic rectal surgery when compared to traditional laparoscopy.

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INTRODUCTION

Laparoscopic colorectal surgery has progressively expanded since a number of randomized controlled trials (RCTs)[1-3], review articles[4,5], meta-analysis[6] and case series[7] have demonstrated its better postoperative outcomes when compared to open surgery. However, laparoscopic surgery has some technical limitations such as poor ergonomics, 2-dimension view, coning and fulcrum effect, that may influence surgery in narrow anatomical fields such as in the pelvis during rectal surgery. The need to overcome these limitations leads to the development of robotic platforms. The da Vinci robotic surgical system is the only totally robotic platform available. After approval by Food and Drug Administration in 2000, its use progressively spreaded as demonstrated by the increasing number of publications. Three-D high definition vision, wrist-like movement of instruments (endowrist™), stable camera holding, motion filter for tremor-free surgery and improved ergonomics for the surgeon are the advantages of the robotic system that may make rectal surgery more affordable and theoretically should provide better outcomes for the patient. Although the positive feedback is by the surgeons, there is still no evidence in literature about the superiority of robotic rectal surgery when compared to traditional laparoscopy. The aim of this study was to review the rapidly expanding literature in order to focus on the current state and assess any benefits of robotic rectal cancer surgery.

RESEARCH AND LITERATURE

A review of the literature examining robotic surgery for rectal cancer during the period from 2000 to 2015 was performed. Two reviewers independently conducted a search of electronic databases (PubMed and EMBASE) using the key words "rectum", "rectal", "cancer", "laparoscopy", "robot". The reference lists provided by the identified articles were additionally hand-searched to prevent article loss by the search strategy. This method of cross-references was continued until no further relevant publications were identified. The last search was performed on December 2015. Inclusion criteria were prospective, retrospective, randomized, comparative studies about robotic rectal surgery for cancer including anterior resections, low anterior resections, ultralow anterior resections, abdominoperineal resections, proctectomies, proctocolectomies. Exclusion criteria were: Abstracts, letters, editorials, technical notes, expert opinions, reviews, meta-analysis, studies reporting benign pathologies, studies in which the outcomes and parameters of patients were not clearly reported, studies in which it was not possible to extract the appropriate data from the published results, overlap between authors and centers in the published literature, non-English language papers.

The literature search yielded 266 papers, the process is listed in Figure 1. After the 1st filtering, the remaining 60 studies were 33 comparative, 26 case series, and 1 RCT. Then 17 studies were excluded due to duplicated data. They were 7 comparative and 9 case series. After this process a total of 43 papers, 27 comparative including only 1 RCT and 16 case series were included and reviewed.

STUDIES OVERVIEW

The number of publications about robotic rectal surgery for cancer has been constantly increasing. Among the papers we included there was only 1 paper per year published in 2006, 2007, 2008, 3 papers in 2009, 2 in 2010, 5 per year in 2011 and 2012, 10 in 2013 and 15 in 2014. With regard to the nationality of the 1st author there were 16 studies in the South Korea (37.2%), 11 in the United States (25.5%), 4 in Italy (9.3%), 2 in Turkey (4.6%), 2 in the Singapore (4.6%), 1 in Japan (2.3%), 1 in Denmark (2.3%), 1 in Spain (2.3%), 1 in Romania (2.3%), 1 in Brazil (2.3%), 1 in Canada (2.3%), 1 in Taiwan (2.3%), 1 in China (2.3%) (Table 1).

Surgical technique

A total of 3013 robotic operations were performed. Sixteen studies[10,12,14,16,17,22,23,25,27,28,37,38,40-42,48] (1257 patients) reported a totally robotic procedure which was carried out with either a single[10,16,17,22,23,25,27,28,37,38,40-42,48] or a double docking[12,28] technique. In 22 studies[8,13,15,18,20,21,25,26,30-34,36,39,43-47,49,50] (1384 patients) an

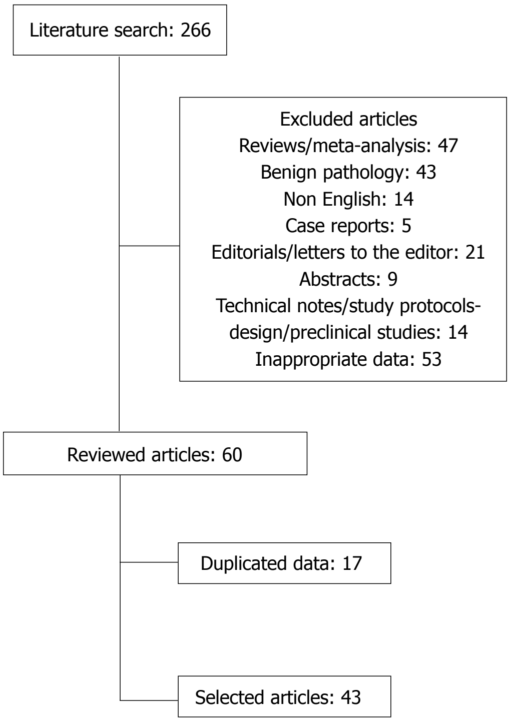

Figure 1 Flow diagram of literature search.

hybrid robotic technique was performed: The inferior mesenteric vessels ligation and splenic flexure mobilization were performed laparoscopically whereas pelvic dissection and total mesorectal excision were performed robotically. In 5 studies[9,11,19,29,35] (372 patients) the robotic technique was not specified. Laparoscopic procedures described in the 27 comparative studies[8-33] were performed in the same manner as robotic surgery using laparoscopic instruments (Table 1).

Demographics and preoperative data

Most of patients were male (1911, 63%), the mean age was 58, the mean BMI was 26.6. Nine hundred-eight patients (20%) underwent a neoadjuvant chemotherapy, 71 (2.3%) a neoadjuvant chemo-radiotherapy and 8 (0.2%) radiotherapy only. With regard to the type of operation, 1450 (48.1%) were low anterior resections, 997 (33%) were anterior resections (AR), 393 (13%) ultra-low anterior resections (ULAR) and 173 (5.7%) abdominoperineal resections (APR). In the studies where the type of operation was not specified and where it was stated that a TME was performed[27,29,41] we assumed that all operations were low anterior resections (LAR) (Table 2)

Operative data

The mean robotic operative time ranged from 202 min[31] to 485.8 min[17]. For the 1345 laparoscopic patients in the selected comparative studies the mean operative time ranged from 158.1[30] to 374.3 min[17]. This difference was statistically significant in 12 comparative studies[10,14,17-24,27,28,30] with a longer time for robotic surgery. Levic *et al*[9] were the only authors that reported a longer laparoscopic operative time (P = 0.055), but all interventions were performed with a single port technique (Table 3).

The estimated blood loss (EBL) was not reported in 14 studies. The mean value ranged from 17 mL[36] to 280 mL[14] with the robotic approach and from 59.2[18] to 271.4[15] in the laparoscopic group. Among 16 comparative studies[8-10,12-15,17,19-21,23,24,29,31,33] that evaluated the EBL only Kang *et al*[23] and Erguner *et al*[21] reported a significantly lower EBL with the robotic approach when compared to the laparoscopic one.

Thirty seven studies reported the conversion rate to open surgery. Three[8,22,31] out of 22 comparative studies[8-15,17,19-25,28-33] showed a significantly lower conversion rate in the robotic series when compared to laparoscopy. The difference in overall conversion rate reported by Ielpo *et al*[14] was not statistically significant. However, when data were analyzed according to the tumor location (upper, mid, lower rectum), the conversion rates between robotic and laparoscopic procedures for lower rectal cancers were respectively 1.8% and 9.2% (P = 0.04).

The rate of patients that underwent a protective ileostomy creation ranged from 0%[30] to 100%[10] both in the robotic and laparoscopic group. The difference in protective ileostomy creation was statistically significant in 5 studies. Kuo *et al*[17] reported a lower rate in the robotic *vs* the laparoscopic group whereas Saklani *et al*[19], Erguner *et al*[21], Kim *et al*[25], Baek *et al*[29] showed a lower rate in the laparoscopic *vs* the robotic group.

Postoperative data

The mean postoperative day to first flatus ranged from 1.9[48] to 3.2[30] d in the robotic cases and from 2.4[23] to 3.4[17] in the laparoscopic ones. No statistically significant difference between robotic and laparoscopic cases was reported in any of the articles reviewed (Table 4).

The day of first postoperative liquid diet was available in 11 studies[6,22,27,29,34,36,43,45,47,48,50] ranging from 1[16] to 3.9[45] d in the robotic cases. Only two[22,29] comparative studies reported the first postoperative liquid diet in their robotic and laparoscopic series, in one[22] of these the difference was statistically significant in favour of robotic surgery (3 d *vs* 5 d, P = 0.005).

The day of first postoperative solid diet was available in 11 studies[8,10,13,17,19,23-25,30,34,37] ranging from 2.58[10] to 7.5[18] d in the robotic cases and from 2.48[10] to 7.7[18] d in laparoscopic cases. Among 9 comparative studies[8,10,13,17,19,23-25,30] only Kang *et al*[23] reported a significant earlier oral intake in the robotic group (4.5 d *vs* 5.2 d. P = 0.004) when compared to the laparoscopic one.

The mean length of hospital stay ranged from 4.5[33] to 14.2[17] and from 3.6[33] to 15.1[17] d after robotic and laparoscopic surgery respectively. Among 8 comparative studies, Tam *et al*[15], Levic *et al*[9] and Park *et al*[30] reported a shorter length of stay in their laparoscopic series whereas 5[8,22-24,32] studies reported a significant

Table 1 Studies overview

Ref.	Year	Country	Study design	Surgical technique	Platform	No. of pts Robot	No. of pts Lap	No. of pts Open
Park *et al*[8]	2015	South Korea	Comparative	Hybrid	DV	133	84	
Levic *et al*[9]	2014	Denmark	Comparative	NS	DV	56	36	
Yoo *et al*[10]	2014	South Korea	Comparative	Tot rob	NS	44	26	
Koh *et al*[11]	2014	Singapore	Comparative	NS	NS	19	19	
Melich *et al*[12]	2014	Canada	Comparative	Tot rob	DV	92	106	
Barnajian *et al*[13]	2014	United States	Comparative	Hybrid	DV-S	20	20	20
Ielpo *et al*[14]	2014	Spain	Comparative	Tot rob	NS	56	87	
Tam *et al*[15]	2014	United States	Comparative	Hybrid	DV	21	21	
Ghezzi *et al*[16]	2014	Brazil	Comparative	Tot rob	DV-S	65		109
Kuo *et al*[17]	2014	Taiwan	Comparative	Tot rob	DV	36	28	
Park *et al*[18]	2014	South Korea	Comparative	Hybrid	DV	32	32	
Saklani *et al*[19]	2013	South Korea	Comparative	NS	NS	74	64	
Fernandez *et al*[20]	2013	United States	Comparative	Hybrid	DV-S	13	59	
Erguner *et al*[21]	2013	Turkey	Comparative	Hybrid	NS	27	37	
D'Annibale *et al*[22]	2013	Italy	Comparative	Tot rob	DV-S	50	50	
Kang *et al*[23]	2013	South Korea	Comparative	Tot rob	NS	165	165	165
Park *et al*[24]	2013	South Korea	Comparative	Hybrid	DV	40	40	
Kim *et al*[25]	2012	South Korea	Comparative	Tot rob	DV	62	147	
Kim *et al*[26]	2012	South Korea	Comparative	Hybrid	DV	30	39	
Bertani *et al*[27]	2011	Italy	Comparative	Tot rob	DV	52		34
Kwak *et al*[28]	2011	South Korea	Comparative	Tot rob	DV	59	59	
Baek *et al*[29]	2011	United States	Comparative	NS	NS	41	41	
Park *et al*[30]	2011	South Korea	Comparative	Hybrid	DV	52	123	88
Patriti *et al*[31]	2009	Italy	Comparative	Hybrid	DV	29	37	
Baik *et al*[32]	2008	South Korea	Comparative	Hybrid	DV	18	18	
Pigazzi *et al*[33]	2006	United States	Comparative	Hybrid	DV	6	6	
Parisi *et al*[34]	2014	Italy	Case series	Hybrid	DV Si	40		
Baek *et al*[35]	2014	South Korea	Case series	NS	NS	182		
Shiomi *et al*[36]	2014	Japan	Case series	Hybrid	DV	113		
Kim *et al*[37]	2014	South Korea	Case series	Tot rob	DV-S	200		
Stănciulea *et al*[38]	2013	Romania	Case series	Tot rob	DV-Si	100		
Zawadzki *et al*[39]	2013	United States	Case series	Hybrid	DV	77		
Sng *et al*[40]	2013	South Korea	Case series	Tot rob	DV-S	197		
Du *et al*[41]	2013	China	Case series	Tot rob	DV	22		
Alimoglu *et al*[42]	2012	Turkey	Case series	Tot rob	DV	7		
Akmal *et al*[43]	2012	United States	Case series	Hybrid	DV	80		
Park *et al*[44]	2012	United States	Case series	Hybrid	DV-S	30		
Kang *et al*[45]	2011	South Korea	Case series	Hybrid	DV	389		
deSouza *et al*[46]	2010	United States	Case series	Hybrid	DV	44		
Pigazzi *et al*[47]	2010	United States	Case series	Hybrid	DV	143		
Choi *et al*[48]	2009	South Korea	Case series	Tot rob	DV	50		
Ng *et al*[49]	2009	Singapore	Case series	Hybrid	DV	8		
Hellan *et al*[50]	2007	United States	Case series	Hybrid	DV	39		

Tot rob: Totally Robotic; DV: Da Vinci; NS: Not specified.

shorter length of stay after robotic surgery.

No statistically significant differences in the overall 30 d mortality between the robotic and laparoscopic approach was found among 15 comparative studies[8-11,13,14,19-24,29-31] (0.10% and 0.45% respectively).

Twenty-three studies reported the reintervention rate. In the robotic series it ranged from 0%[8,22,32,33,42,48] to 15%[20] whereas it ranged from 0%[32,33] to 15.7%[11] after laparoscopic surgery. The most common cause of reintervention was anastomotic leak in both the robotic and laparoscopic groups. No statistically significant differences were found in any of the 12 comparative studies[11-15,20-24,32,33].

The overall complication rate in the robotic and laparoscopic groups was 24.5% and 27.7% respectively. No significant differences in this parameter were reported between the robotic and laparoscopic series[8-11,13-15,19-25,28-33]. The most frequent complication in both the robotic and laparoscopic cases was anastomotic leak followed by bowel obstruction and urinary complications (Table 5). Thirteen studies[10,18,19,22-24,26,31,37,38,40,44,45] reported urinary and sexual dysfunction after rectal surgery, 9 of these were comparative. Park *et al*[18] reported an earlier and significant restoration of erectile function after robotic surgery when compared to the laparoscopic one. Kim *et al*[26] observed an earlier recover of urinary function after robotic intervention within six months from the operation (P = 0.001). After 6 mo the difference was no more statistically significant.

Table 6 shows the studies which classified complications according to the Clavien Dindo Scoring System. Clavien-Dindo 1 and 2 were the most frequent

Table 2 Demographics and preoperative data

Ref.	M/F	Age	BMI	ASA				Preop CHT	Type of operation			
				1	2	3	4		AR	LAR	ULAR	APR
Park *et al*[8]	86/47	59.2 (32-86)	23.1 (14.6-32.8)	94	31	8	0	15	100	33	0	0
Levic *et al*[9]	34/22	65 (23-83)	24.8 (16-34.5)	17	35	4	0	15	0	41[1]	0	15
Yoo *et al*[10]	35/9	59.77 (+ 12.33)	24.13 (+ 3.33)	26	17	1	0	24	0	0	44	0
Koh *et al*[11]	15/4	62 (47-92)	-	5	14	0	0	8	0	0	17	2
Melich *et al*[12]	52/40	60 (57.7-62.2)	23.1 (22.5-23.7)		1 (1-3)			13	0	92	0	0
Barnajian *et al*[13]	12/8	62 (44-82)	22 (18-31)	0	4	16	0	10	0	15	0	5
Ielpo *et al*[14]	25/31	43.4 (+ 11)	22.8 (+ 2.5)	11	32	11	0	46	0	40	1	15
Tam *et al*[15]	10/11	60 (41-73)	25 (20-37)	_	_	_	_	18	11	1	4	5
Ghezzi *et al*[16]	41/24	61	24.7	12	49	4	0	47	0	44	11	10[2]
Kuo *et al*[17]	21/15	55.9 (30-89)	-	0	33	3	0	28	0	0	36	0
Park *et al*[18]	32/0	-	23.8	-	-	-	-	15 (+ RT)	0	22	9	1
Saklani *et al*[19]	50/24	59.6 (32-85)	23.4 (16.9-29.8)	50	24	0	0	74	0	46	26	2
Fernandez *et al*[20]	13/0	67.9 (+ 2.1)	-	0	0	11	2	10	0	5	0	8
Erguner *et al*[21]	14/13	54 (24-78)	28.3 (19.8-30.8)	-	-	-	-	4	0	27	0	0
D'Annibale *et al*[22]	30/20	66 (+ 12.1)	-	-	-	-	-	34 (+ RT)	17	33	0	0
Kang *et al*[23]	104/61	61.2 (+ 11.4)	23.1 (+ 2.8)	109	56	0	0	39	165[3]	0	0	0
Park *et al*[24]	41/21	56	24.2	33	28	1	0	9	0	51	10	1
Kim *et al*[25]	28/12	57.3	23.9	27	9	4	0	32	0	0	40	0
Kim *et al*[26]	18/12	54.13 (+ 8.52)	24.36 (+ 2.4)	29	1	0	0	10	29	1[3]	0	0
Bertani *et al*[27]	31/21	59.6 (+ 11.6)	24.8 (+ 3.62)	49		3		24	0	52	0	0
Kwak *et al*[28]	39/20	60 (53-68)	23.3 (21.8-25.2)	28	27	4	0	8 (RT)	0	54	5	0
Baek *et al*[29]	25/16	63.6 (48-87)	-	0	18	22	1	33	0	33	2	6
Park *et al*[30]	28/24	57.3	23.7	21	26	5	0	12 (+ RT)	52	0	0	0
Patriti *et al*[31]	11/18	68	24	2	13	14	0	7 (+ RT)	29	0	0	0
Baik *et al*[32]	14/4	57.3 (37-79)	22.8 (19.4-31.7)	12	6	0	0	-	18	0	0	0
Pigazzi *et al*[33]	2/4	60 (42-78)	31 (25-36)	0	2	4	0	2	0	6	0	0
Parisi et al[34]	19/21	67 (39-86)	25.22 (18.36-33.20)	20	14	6	0	17	0	35	0	5
Baek *et al*[35]	117/65	57.6 (26-78)	23.4 (14.8-30.5)	111	65	6	0	50	0	182	0	0
Shiomi *et al*[36]	78/35	64 (23-84)	23.4 (16.7-30.6)	39	74	0	0	3	11	71	23	8
Kim *et al*[37]	134/66	58.15	23.85	-	-	-	-	43	0	200	0	0
Stănciulea *et al*[38]	66/34	62 (32-84)	26 (16.4-38)	-	-	-	-	58	30	39	8	23
Zawadzki *et al*[39]	45/32	60.1 (34-82)	28 (18-43)	62	15	0	48	0	68	9	0	0
Sng *et al*[40]	131/66	60 (20-89)	23.5 (16.9-33.1)	117	71	9	0	54	3	126	55	13
Du *et al*[41]	14/8	56.4 (+ 7.8)	22.5 (+ 2.1)	-	-	-	-	-	0	22	0	0
Alimoglu *et al*[42]	5/2	52.9 (32-88)	-	-	-	-	-	4	0	0	0	7
Akmal *et al*[43]	50/30	60.35 (24-85)	27.2 (18-44)	0	37	39	4	62	0	40	21	19
Park *et al*[44]	16/14	58	27.6	0	12	18	0	20	0	5	19	6
Kang *et al*[45]	252/137	59 (26-86)	-	280	107	2	0	72	382	1[3]	0	6
deSouza *et al*[46]	28/16	63	-	4	27	13	0	31	0	30	6	8
Pigazzi *et al*[47]	87/56	62 (26-87)	26.5 (16.5-44)	0	0	57	93 (+ RT)	0	80	32	31	0
Choi *et al*[48]	32/18	58.5 (30-82)	23.2 (19.4-29.2)	27	19	4	0	3 (+ RT)	0	40	8	2
Ng *et al*[49]	5/3	55 (42-80)	-	-	-	-	-	-	2	0	6	0
Hellan *et al*[50]	21/18	58 (26-84)	26 (16-44)	0	0	17		33	0	22	11	6

[1]9 hartmann; [2]1 Posterior pelvic exenteration; [3]1 hartmann. AR: Anterior resections; ULAR: Ultra-low anterior resections; APR: Abdominoperineal resections; CHT: Chemotheraypy; BMI: Body mass index; ASA: American society anesthesiologists.

complications in both groups (13.8% robotic *vs* 12.4% laparoscopic).

Oncological outcome

The mean number of harvested nodes ranged from 10[14] to 20.6[48] and from 9[14] to 21[10] in the robotic and laparoscopic cases respectively. Three of 22 comparatives[8-15,17,19-25,28-33] studies reported a statistically significant difference in the number of harvested nodes between the robotic and laparoscopic approach: Levic *et al*[9] and D'Annibale *et al*[22] showed an higher number of examined nodes after robotic surgery whereas Yoo *et al*[10] showed an higher number of examined nodes after laparoscopic surgery (Table 7).

The mean length of distal resection margins after robotic rectal surgery was available in 20 studies[8-10,13,15-17,19,21-38,40,41,43,45,48,50]. It ranged from 13.3 mm[10] to 460 mm[15]. Tumor involvement rate of distal margins was available 21 studies[8,9,11,12,15,17,20,21,23,25,26,28-30,34,36,37,39,46,48,50] and ranged from 0%[8,15,17,20,21,25,26,28-30,34,36,37,48,50] to 2.6%[39] of patients. An involvement of distal resection margin was found in 6 (0.47%) out of 1257 patients operated on with the robotic technique.

The mean length of distal resection margins after laparoscopic rectal surgery was available in 19[8-10,13,15,17,19,21-26,28-33] studies. It ranged from 13 mm[25] to 510 mm[15]. The involvement of distal margins was available in 14 studies[8,9,11,12,15,17,20,21,23,25,26,28-30] and ranged from 0%[8,9,11,12,15,21,23,25,26,28-30] to 5%[15] of patients. A distal margin positivity was reported in 3 (0.3%) out of 857

Table 3 Operative data

Ref.	Patients	Mesorectum	Technique	Mean operative time (min)	EBL (mL)	Conversion to open (%)	Stoma (%)
Park *et al*[8]	133	RME	Hybrid	205.7 (109-505)	77.6 (0-700)	0 (0)	29 (21.8)
	84	LME	Tot lap	208.8 (94-407)	82.3 (0-1100)	6 (7.1)	20 (23.8)
Levic *et al*[9]	56	RME	NS	247 (135-111)[1]	50 (0-400)[1]	3 (5.4)	31 (55.3)
	36	LME	SP	295 (108-465)[1]	35 (0-400)[1]	0 (0)	9 (25)
Yoo *et al*[10]	44	RME	Tot rob	316.43 (+ 65.11)	239.77 (+ 278.61)	0 (0)	44 (100)
	26	LME	Tot lap	286.77 (+ 51.46)	215.38 (+ 247.29)	0 (0)	26 (100)
Koh *et al*[11]	19	RME	NS	390 (289-771)[1]	-	1 (5.2)	17 (89)
	19	LME	HAL	225 (130-495)[1]	-	5 (26.3)	0 (0)
Melich *et al*[12]	92	RME	Tot rob	285 (266-305)	201 (165-237)	1 (1.1)	-
	106	LME	Tot lap	262 (252-272)	232 (191-272)	4 (3.8)	-
Barnajian *et al*[13]	20	RME	Hybrid	240 (150-540)[1]	125 (50-650)[1]	0 (0)	11 (55)
	20	LME	Tot lap	180 (140-480)[1]	175 (50-900)[1]	2 (10.5)	11 (55)
	20	OME	Open	240 (115-475)[1]	250 (50-800)[1]	na	12 (60)
Ielpo *et al*[14]	56	RME	Tot rob	309 (150-540)	280 (0-4000)	2 (3.5)	28 (50)
	87	LME	Tot lap	252 (180-420)	240 (0-4000)	10 (11.5)	53 (60.9)
Tam *et al*[15]	21	RME	Hybrid	274.8 (189-449)	252.6 (30-2000)	1 (4.7)	13 (62)
	21	LME	Tot lap	236.3 (171-360)	271.4 (50-1200)	0 (0)	11 (52)
Ghezzi *et al*[16]	65	RME	Tot rob	299 (+ 58)	0 (0-175)[1]	1 (1.5)	51 (91.1)
	109	OME	Open	207 (+ 56.5)	150 (0-400)[1]	na	66 (63.3)
Kuo *et al*[17]	36	RME	NS	485.8 (315-720)	80 (30-200)	0 (0)	7 (19.4)
	28	LME	Tot lap	374.3 (210-570)	103.6 (30-250)	0 (0)	13 (46.4)
Park *et al*[18]	32	RME	Hybrid	-	-	-	3 (9.4)
	32	LME	Tot lap	-	-	-	3 (9.4)
Saklani *et al*[19]	74	RME	NS	365.2 (150-710)	180 (0-1100)	1 (1.4)	53 (71.6)
	64	LME	Tot lap	311.6 (180-530)	210 (0-1200)	4 (6.3)	35 (54.7)
Fernandez *et al*[20]	13	RME	Hybrid	528 (416-700)[1]	157 (50-550)[1]	1 (8)	-
	59	LME	HAL	344 (183-735)[1]	200 (25-1500)[1]	10 (17)	-
Erguner *et al*[21]	27	RME	Hybrid	280 (175-480)	50 (20-100)	0 (0)	19 (70.3)
	37	LME	Tot lap	190 (110-300)	125 (50-400)	0 (0)	13 (35.1)
D'Annibale *et al*[22]	50	RME	Tot rob	270 (240-315)[1]	-	0 (0)	-
	50	LME	Tot lap	280 (240-350)[1]	-	6 (12)	-
Kang *et al*[23]	165	RME	Tot rob	309.7 (+ 115.2)	133 (+ 192.3)	1 (0.6)	41 (25)
	165	LME	Tot lap	277.8 (+ 81.9)	140.1 (+ 216.4)	3 (1.8)	43 (27.2)
	165	OME	Open	252.6 (+ 88.1)	275.4 (+ 368.4)	na	47 (31.8)
Kim *et al*[25]	62	RME	Tot rob	390 (+ 97)	-	3 (4.8)	22 (35.5)
	147	LME	Tot lap	285 (+ 80)	-	5 (3.4)	34 (23.1)
Park *et al*[24]	40	RME	Hybrid	235.5 (+ 57.5)	45.7 (+ 40)	0 (0)	14 (35)
	40	LME	Tot lap	185.4 (+ 72.8)	59.2 (+ 35.8)	0 (0)	6 (15)
Kim *et al*[26]	30	RME	Hybrid	-	-	-	-
	39	LME	Tot lap	-	-	-	-
Bertani *et al*[27]	52	RME	Tot rob	260 (190-570)	100 (50-1000)	-	-
	34	OME	Tot lap	164 (100-350)	120 (50-2000)	-	-
Kwak *et al*[28]	59	RME	Tot rob	270 (241-325)[1]	-	0 (0)	25 (42.4)
	59	LME	Tot lap	228 (177-254)[1]	-	2 (3.4)	26 (44.1)
Baek *et al*[29]	41	RME	NS	296 (150-520)	200 (20-2000)[1]	3 (7.3)	33 (94.3)
	41	LME	NS	315 (174-584)	300 (17-1000)[1]	9 (22)	14 (40)
Park *et al*[30]	52	RME	Hybrid	232.6 (+ 54.2)	-	0 (0)	1 (1.9)
	123	LME	Tot lap	158.1 (+ 49.2)	-	0 (0)	5 (4.1)
	88	OME	Open	233.8 (+ 59.2)	-	na	4 (4.5)
Patriti *et al*[31]	29	RME	Hybrid	202 (+ 12)	137.4 (+ 156)	0 (0)	0 (0)
	37	LME	Tot lap	208 (+ 7)	127 (+ 169)	7 (19)	0 (0)
Baik *et al*[32]	18	RME	Hybrid	217.1 (149-315)	-	0 (0)	-
	18	LME	Tot lap	204.3 (114-297)	-	2 (11)	-
Pigazzi *et al*[33]	6	RME	Hybrid	264 (192-318)	104 (50-200)	0 (0)	-
	6	LME	Tot lap	258 (198-312)	150 (50-300)	0 (0)	-
Parisi *et al*[34]	40	RME	Hybrid	340 (235-460)[1]	50 (20-250)[1]	0 (0)	22 (55)
Baek *et al*[35]	182	RME	NS	-	-	-	-
Shiomi *et al*[36]	113	RME	Hybrid	302 (135-683)[1]	17 (0-690)[1]	0 (0)	-
Kim *et al*[37]	200	RME	Tot rob	308.3	-	1 (0.5)	9 (4.5)
Stănciulea *et al*[38]	100	RME	Tot rob	-	150 (0-250)[1]	4 (4)	64 (64)
Zawadzki *et al*[39]	77	RME	Hybrid	327 (178-510)[1]	189 (30-1000)[1]	3 (3.9)	53 (69)
Sng *et al*[40]	197	RME	Tot rob	278.7 (145-515)	< 50 (50-1500)[1]	0 (0)	-
Du *et al*[41]	22	RME	Tot rob	220 (152-286)	33 (10-70)	0 (0)	-
Alimoglu *et al*[42]	7	RME	Tot rob	-	-	0 (0)	-
Akmal *et al*[43]	80	RME	Hybrid	303.5	-	4 (5)	46 (57.5)
Park *et al*[44]	30	RME	Hybrid	369 (306-410)[1]	100 (75-200)[1]	-	-
Kang *et al*[45]	389	RME	Hybrid	322.35	-	3 (0.7)	93 (24)

deSouza *et al*[46]	44	RME	Hybrid	347 (155-510)[1]	150 (50-1000)[1]	-	34 (77.2)
Pigazzi *et al*[47]	143	RME	Hybrid	297 (90-660)	283 (0-6000)	7 (4.9)	71 (50)
Choi *et al*[48]	50	RME	T Tot rob	304.8 (190-485)	-	0 (0)	16 (32)
Ng *et al*[49]	8	RME	Hybrid	278.7 (145-515)	-	0 (0)	6 (75)
Hellan *et al*[50]	39	RME	Hybrid	285 (180-540)[1]	200 (25-6000)[1]	1 (2.5)	4 (10.2)

Tot rob: Totally robotic; Tot lap: Totally laparoscopic; HAL: Hand assisted laparoscopy; SP: Single port; NS: Not specified. [1]Median. EBL: Estimated blood loss; RME: Robotic mesorectal excision; LME: Laparoscopic mesorectal excision; OME: Open mesorectal excision.

Table 4 Postop data

Ref.	Pts	Mesorectum	Flatus (POD)	Liquid diet (POD)	Solid diet (POD)	Length of stay (d)	30 d mortality (%)	Reinterventions (%)	
Park *et al*[8]	133	RME	2.42 (1-6)	-	4.92 (3-11)	5.86 (4-14)	0 (0)	-	
	84	LME	2.47 (1-6)	-	5.19 (2-11)	6.54 (3-25)	0 (0)	-	
Levic *et al*[9]	56	RME	-	-	-	8 (4-100)	0 (0)	-	
	36	LME	-	-	-	7 (3-51)	2 (5.6)	-	
Yoo *et al*[10]	44	RME	-	-	2.58 (+ 1.62)	11.41 (+ 5.56)	0 (0)	-	
	26	LME	-	-	2.48 (+ 1.53)	11.04 (+ 6.33)	0 (0)	-	
Koh *et al*[11]	19	RME	-	-	-	7 (4-21)[1]	0 (0)	1 (5.2)	Bleeding
	19	LME	-	-	-	6 (4-28)[1]	0 (0)	3 (15.7)	Adhesive SBO, colonic infarction, anastomotic leak
Melich *et al*[12]	92	RME	-	-	-	9.6 (8.3-11)	-	6 (6.5)	6 leak/abscess
	106	LME	-	-	-	9.9 (8.5-11.3)	-	5 (4.7)	4 leak/abscess, 1 obstruction due to adhesions
Barnajian *et al*[13]	20	RME	3 (1-8)[1]	-	4 (2-9)[1]	6 (4-31)[1]	0 (0)	2 (10)	Presacral bleeding, pelvic abscess
	20	LME	4 (3-13)[1]	-	4 (4-14)[1]	7 (5-36)[1]	0 (0)	1 (5)	Pancreatic tail injury
	20	OME	4 (2-8)[1]	-	4.5 (2-9)[1]	7 (3-16)[1]	0 (0)	2 (10)	Presacral bleeding, enterotomy
Ielpo *et al*[14]	56	RME	-	-	-	13 (5-60)	0 (0)	3 (5.3)	NS
	87	LME	-	-	-	10 (5-16)	0 (0)	3 (3.4)	NS
Tam *et al*[15]	21	RME	-	-	-	8.7 (4-23)	-	0 (0)	
	21	LME	-	-	-	6 (3-14)	-	1 (5)	Bleeding
Ghezzi *et al*[16]	65	RME	2 (1-2)	1 (1-2)	-	6 (5-8)[1]	0 (0)	3 (4.6)	NS
	109	OME	3 (2-5)	5 (4-6)	-	9 (8-10)[1]	0 (0)	2 (1.8)	NS
Kuo *et al*[17]	36	RME	2.9 (1-6)	-	6.4 (4-12)	14.2 (9-27)	-	-	
	28	LME	3.4 (1-11)	-	5.8 (3-16)	15.1 (7-57)	-	-	
Park *et al*[18]	32	RME	-	-	-	-	-	-	
	32	LME	-	-	-	-	-	-	
Saklani *et al*[19]	74	RME	2.45 (1-10)	-	4.6 (2-13)	8 (4-21)	0 (0)	-	
	64	LME	2.48 (1-6)	-	5.1 (2-14)	9.2 (5-29)	0 (0)	-	
Fernandez *et al*[20]	13	RME	-	-	-	13[1]	0 (0)	2 (15)	SBO
	59	LME	-	-	-	8[1]	1 (2)	7 (12)	NS
Erguner *et al*[21]	27	RME	-	-	-	-	1 (3.7)	1 (3.7)	Colonic necrosis
	37	LME	-	-	-	-	1 (2.7)	3 (8.1)	1 ileostomy retraction, 2 anastomotic leak
D'Annibale *et al*[22]	50	RME	-	3 (3-5)[1]	-	8 (7-11)[1]	0 (0)	0 (0)	
	50	LME	-	5 (4-6)[1]	-	10 (8-14)[1]	0 (0)	3 (6)	Anastomotic leak
Kang *et al*[23]	165	RME	2.2 (+ 1.1)	-	4.5 (+ 1.9)	10.8 (+ 5.5)	0 (0)	15 (9)	NS
	165	LME	2.4 (+ 1.2)	-	5.2 (+ 2.4)	13.5 (+ 9.2)	0 (0)	5 (15)	NS
	165	OME	3 (+ 1.4)	-	6.4 (+ 2.5)	16 (+ 8.6)	0 (0)	9 (5.4)	NS
Kim *et al*[25]	62	RME	-	-	6 (+ 5)	12 (+ 6)	-	-	
	147	LME	-	-	7 (+ 5)	14 (+ 9)	-	-	

Park *et al*[24]	40	RME	2.4 (+ 1.6)	-	7.5 (+ 3.5)	10.6 (+ 4.2)	0 (0)	2 (5)	Anastomotic leak
	40	LME	2.5 (+ 1.3)	-	7.7 (+ 2.3)	11.3 (+ 3.6)	0 (0)	1 (2.5)	Anastomotic leak
Kim *et al*[26]	30	RME	-	-	-	-	-	-	
	39	LME	-	-	-	-	-	-	
Bertani *et al*[27]	52	RME	2 (1-5)	2 (1-13)	-	6 (4-51)[1]	-	2 (4)	
	34	OME	3 (1-9)	3 (2-12)	-	7 (4-24)[1]	-	0 (0)	
Kwak *et al*[28]	59	RME	-	-	-	-	-	-	
	59	LME	-	-	-	-	-	-	
Baek *et al*[29]	41	RME	-	2.3 (1-13)	-	6.5 (2-33)	0 (0)	-	
	41	LME	-	2.4 (1-9)	-	6.6 (3-20)	0 (0)	-	
Park *et al*[30]	52	RME	3.2 (+ 1.8)	-	6.7 (+ 3.8)	10.4 (+ 4.7)	0 (0)	-	
	123	LME	3 (+ 1.1)	-	6.1 (+ 2.7)	9.8 (+ 3.8)	0 (0)	-	
	88	OME	4.4 (+ 3)	-	7.6 (+ 3.3)	12.8 (+ 7.1)	1 (1.1)	-	
Patriti *et al*[31]	29	RME	-	-	-	11.9 (6-29)	0 (0)	-	-
	37	LME	-	-	-	9.6 (5-37)	0 (0)	-	-
Baik *et al*[32]	18	RME	1.8 (1-2)[1]	-	-	6.9 (5-10)[1]	-	0 (0)	
	18	LME	2.4 (1-6)[1]	-	-	8.7 (6-12)[1]	-	0 (0)	
Pigazzi *et al*[33]	6	RME	-	-	-	4.5 (3-11)	-	0 (0)	
	6	LME	-	-	-	3.6 (3-6)	-	0 (0)	
Parisi *et al*[34]	40	RME	1 (1-3)[1]	1 (1-5)[1]	2 (2-6)[1]	5 (3-18)[1]	0 (0)	1 (2.5)	Anastomotic leak
Baek *et al*[35]	182	RME	-	-	-	-	-	-	-
Shiomi *et al*[36]	113	RME	2 (1-3)[1]	3 (3-7)[1]	-	7 (6-24)[1]	0 (0)	2 (1.8)	Anastomotic leak
Kim *et al*[37]	200	RME	2.4	-	5	10.7		16 (8)	ns
Stănciulea *et al*[38]	100	RME	-	-	-	10 (6-38)[1]	-	6 (6)	3 anastomotic leak, 1 bowel obstruction, 1 bleeding, 1 bowel injury
Zawadzki *et al*[39]	77	RME	-	-	-	6.4 (3-26)	0 (0)	3 (3.9)	Anastomotic leak
Sng *et al*[40]	197	RME	-	-	-	9 (5-122)[1]	-	-	
Du *et al*[41]	22	RME	2.6 (1.41-4.37)[1]	-	-	7.8 (7-13)[1]	-	-	
Alimoglu *et al*[42]	7	RME	-	-	-	8.1 (5-10)[1]	0 (0)	0 (0)	
Akmal *et al*[43]	80	RME	-	2.75 (1-19)	-	7.55 (2-33)	0 (0)	-	
Park *et al*[44]	30	RME	-	-	-	4 (3-6)[1]	0 (0)	-	
Kang *et al*[45]	389	RME	2.3	3.9	-	13.5	0 (0)	36 (9.2)	ns
deSouza *et al*[46]	44	RME	-	-	-	5 (3-36)[1]	1 (0.46)	2 (0.92)	1 anastomotic leak
Pigazzi *et al*[47]	143	RME	-	2.7 (1-19)	-	8.3 (2-33)	0 (0)	-	
Choi *et al*[48]	50	RME	1.9 (1-3)	2.6 (2-12)	-	9.2 (5-24)	-	0 (0)	
Ng *et al*[49]	8	RME	-	-	-	5 (4-30)[1]	0 (0)	-	-
Hellan *et al*[50]	39	RME	-	2 (1-11)[1]	-	4 (2-22)[1]	0 (0)	4 (10.3)	Anastomotic leak

[1]Values are expressed as mean, solid diet includes soft diet. SBO: Small bowel obstruction; RME: Robotic mesorectal excision; LME: Laparoscopic mesorectal excision; OME: Open mesorectal excision; POD: Post operative day.

patients. Among the 19 comparative[8-10,13,15,17,19,21-26,28-33] studies only Park *et al*[24] reported a longer distal margin in the robotic than in the laparoscopic group (P = 0.04). No significant difference in distal margins tumor involvement was reported when the robotic and laparoscopic approaches were compared.

Mean circumferential resection margins (CRM) after robotic rectal surgery were reported in 9 studies[9,13,17,21,25,30,43,44,47] ranging from 1.8 mm[43] to 11 mm[44]. CRM tumor involvement was available in 32 studies[8,10-12,14-17,19,20,22-30,35-37,39,40,42,44-50] and ranged from 0%[15,16,20,22,36,42,44,46,49,50] to 11.1%[17] of patients with a 2.94 overall rate (76 out of 2583 patients).

Mean CRM after laparoscopic rectal surgery were reported in 6[9,13,17,21,25,30] comparative studies. It ranged from 4 mm[21] to 8.2 mm[30]. CRM involvement was reported in 17 studies[8,10-12,14,15,17,19,20,22-26,28-30] and occurred in 51 out of 1158 patients (4.4%) Where the 2 procedures where compared only D'Annibale *et al*[22] observed a significantly greater number of patients with positive CRM in the laparoscopic series when compared with the robotic one.

Only in 11 papers[9,11,13,20,21,26,32,34,36,41,44] reported the quality of mesorectum. Complete mesorectum excision ranged from 100%[11,36] to 60%[9] in the robotic series and from 100%[11] to 40.6%[9] after laparoscopy. Total mesorectal excision was achieved in 83.62% of robotic cases *vs* 77.22% of laparoscopic ones. None of the 7 comparative studies showed a significant difference in the quality of mesorectum between the 2 procedures.

Table 5 Complications according to Clavien Dindo classification

Ref.	Pts	Mesorectum	Complicated pts (%)	1 (%)	2 (%)	3 (%) 3a	3 (%) 3b	4 (%)	5 (%)
Park *et al*[8]	133	RME	26 (19.5)	11 (42.3)	5 (19.2)	9 (34.6)		1 (3.8)	
	84	LME	19 (22.6)	7 (36.8)	4 (21)	6 (31.6)		2 (10.5)	
Yoo *et al*[10]	44	RME	17 (38.6)	13 (76.5)			4 (23.5)		
	26	LME	7 (26.9)	5 (71.4)			2 (28.5)		
Koh *et al*[11]	19	RME	3 (15.7)	2 (66.7)			1 (33.3)		
	19	LME	7 (36.8)	4 (57)			3 (43)		
Melich *et al*[12]	92	RME	17 (18.4)	11 (64.7)			6 (35.3)		
	106	LME	18 (17)	13 (72.2)			5 (27.8)		
Barnajian *et al*[13]	20	RME	8 (40)		3	3 (37.5)	2 (25)		
	20	LME	4 (10)	2		1	1		
	20	OME	8 (40)		5		2	1 (33.3)	
Ielpo *et al*[14]	56	RME	15 (26.8)	11 (73.3)			4 (26.7)		
	87	LME	20 (23)	15 (75)			5 (25)		
Ghezzi *et al*[16]	65	RME	27 (41.5)	22 (81.5)			5 (18.5)		
	109	OME	45 (41.3)	38 (84.5)			7 (15.5)		
Kuo *et al*[17]	36	RME	11 (30.5)	4 (36.3)		3 (27.2)	4 (36.3)		
	28	LME	14 (50)	11 (78.6)		1 (7)	2 (14.2)		
Fernandez *et al*[20]	13	RME					2		
	59	LME							
Erguner *et al*[21]	27	RME	3 (11.1)	2 (66.7)			1 (33.3)		
	37	LME	8 (21.6)	5 (62.5)			3 (37.5)		
D'Annibale *et al*[22]	50	RME	5 (10)	5 (100)					
	50	LME	10 (20)	7 (70)			3 (30)		
Kang *et al*[23]	165	RME	34 (20.6)	16 (47.1)			3 (8.8)		
	165	LME	46 (27.9)	20 (43.5)			1 (2.2)		
	165	OME	41 (24.8)	30 (73.2)			2 (4.9)		
Park *et al*[24]	40	RME	6 (15)	4 (66.7)			2 (33.3)		
	40	LME	5 (12.5)	4 (80)			1 (20)		
Park *et al*[30]	52	RME	10 (19.2)	6 (60)			4 (40)		
	123	LME	15 (12.2)	9 (60)			6 (40)		
	88	OME	18 (20.5)	9 (50)			9 (50)		
Baik *et al*[32]	18	RME	4 (22.2)	3 (75)	1 (25)				
	18	LME	1 (5.5)		1 (100)				
Pigazzi *et al*[33]	6	RME	1 (16.6)		1 (100)				
	6	LME	1 (16.6)			1 (100)			
Parisi *et al*[34]	40	RME	4 (10)	1 (25)	1 (25)		2 (50)		
Shiomi *et al*[36]	113	RME	23 (20.3)	10 (43.5)	10 (43.5)	1 (4.3)	2 (8.7)		
Kim *et al*[37]	200	RME				16 (59.2)			
Stănciulea *et al*[38]	100	RME	18 (18)		10 (55.5)	2 (5.5)	6 (38.9)		
Zawadzki *et al*[39]	77	RME			2	3			
Sng *et al*[40]	197	RME	74 (37)	58 (78.3)	5 (6.8)	9 (12.1)	1 (1.3)	1 (1.3)	
Du *et al*[41]	22 (4.5)	RME	1 (4.5)	1 (100)	0				
Alimoglu *et al*[42]	7	RME	2 (28.5)	2 (100)					
Kang *et al*[45]	389	RME	74 (19)	34 (45.9)	4 (5.4)	36 (48.6)			
deSouza *et al*[46]	44	RME	19 (43)	15 (79)	1 (5.2)	1 (5.2)	1 (5.2)	1 (5.2)	
Choi *et al*[48]	50	RME	9 (18)		4 (44.4)	5 (55.5)			
Hellan *et al*[50]	39	RME	15 (38.4)	11 (73.3)	4 (26.7)				

RME: Robotic mesorectal excision; LME: Laparoscopic mesorectal excision; OME: Open mesorectal excision.

Short-term oncologic outcomes

Only 11 authors[8-10,16,19,25,28,31,38,42,47] reported short term oncologic outcomes (Table 8). The main drawback is the heterogeneity of the length of follow up ranging from 1 mo[9,42] to 80 mo[8] making results difficult to compare. The disease free survival in the laparoscopic group ranged from 75%[10] to 89.2%[31] with local recurrence ranging from 0%[9,42] to 16.6%[8] and an overall survival ranging from 88.5%[10] to 98%[24]. The disease free survival in the robotic group ranged from 70.4%[16] to 100%[31,42] with local recurrence ranging from 0%[9,31,42] to 12.8%[10] and an overall survival ranging from 85%[16] to 100%[42].

CONCLUSION AND DISCUSSION

Robotic rectal surgery is constantly increasing over the years. Previous reviews have already demonstrated its safety and feasibility[51-53], although there are not published studies demonstrating its superiority over the laparoscopic approach mainly due to the lack of randomized control trials. This lack of evidence about the effectiveness of robotic rectal surgery is in contrast with the overall opinion of surgeons that report an easier surgical approach especially to narrow and difficult anatomic spaces such as the pelvis. Several authors[52-54] reported 3D high definition vision, wrist-like movement

Table 6 Short term oncologic outcomes

Ref.	Pts	Mesorectum	DSF% (yr)	LR (%)	Distant metastases (%)	OS % (yr)	F-u mo (median)
Park *et al*[8]	133	RME	81.9 (5)	3 (2.3)	16 (12)	92.8 (5)	58 (4-80)
	84	LME	78.7 (5)	1 (1.2)	14 (16.6)	93.5 (5)	58 (4-80)
Levic *et al*[9]	56	RME		0 (0)	8 (14.3)		12 (1-31)
	36	LME		0 (0)	2 (5.6)		10 (1-33)
Yoo *et al*[10]	43[1]	RME	76.7 (3)	6 (12.8)		95.2 (3)	33.9 (4.4-61.3)
	26	LME	75 (3)	2 (8.3)		88.5 (3)	36.5 (3.7-69.9)
Ghezzi *et al*[16]	65	RME	73.2 (5)	2 (3.2)	19 (29.6)	85 (5)	60
	109	OME	69.5 (5)	17.5 (16.1)	26 (24.2)	76.1 (5)	60
Saklani *et al*[19]	74	RME	77.7 (3)	2 (2.7)		90 (3)	30.1 (11-61)[2]
	64	LME	78.8 (3)	4 (6.3)		92.1 (3)	30.1 (11-61)[2]
Kim *et al*[25]	62	RME		0 (0)	3 (4.2)	98 (1.5)	17.4
	147	LME		1 (0.7)	8 (5.4)	98 (1.7)	20.6
Kwak *et al*[28]	59	RME		1 (1.8)	2 (3.6)		17 (11-25)
	59	LME		1 (1.9)	2 (3.7)		13 (9-22)
Patriti *et al*[31]	29	RME	100 (3)	0 (0)	0 (0)	96.6 (2.4)	29.2[2]
	37	LME	83.7 (3)	2 (5.4)	4 (6)	97.2 (1.5)	18.7[2]
Stănciulea *et al*[38]	100	RME		2 (2)		90 (3)	24 (9-63)
Alimoglu *et al*[42]	7	RME	100 (1)	0 (0)	0 (0)	100 (1)	12 (6-21)[2]
Pigazzi *et al*[47]	143	RME	77.6 (3)	2 (1.4)	13 (9)	97 (3)	17.4 (0.1-52.5)[2]

[1]1 patient excluded (palliative ISR); [2]Mean. DSF: Disease free survival rate; LR: Local recurrence; OS: Overall survival; RME: Robotic mesorectal excision; LME: Laparoscopic mesorectal excision; OME: Open mesorectal excision.

Table 7 Histopathological data

Ref.	Pts	Mesore-ctum	Harvested nodes	Quality of mesorectum (complete)	Proximal margin (mm)	Distal margin (mm)	Distal margin + (%)	CRM (mm)	CRM + (%)	pTpN stage (%)				
										0	1	2	3	4
Park *et al*[8]	133	RME	16.34 (2-43)	-	111.7 (40-350)	27.5 (10-140)	0 (0)	-	9 (6.8)	0 (0)	49 (36.8)	36 (27.1)	48 (36.1)	0 (0)
	84	LME	16.63 (2-49)	-	105.1 (40-340)	28.7 (10-90)	0 (0)	-	6 (7.1)	0 (0)	22 (26.2)	28 (33.3)	34 (40.5)	0 (0)
Levic *et al*[9]	56	RME	21 (7-83)[1]	34	-	30 (5-80)	1 (0.56)	9 (0-60)[1]	-	3 (5.4)	12 (21.4)	20 (35.7)	21 (37.5)	0 (0)
	36	LME	13 (3-33)[1]	26	-	30 (5-75)	0 (0)	10 (1-43)[1]	-	1 (2.8)	6 (16.7)	15 (41.7)	14 (38.8)	0 (0)
Yoo *et al*[10]	44	RME	13.93 (+ 9.27)	-	225.2 (+ 102.5)	13.3 (+ 9.7)	-	-	4 (9.1)	5 (11.4)	14 (31.8)	11 (25)	9 (20.5)	5 (11.4)
	26	LME	21.42 (+ 15.71)	-	208.4 (+ 89.5)	16.7 (+ 30)	-	-	5 (19.2)	1 (3.8)	7 (26.9)	8 (30.8)	8 (30.8)	2 (7.7)
Koh *et al*[11]	19	RME	16 (4-24)[1]	19	-	-	1 (5.2)	-	1 (5.2)	2(10.5)	3 (15.7)	4 (21)	9 (47.3)	1 (5.2)
	19	LME	14 (5-27)[1]	19	-	-	0 (0)	-	0 (0)	0 (0)	5 (26.3)	4 (21)	9 (47.3)	1 (5.2)
Melich *et al*[12]	92	RME	17.2 (15-19.5)	-	-	-	1 (1.1)	-	3 (3.3)	-	-	-	-	-
	106	LME	16.3 (14.4-18.1)	-	-	-	0 (0)	-	3 (2.8)	-	-	-	-	-
Barnajian *et al*[13]	20	RME	14 (3-22)[1]	16	-	20.5 (5-50)[1]	-	10.5 (1-30)[1]	-	0 (0)	6 (40)	4 (25)	10 (35)	0 (0)
	20	LME	11 (4-18)[1]	19	-	21.5 (1-55)[1]	-	4 (0-30)[1]	-	0 (0)	7 (35)	3 (15)	10 (50)	0 (0)
	20	OME	12 (4-20)[1]	19	-	20.5 (1-45)[1]	-	8 (0-30)[1]	-	0 (0)	8 (40)	3 (15)	9 (45)	0 (0)
Ielpo *et al*[14]	56	RME	10 (0-29)	-	-	-	-	-	2 (3.6)	0 (0)	14 (25)	21 (37.5)	21 (37.5)	0 (0)
	87	LME	9 (0-17)	-	-	-	-	-	2 (2.3)	0 (0)	19 (21.8)	38 (43.6)	30 (34.5)	0 (0)
Tam *et al*[15]	21	RME	19.7 (8-40)	-	-	460 (10-180)	0 (0)	-	0 (0)	2 (10)	5 (24)	4 (19)	9 (43)	1 (5)
	21	LME	14.8 (8-21)	-	-	510 (5-80)	1 (5)	-	1 (5%)	3 (14)	7 (33)	4 (19)	7 (33)	0 (0)
Ghezzi *et al*[16]	65	RME	20.1	-	-	27 (16-44)	-	-	0 (0)	10 (15.4)	5 (7.7)	17 (26.2)	27 (41.5)	6 (9.2)
	109	OME	14.1	-	-	22 (15-30)	-	-	2 (1.8)	15 (13.8)	10 (9.2)	38 (34.9)	42 (38.5)	4 (3.7)
Kuo *et al*[17]	36	RME	14 (2-33)	-	-	22 (4-42)	0 (0)	6.7 (0-18)	4 (11.1)	7 (19.4)	4 (11.1)	11 (30.5)	14 (38.8)	0 (0)
	28	LME	13.9 (3-31)	-	-	17.9 (1-60)	1 (3.6)	7 (0-16)	4 (14.2)	6 (21.4)	2 (7.1)	8 (28.6)	12 (42.8)	0 (0)
Park *et al*[18]	32	RME	-	-	-	-	-	-	-	-	-	-	-	-
	32	LME	-	-	-	-	-	-	-	-	-	-	-	-

Saklani *et al*[19]	74	RME	11.6 (1-36)	-	128 (50-240)	17 (1-60)	-	-	3 (4)	18 (24.3)	16 (21.6)	22 (29.7)	18 (24.3)	0 (0)
	64	LME	14.7 (1-27)	-	140 (55-280)	22 (2-70)	-	-	1 (1.6)	8 (12.5)	13 (20.3)	23 (35.9)	20 (31.3)	0 (0)
Fernandez *et al*[20]	13	RME	16	9	-	-	0 (0)	-	0 (0)		-	-	-	-
	59	LME	20	24	-	-	1 (2)	-	1 (2)		-	-	-	-
Erguner *et al*[21]	27	RME	16 (3-38)	19	120 (40-180)	40 (30-80)	0 (0)	4 (2-8)	-	0 (0)	15 (55.5)	11 (40.7)	1 (3.7)	0 (0)
	37	LME	16 (3-31)	17	140 (45-230)	25 (5-50)	0 (0)	4 (1-10)	-	0 (0)	17 (46)	16 (43.2)	4 (10.8)	0 (0)
D'Annibale *et al*[22]	50	RME	16.5 (11-44)	-	-	30 (20-70)	-	-	0 (0)	-	-	-	-	-
	50	LME	13.8 (4-29)	-	-	30 (10-60)	-	-	6 (12)	-	-	-	-	-
Kang *et al*[23]	165	RME	15 (+ 9.4)	-	120 (+ 49)	19 (+ 14)	0 (0)	-	7 (4.2)	4 (2.4)	56 (33.9)	51 (30.9)	54 (32.7)	0 (0)
	165	LME	15.6 (+ 9.1)	-	113 (+ 51)	20 (+ 17)	0 (0)	-	11 (6.7)	9 (5.4)	55 (33.1)	47 (28.5)	54 (32.7)	0 (0)
	165	OME	17.4 (+ 10.9)	-	114 (+ 55)	22 (+ 17)	0 (0)	-	17 (10.3)	14 (8.5)	55 (33.3)	41 (24.8)	55 (33.3)	0 (0)
Kim *et al*[25]	62	RME	16 (+ 10)	-	-	30 (+ 14)	-	-	2 (3.2)	4 (6.5)	17 (27.4)	16 (25.8)	24 (38.7)	0 (0)
	147	LME	16 (+ 9)	-	-	25 (+ 16)	-	-	4 (2.7)	6 (4.1)	55 (37.7)	35 (24)	46 (31.5)	4 (2.7)
Park *et al*[24]	40	RME	12.9 (+7.5)	-	198 (+ 69)	14 (+ 9)	0 (0)	6.2 (4.7)	3 (7.5)	0 (0)	19 (47.5)	9 (22.5)	11 (27.7)	1 (2.5)
	40	LME	13.3 (+8.6)	-	213 (+ 139)	13 (+ 9)	0 (0)	6.9 (5.1)	2 (5)	0 (0)	13 (32.5)	15 (37.5)	11 (27.5)	1 (2.5)
Kim *et al*[26]	30	RME	-	29	-	27.9 (+ 10.2)	0 (0)	-	2 (6)	-	-	-	-	-
	39	LME	-	37	-	28.6 (+ 13.6)	0 (0)	-	1 (2.5)	-	-	-	-	-
Bertani *et al*[27]	52	RME	20.5 (5-43)[1]	-	-	26 (1-70)	-	-	2 (4)	-	-	-	-	-
	34	OME	16 (6-46)[1]	-	-	26 (1-80)	-	-	2 (6)	-	-	-	-	
Kwak *et al*[28]	59	RME	20 (12-27)[1]	-	-	22 (15-30)	0 (0)	-	1 (1.7)	3 (5.1)	16 (27.1)	23 (39)	13 (22)	4 (6.8)
	59	LME	21 (14-28)[1]	-	-	20 (12-35)	0 (0)	-	0 (0)	3 (5.1)	16 (27.1)	23 (39)	12 (20.3)	5 (8.5)
Baek *et al*[29]	41	RME	13.1 (3.33)	-	-	36 (4-100)	0 (0)	-	1 (2.4)	7 (17.1)	12 (29.3)	4 (9.8)	15 (36.6)	3 (7.3)
	41	LME	16.2 (5-39)	-	-	38 (4-110)	0 (0)	-	2 (4.9)	3 (7.3)	15 (36.6)	3 (7.3)	19 (46.3)	1 (2.4)
Park *et al*[30]	52	RME	19.4 (+ 10.2)	-	165 (+ 60)	28 (+ 19)	0 (0)	7.9 (+ 4.5)	1 (1.9)	0 (0)	15 (28.8)	15 (28.8)	22 (42.3)	0 (0)
	123	LME	15.9 (+ 10.1)	-	169 (+ 84)	32 (+ 21)	0 (0)	8.2 (+ 5.8)	3 (2.4)	0 (0)	34 (27.6)	52 (42.3)	37 (30.1)	0 (0)
	88	OME	18.5 (+ 10.9)	-	124 (+ 66)	23 (+ 15)	0 (0)	8.5 (+ 5.7)	2 (2.3)	0 (0)	27 (30.7)	32 (36.4)	29 (33)	0 (0)
Patriti *et al*[31]	29	RME	10.3 (+ 4)	-	-	21 (+ 9)	-	-	-	0 (0)	11 (38)	9 (31)	7 (24.1)	2 (6.9)
	37	LME	11.2 (+ 5)	-	-	45 (+ 72)	-	-	-	0 (0)	17 (46)	8 (21.6)	10 (27.2)	2 (5.4)
Baik *et al*[32]	18	RME	20 (6-49)	17	109 (75-200)	40 (10-55)	-		-	0 (0)	5 (27.8)	4 (22.2)	9 (50)	0 (0)
	18	LME	17.4 (9-42)	13	103 (55-85)	37 (15-60)	-	-	-	0 (0)	5 (27.8)	4 (22.2)	9 (50)	0 (0)
Pigazzi *et al*[33]	6	RME	14 (9-28)	-	-	38 (18-90)	-	-	-	-	-	-	-	-
	6	LME	17 (9-39)	-	-	35 (22-50)	-	-	-	-	-	-	-	-
Parisi *et al*[34]	40	RME	19 (6-35)[1]	32	118.5 (65-390)[1]	40 (20-80)[1]	0 (0)	-	-	2 (5)	10 (25)	9 (22.5)	19 (47.5)	0 (0)
Baek *et al*[35]	182	RME	14.8 (2-47)	-	-	22 (+ 14.3)	-	-	10 (5.5)	5 (2.7)	57 (31.3)	52 (28.5)	62 (34)	6 (3.3)
Shiomi *et al*[36]	113	RME	32 (11-112)[1]	113	180 (65-376)	26 (5-100)	0 (0)	-	0 (0)	5 (4.4)	35 (31)	28 (24.7)	38 (33.6)	7 (6.2)
Kim *et al*[37]	200	RME	16.1	-	132.5	22	0 (0)	-	2 (1)	-	-	-	-	-
Stănciulea *et al*[38]	100	RME	14 (4-32)[1]	-	-	30 (2-70)[1]	-	-	-	5 (5)	24 (24)	43 (43)	21 (21)	7 (7)
Stănciulea *et al*[38]	77	RME	12.9 (3-45)	-	-	-	2 (2.6)	-	1 (1.2)	26 (34)	8 (10)	15 (19)	26 (34)	2 (3)
Sng *et al*[40]	197	RME	16 (1-80)[1]	-	-	17 (0-8.3)[1]	-	-	2 (2.5)	-	-	-	-	-
Du *et al*[41]	22	RME	14.3 (8-27)[1]	19	-	26 (10-55)	-	-	-	0 (0)	1 (4.5)	9 (40.9)	12 (54.5)	0 (0)
Alimoglu *et al*[42]	7	RME	16 (14-21)	-	-	-	-	-	0 (0)	0 (0)	3 (42.8)	1 (14.2)	3 (42.8)	0 (0)
Akmal *et al*[43]	80	RME	14.2 (2-33)	-	-	32.5 (2-100)	-	1.8 (0-45)	-	15 (18.8)	20 (25)	12 (15)	27 (33.8)	5 (6.3)
Park *et al*[44]	30	RME	20 (14-25)[1]	25	-	-	-	11 (5-20)	0 (0)	6 (20)	7 (23.3)	4 (13.3)	10 (33.3)	3 (10)
Kang *et al*[45]	389	RME	15.7 (+ 10)	-	11.7	2.15	-	-	14 (3.6)	24 (6.2)	122 (31.4)	103 (26.5)	140 (36)	0 (0)
deSouza *et al*[46]	44	RME	14 (5-45)	-	-	-	1 (2.7)	-	0 (0)	4 (9.1)	14 (31.8)	15 (34.1)	8 (18.2)	3 (6.8)
Pigazzi *et al*[47]	143	RME	14.1 (1-39)	-	-	29 (0-100)	-	19 (1-45)	1 (0.7)	18 (12.6)	36 (25.2)	36 (25.2)	53 (37)	0 (0)
Choi *et al*[48]	50	RME	20.6 (6-48)	-	-	19 (5-45)	0 (0)	-	1 (2)	0 (0)	10 (20)	19 (38)	19 (38)	2 (4)
Ng *et al*[49]	8	RME	15 (2-26)[1]	-	-	-	-	-	0 (0)	0 (0)	3 (37.5)	2 (25)	2 (25)	0
Hellan *et al*[50]	39	RME	13 (7-28)[1]	-	-	26.5 (4-75)[1]	0 (0)	-	0 (0)	8 (20.5)	13 (33.3)	4 (10.3)	13 (33.3)	1 (2.6)

[1]Median. RME: Robotic mesorectal excision; LME: Laparoscopic mesorectal excision; OME: Open mesorectal excision.

Table 8 Short term oncologic outcomes

Ref.	Pts	Mesorectum	DSF% (yr)	LR (%)	Distant mtx (%)	OS % (yr)	F-u mo (median)
Park *et al*[8]	133	RME	81.9 (5)	3 (2.3)	16 (12)	92.8 (5)	58 (4-80)
	84	LME	78.7 (5)	1 (1.2)	14 (16.6)	93.5 (5)	58 (4-80)
Levic *et al*[9]	56	RME		0 (0)	8 (14.3)		12 (1-31)
	36	LME		0 (0)	2 (5.6)		10 (1-33)
Yoo *et al*[10]	43[1]	RME	76.7 (3)	6 (12.8)		95.2 (3)	33.9 (4.4-61.3)
	26	LME	75 (3)	2 (8.3)		88.5 (3)	36.5 (3.7-69.9)
Ghezzi *et al*[16]	65	RME	73.2 (5)	2 (3.2)	19 (29.6)	85 (5)	60
	109	OME	69.5 (5)	17.5 (16.1)	26 (24.2)	76.1 (5)	60
Saklani *et al*[19]	74	RME	77.7 (3)	2 (2.7)		90 (3)	30.1 (11-61)[2]
	64	LME	78.8 (3)	4 (6.3)		92.1 (3)	30.1 (11-61)[2]
Kim *et al*[25]	62	RME		0 (0)	3 (4.2)	98 (1.5)	17.4
	147	LME		1 (0.7)	8 (5.4)	98 (1.7)	20.6
Kwak *et al*[28]	59	RME		1 (1.8)	2 (3.6)		17 (11-25)
	59	LME		1 (1.9)	2 (3.7)		13 (9-22)
Patriti *et al*[31]	29	RME	100 (3)	0 (0)	0 (0)	96.6 (2.4)	29.22
	37	LME	83.7 (3)	2 (5.4)	4 (6)	97.2 (1.5)	18.72
Stănciulea *et al*[38]	100	RME		2 (2)		90 (3)	24 (9-63)
Alimoglu *et al*[42]	7	RME	100 (1)	0 (0)	0 (0)	100 (1)	12 (6-21)[2]
Pigazzi *et al*[47]	143	RME	77.6 (3)	2 (1.4)	13 (9)	97 (3)	17.4 (0.1-52.5)[2]

[1]1 patient excluded (palliative ISR); [2]Mean. DSF: Disease free survival rate; RME: Robotic mesorectal excision; LME: Laparoscopic mesorectal excision; OME: Open mesorectal excision.

of instruments (endowrist™), stable camera holding, motion filter for tremor-free surgery and improved ergonomics as major improvements in rectal surgery but it seems that these technical benefits have not reflected better clinical outcomes yet. This review aimed to analyze robotic rectal surgery from the first report to nowadays in order to focus on the current state and assess any benefits of robotic rectal surgery and its evolution through the years.

A well-established finding of this review is the longer operative time of robotic surgery when compared to the laparoscopic one. This is most likely due not to longer dissection but to non-surgical technical time. In fact in the totally robotic approach the docking and undocking has to be performed twice and in the hybrid approach there is the need to switch from laparoscopy to robot. A totally robotic technique without undocking is feasible, but this approach is technically much more difficult and as a consequence, a longer operative time is needed[10,12,14,16,17,22-24,27,28,37,38,40-42,48]. Traditionally, longer operative time is related with increased morbidity, most likely related to the difficulty of the operation[53]. However prolonged times in robotic surgery are not associated with an increased complication rate as demonstrated by this review and previously published review and meta-analysis[55].

In our review 2[21,23], out of 16 comparative studies reported a significantly lower estimated blood loss after robotic rectal surgery confirming that there is still no evidence that robotic rectal surgery for cancer may be associated with a lower intraoperative blood loss.

As regards convertion rates to open surgery, 3[8,22,31] out of 22 comparative studies reported significant lower complication rates in robotic patients. Many authors associated these results to better visualization, 3D view, endowrist™ technology and stable camera holding resulting in an easier dissection in narrow anatomical fields such as the pelvis[56]. Even the results reported by Ielpo *et al*[14] suggest that the robotic approach has lower conversion rates when the tumor location requests a low anterior resection and as a consequence, when the operations is technically more challenging. Since converted cases are associated to greater morbidity and tumor recurrence[57], robotic surgery could provide better oncologic long term results as well as a decreased perioperative morbidity.

The difference in protective ileostomy creation observed in this review can be related to several factors: The surgeon's habit, the tumor location, the surgeon's learning curve. Moreover, a trend toward an increasing stoma creation after robotic surgery could have been verified because of the initial worries about the new technique. On the bases of our findings the robotic approach seems associated with a higher rate of protective stoma creation.

One of the main benefits of minimally invasive surgery is the early recover. In this review we were unable to draw definitive results about any benefit of the robotic technique over conventional laparoscopy. Length of hospital stay, day of 1st flatus, 1st solid diet and 1st liquid diet were substantially similar in both the robotic and laparoscopic series even if some authors reported some advantages for either the robotic or the laparoscopic technique[8,9,15,22-24,30,32].

Anastomotic leak is the most severe surgical complication in rectal surgery. Well known risk factors for anastomotic leak are represented by cancers located less than 6 cm from anal verge, neoadjuvant radiochemotherapy, obesity and intraoperative blood transfusions[58-63]. In this review the overall anastomotic leak rates in the robotic and laparoscopic series were similar (7.3% *vs* 7.6%) with no comparative study reporting any significant difference between the 2 types of procedure. All together these results demonstrate that robotic surgery does not reduce the anastomotic leak rate. Nevertheless results of comparative studies are contradictory since 9[11,15,19,20-22,23,25,30] of these reported less anastomotic leaks in the robotic group and 9[8-10,14,17,24,28,29,31] in the laparoscopic one, but none of these results was significant. Looking at intraoperative complications, only Levic *et al*[9] reported a significant, higher rate in the robotic patients (4.48% *vs* 0%). However it must be considered that in this study there were more obese patients in the robotic group and all robotic and laparoscopic operations were performed in 2 different hospitals.

The number of harvested and examined lymph nodes is pivotal in the postoperative tumor staging whose accuracy increases with the number of nodes retrieved within the surgical specimen. The robotic platform with its 3D high definition vision and wrist-like movement of instruments should improve the lymph nodes retrieving. Nevertheless, the difference between the mean harvested lymph nodes in the robotic and laparoscopic series was not substantial in our review (15.1 *vs* 15.7 respectively) and only 2 authors[9,10] reported a significant higher number of retrieved lymph nodes in the robotic group.

The length of tumor involvement of both the distal and circumferential resection margins is considered an important parameter in evaluating the treatment of rectal cancer. Findings from the present review seems to determinate the lack of any advantages of robotic surgery over the laparoscopic approach. This issue might be explained by the likely surgeon's trend to prefer robotic approach in more advanced and distal tumors because of the theoretical superiority of this technique in pelvic dissection. In this review indeed 7 authors[10,11,15,20,22,25,31] reported a significant lower distance of the tumor from anal verge when the robotic approach was compared with the laparoscopic one. Two comparative studies[13,22] reported even a significant wider CRM in their robotic series when compared to the laparoscopic ones. However a possible bias in the evaluation of this parameter is the non-uniform recording of data: some authors report median values, others the mean values making data not comparable. Even definition of circumferential resection margin is still not clear as it is currently considered as positive as positive if < 1 mm[8,11,14,19,24,25,30,35,64] by some authors and < 2 mm[10,12,15-17,20,22,23,26-29,36,37,39,40,42,44-50] by others.

Thanks to its technical characteristics the robot platform should help in performing total and complete mesorectal excision that is an important target in rectal surgery since it potentially reflects the radicality of the operation. Unfortunately even if this is a major parameter in evaluating the radicality of the intervention, only 11 out of 43 studies in this review have addressed this important parameter. On the basis of our results any superiority of robotic mesorectal excision over the laparoscopic one cannot be demonstrated.

Robotic surgery may help in the identification and preservation of autonomic nerves due to high definition 3D image. Common sites of potential nerve damage are the superior hypogastric plexus, leading to ejaculation dysfunction in males and impaired lubrification in females, and the pelvic splanchnic nerve/pelvic plexus leading to erectile dysfunction in men. According to results of the CLASSIC trial[59] the risk of an autonomic injury with sexual dysfunction in males is significantly higher in laparoscopic surgery when compared to the open approach. The perceived advantages of robotic surgery may translate to decreased incidence of urinary dysfunction and erectile dysfunction in males. Although some preliminary results suggested that robotic assisted rectal surgery is superior to conventional laparoscopic surgery in preventing sexual or urinary dysfunction[63,64], we cannot provide definitive results since only few studies addressed this issue with high heterogeneity in the scores systems used for the analysis. Furthermore not all the patients in the studies agreed in answering questionnaires and this could lead to a possible type Ⅱ error. Some authors[26,18] reported an earlier recovery of erectile, sexual desire and urinary function when the robotic group was compared with the laparoscopic one but they did not report any difference in long-term follow-up.

In conclusion, results from the present review show that robotic surgery is as feasible and safe as conventional laparoscopy in the treatment of rectal cancer, with the only drawback of longer operative time. The magnified view, the improved ergonomics and dexterity might improve the diffusion of minimally invasive approach in the treatment of rectal cancer. Potential clinical benefits of the robotic technique must be demonstrated, if any, only by RCTs.

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