Review Article

Robot-Assisted Rectal Surgery for Malignancy: A Review of Current Literature

Quor Meng Leong,[1] *MBBS (London), M Med (Surgery), FRCSEd (Gen),* Seon Hahn Kim,[2] *MD, PhD*

Abstract

Laparoscopic colorectal surgery is rapidly gaining acceptance for the management of colorectal cancer. However, laparoscopic colorectal surgery is technically more challenging than conventional surgery. This challenge is more profound for laparoscopic rectal cancer, where there is a need to perform a total mesorectal excision (TME), in the confines of the pelvis, with the limitations of the laparoscopic system. The Da Vinci robotic surgical system was designed to overcome the pitfalls of laparoscopic surgery, hence the use of this novel system in colorectal surgery seems logical, in particular with regards to rectal cancer surgery. Recently, there have been an increasing number of reports in the literature on robotic colorectal surgery. The advantages of the robotic surgical system include; 7 degrees of movement, 3 dimensional views, tremor filtration, motion scaling and superior ergonomics. These advantages when applied to robotic TME for rectal cancer surgery may potentially translate to better outcomes. The aim of this review is to summarise the current evidence on clinical and oncological outcomes of robotic rectal cancer surgery.

Ann Acad Med Singapore 2011;40:460-6

Key words: Malignancy, Rectal, Robot

Introduction

Since it was first described in 1991, laparoscopic colorectal surgery has gained popularity and is becoming the standard of care for both benign and malignant colorectal disease. The major benefits of laparoscopic colorectal surgery include; less postoperative pain, better cosmesis, earlier return of normal bowel function and shorter hospital stay without sacrificing oncological clearance.[1] However, despite its popularity, conventional laparoscopic surgery has its shortcomings, such as a limited 2-dimensional views, limited dexterity of instruments within the confines of the abdominal space, fixed instrument tips with only 4 degrees of freedom and possible misalignment of hands and instruments. These limitations make laparoscopic surgery more challenging and technically demanding than conventional open surgery. Total mesorectal excision (TME) introduced by Heald et al[2] in 1982 has revolutionised the surgical management of rectal cancer. TME has gained worldwide acceptance as a standard surgical technique for rectal cancer.[2] When performing a laparoscopic total mesorectal excision (LapTME), meticulous and precise dissection of the mesorectum in a previously irradiated rectum down to the pelvic floor within the confines of a narrow pelvis, is a technical challenge even for experienced laparoscopic colorectal surgeons.[3-7] The preservation of anal sphincter function while obtaining an oncological clearance in rectal cancers can be very challenging.

The da Vinci Surgical System (Intuitive Surgical, Sunnyvale, CA, USA) was developed to overcome the shortcomings of conventional laparoscopic surgery. Compared with conventional laparoscopic surgery, the da Vinci system has several advantages such as 3-dimensional imaging, a stable camera and operating platform, articulating instruments with 7 degrees of freedom, excellent ergonomics, motion scaling and tremor free movements.[8-10] Robotic total mesorectal excision (RTME) may be advantageous in the dissection of the avascular plane between the presacral fascia and the fascia propria of the rectum without injury to the integrity of the mesorectum in the narrow pelvic cavity.[11] Currently, experience with robotic rectal cancer

[1]Department of General Surgery, Tan Tock Seng Hospital, Singapore 308433
[2]Department of Surgery, Colorectal Division, Korea University Anam Hospital
Address for Correspondence: Prof Kim Seon Hahn, Department of Surgery, Colorectal Division, Korea University Anam Hospital,126-1 Anam-dong 5-ga, SungBook-gu, Seoul, 136-705 Korea.
Email: drkimsh@korea.ac.kr

surgery is in its infancy.

The aim of this review is to provide a comprehensive and critical analysis of the literature on the use of robot technology in rectal cancer surgery.

Materials and Methods

A PubMed search was systemically reviewed for evidence up till May 2011, using the key words 'robot', 'rectal', cancer' and robotic rectal surgery'. The following publications types: randomised controlled trials, prospective studies, case studies and retrospective studies were considered. Studies published only as abstracts and reports from meetings were not included in this review. To be included in the review process, studies had to report outcomes on robotic rectal cancer resection surgery and were limited to those published in English. When multiple studies describing the same patient population were identified, the most recent publication was used. A total of 9 studies were identified and included in this review. Four studies were case series,[12-15] 5 were comparative studies, assessing robotic vs laparoscopic surgery for rectal malignancy.[11,16-19] The reviewers extracted the following data from eligible studies according to a pre-specified protocol: first author, publication year, study design, number of subjects, procedures performed, operating time, length of stay, estimated blood loss, cost, conversion rates and complications.

Operative Procedure

A total of 434 patients whose data were accrued from the 9 studies have undergone robotic rectal surgery and included in this review (Table 1). All 434 patients underwent robotic assisted rectal resections for neoplastic disease. All 9 studies used the da Vinci Surgical System (Intuitive Surgical Inc., Sunnydale, CA). Five studies used a hybrid technique which comprised a laparoscopic colon mobilisation, followed by a robot-assisted TME/TSME of the rectum. Three studies used the full robot-assisted approach which includes robot assisted colonic mobilisation and robot-assisted TME/TMSE of the rectum.[15,17,19] One study which was a multicentre study involving 3 institutions had a mixed approach, using both techniques.[14] Among the 434 patients who underwent robotic rectal resections, 302 (69.5%) patients had an anterior resection (high and low), 85 (19.6%) patients had an intersphincteric resection (ISR) with coloanal anastomosis while 47 (10.8%) patients had an abdominealperineal resection (APR).

Operating Times (Table 2)

The duration of the entire procedure is one of the key outcomes evaluated by all studies. Among the 9 studies included in this review, the operating times for rectal resections ranged from 190 to 347 minutes; however, there was considerable inconsistency in the reporting of data, as some studies expressed the timings in mean while others used median. Among the 5 studies comparing robotic and laparoscopic rectal surgery, 2 studies had a shorter operating time for robot-assisted surgery although the difference was not statistically significant.[11,16] However, when Patriti et al[16] performed a subset analysis on the timings for TME, they found that RTME could be performed in a significantly shorter operative time compared with LapTME. The 3 other studies report increased procedure duration with robotic procedures[17-19] when compared with laparoscopic rectal surgery. In 2 of these studies,[18,19] the difference was statistically significant. (270min vs 228 min, P <0.0001 and 239.1 min vs 168.6 min, P <0.0001, respectively)

Length of Stay (Table 2)

Eight studies have reported on the duration of length of stay, with results ranging from 5 to 11.9 days.[11-18] Among the 5 comparative studies, only Kwak et al[19] did not report the impact of robotic surgery on length of stay. The results

Table 1. Clinical Application of Robots in Rectal Cancer Surgery

Reference	Year	Study design	Method	Total	Type of operation		
					AR/LAR	ISR	APR
Ng et al[12]	2009	case series	Hybrid	8	8		
deSouza et al[13]	2010	case series	Hybrid	44	30	6	8
Pigazzi et al[14]	2010	case series	Mixed	143	80	32	31
Leong et al[15]	2011	case series	Full	29		29	
Baik et al[11]	2009	comparative	Hybrid	56	56		
Patriti et al[16]	2009	comparative	Hybrid	29	29		
Park et al[18]	2010	comparative	Hybrid	41	29	12	
Bianchi et al[17]	2010	comparative	Full	25	18		7
Kwak et al[19]	2011	comparative	Full	59	52	6	1

AR: Anterior resection; LAR: Low anterior resection; ISR: Intersphincteric resection; APR: Abdominoperineal resection

Table 2. Clinical Outcomes of Robotic Rectal Cancer Surgery

Reference	Sample		Operating time (min)		Length of stay (days)		Conversion (%)		Leak (%)		Complications (%)	
	Robot	Lap	Robot	Lap	Robot	Lap	Robot	Lap	Robot	Lap	Robot	Lap
Ng et al[12]	8	0	192.5 (145-250)	NA	5 (4-30)	NA	0	NA	0	NA	1 (12.5)	NA
deSouza et al[13]	44	0	347 (155-510)	NA	5 (3-36)	NA	2 (4.5)	NA	2 (5.6)	NA	19 (43.2)	NA
Pigazzi et al[14]	143	0	297 (90-660)	NA	8.3 (2-33)	NA	7 (4.9)	NA	15 (10.5)	NA	59 (41.3)	NA
Leong et al[15]	29	0	325 (235-435)	NA	9 (5-15)	NA	0	NA	3 (10.3)	NA	9 (31)	NA
Baik et al[11]	56	57	190.1 ± 45	191.1 ± 65.3	5.7 ± 1.1	7.6 ± 3.0	0	6 (10.5)	1 (1.8)	4 (7)	3 (5.4)	11 (19.3)
Patriti et al[16]	29	37	202 ± 12	208 ± 7	11.9 ± 7.5	9.6 ± 6.9	0	7 (18.9)	2 (6.8)	1 (2.7)	9 (30.6)	7 (18.9)
Park et al[18]	41	82	231.9 ± 61.4	168.6 ± 49.3	9.9 ± 4.2	9.4 ± 2.9	0	0	4 (9.7)	6 (7.3)	12 (29.3)	19 (23.2)
Bianchi et al[17]	25	25	240 (170-420) 6.5 (4-15)	237 (170-545)	6.5 (4-15)	6.0 (4-20)	0	1 (4.0)	1 (5.6)	2 (8)	4 (16.0)	5 (24)
Kwak et al[19]	59	59	270 (241-325)	228 (177-254)	NA	NA	0	2 (3.4)	8 (13.6)	6 (10.2)	19 (32.2)	16 (27.1)

NA: Not available

varied, with 3 studies observing a non-significant, longer length of stay after robotic surgery[16-18] while another observed a statistically significant shorter length of stay after robotic surgery.[11]

Blood Loss/Haemoglobin Change

Blood loss was reported in 4 studies[13-16] with losses ranging from 50 mls to 283 mls. Conflicting results on blood loss have been reported in studies comparing robotic and laparoscopic rectal surgery. In a comparative study, the estimated blood loss was higher in robot-assisted surgery compared to laparoscopic assisted surgery.[16] This difference was small and was not statistically significant (137.4 vs 127, P >0.05).

Conversion (Table 2)

Among the 434 patients in this review, there were only 9 (2%) conversions reported from the 2 studies.[13,14] These 9 patients were converted to open surgery. The most common reason (66%) for conversion was inability to perform pelvic dissection satisfactorily because of a heavy mesorectum from obesity or a narrow pelvis.[13,14] Among the 5 comparative studies, there were no conversions for robotic rectal surgery, compared to 16 (6.2%) conversions for laparoscopic rectal surgery. Two studies showed that these conversions were statistically significant.[11,16]

Leak Rate (Table 2)

A total of 36 (8.3%) leaks were reported among the 434 patients in this review. The reported leak rates among the 10 studies in this review ranged from 0% to as high as 13.6%. Among these reported leaks, 2 studies elaborated on the management of the leaks. For example, deSouza et al[13] had 2 leaks, one was managed with laparoscopic drainage of the pelvic collection and a diverting ileostomy; the second patient required a transanal drainage of the localised pelvic collection. Bianchi et al,[17] managed 1 patient with a leak by maintaining pelvic drainage until the infection had resolved clinically. Among the 5 comparative studies, 3 studies demonstrated a higher leak rate for robotic rectal surgery compared to conventional laparoscopic surgery,[16,18,19] while the other 2 studies[11,17] had a lower leak rate for robotic rectal surgery. None of the findings were statistically significant.

Complication Rates/ Mortality (Table 2)

The complication rate from robotic rectal surgery ranged from 5.4% to 43.2%. The overall complication rate was 31.1%. The 4 most common complications are ileus, anastomotic leak, bleeding and wound infection. Among the 5 comparative studies, 3 studies reported a higher complication rate for robotic rectal surgery[16,18,19] while 2 studies reported a lower complication rate.[11,17] Only one comparative study showed a statistically significant

Table 3. Pathological Outcomes of Robotic Rectal Cancer Surgery

Reference	Sample		Lymph nodes harvested		DRM (cm)		CRM (involved)		TME completeness	
	Robot	Lap	Robot	Lap	Robot	Lap	Robot	Lap	Robot	Lap
Ng et al[12]	8	0	15 (2-26)	NA	>2	NA	0	NA	NA	NA
deSouza et al[13]	44	0	14 (5-45)	NA	?	NA	0	NA	NA	NA
Pigazzi et al[14]	143	0	14.1 (1-39)	NA	2.9 (0-10)	NA	0.7%	NA	NA	NA
Leong et al[15]	29	0	16 (1-44)	NA	0.8 (0-4)	NA	6.9%	NA	NA	NA
Baik et al[11]	56	57	18.4 ± 9.2	18.7 ± 12	4.0 (1.0-7.0)	3.0 (1.0-9.0)	7.1%	8.8%	92.9%	75.4%
Patriti et al[16]	29	37	10.3 ± 4	11.2 ± 5	2.1 ± 0.9	4.5 ± 7.2	0	0	NA	NA
Park et al[18]	41	82	17.3 ± 7.7	14.2 ± 8.9	2.1 ± 1.4	2.3 ± 1.5	4.9%	3.7%	NA	NA
Bianchi et al[17]	25	25	18 (7-34)	17 (8-37)	2 (1.5-4.5)	2 (1.8-3.5)	0	4.0%	NA	NA
Kwak et al[19]	59	59	20 (12-27)	21 (14-28)	2.2 (1.5-3.0)	2.0 (1.2-3.5)	1.7%	0%	NA	NA

DRM: Distal resection margin; CRM: Circumferential resection margin; TME: Total mesorectal excision; NA: Not available

reduction in complications for robot rectal surgery.[11] There was one death reported among the 9 studies in this review.[13] The patient died from aspiration pneumonia on postoperative day 21.

Oncological Outcomes (Table 3)

The number of lymph nodes harvested from robotic rectal surgery ranged from 10.3 to 20 in our review. Among the 5 comparative studies, 2 studies reported a larger number of lymph nodes harvested using the robot technique,[17,18] while 3 studies reported a larger number of lymph nodes harvested using conventional laparoscopic surgery.[11,16,19] None of these reported differences were statistically significant.

The distal resection margins from robotic rectal resections ranged from 0.8 cm to 4.0 cm. Three case series reported a positive distal margin each.[13-15] Among the 5 comparative studies, 2 studies reported better distal margin clearance with robotic resections,[11,19] one study had identical results while two studies had smaller distal clearance.[16,18] None were statistically significant.

There were 10 cases (2.3%) of positive circumferential margins (CRM) among the 4 case series and 5 comparative studies. The 5 comparative studies showed that 2 studies had less CRM[11,17] while 2 studies had more involvement for robot surgery.[18,19] One study had zero CRM for both robot and laparoscopic surgery.[16]Baik et al[11] used TME completeness instead of CRM and demonstrated a superior result with robot surgery (92.8% vs 75.4%). Only one of these differences was statistically significant.

Follow-up

Five studies reported results on the follow-up.[11,14,16,17,19] The length of follow-up ranged from 10 months to 29.2 months. Kwak et al[19] reported no difference in cancer recurrence between robot and laparoscopic rectal cancer surgery. Patriti et al[16] reported no differences in overall and disease free survival but a trend towards a better disease survival in the robotic rectal surgery group. Baik et al[11] reported 2 systemic recurrences in the robotic group, and 2 systemic recurrences in the laparoscopic group. Bianchi et al[17] reported that all 50 patients in their comparative study were alive and disease free at 10 months. Pigazzi et al[14] reported a 97% 3-year survival rate among the 143 patients who underwent robotic rectal cancer surgery with no isolated local recurrence during a mean 17.4 month of follow-up.

Discussion

Laparoscopic resection of rectal cancer is safe but technically demanding with a steep learning curve. The technical challenges to conventional laparoscopic surgery include the limited range of motions of the instruments in a narrow pelvic cavity, an inadequate visual field with an unstable camera view, a relative loss of dexterity and an assistant's retraction not under the direct control of the surgeon.[20] The advantage of the da Vinci robotic system, such as the 7 degrees of freedom of movement mimicking the movements of the surgeon's wrist, the 3-dimensional view, lack of tremor, scaled down movements and superior ergonomics are extremely useful for pelvic surgery. These advantages have been best demonstrated by the urologists in robot-assisted radical prostatectomy. In a short span of 3 years, robotic radical prostatectomy has increased form 41% to nearly 80% in 2008.[21] Multiple robotic radical prostatectomy series are mature enough to demonstrate safety, efficiency and reproducibility, with oncological and functional outcome comparable to open surgery. [22-24]

The technological advantages of robotic surgery may be maximised in rectal cancer surgery, as this part of the procedure occurs in the confines of the pelvis, translating the advantages to better oncological and functional outcomes.[20] Other procedures such as right hemicolectomies and sigmoid colectomies are relatively straightforward procedures and can usually be performed effectively and safely with conventional laparoscopic surgery.[25] However, some authors suggest a role for robotic colon surgery in the terms of intracorporeal anastomosis, splenic flexure take down and natural orifice specimen retrieval.[18,26]

In general, most studies report a longer operating time for robot surgery. This is considered to be one of the disadvantages of robotic surgery, together with the lack of tactile feedback and higher cost. In this review, we found that operating time may not be longer as 2 comparative studies reported a shorter operating time for robotic surgery.[11,16] Operating time may also depend on the technique used, whether fully robotic or the hybrid technique. Interestingly, studies that reported a shorter operating time used the hybrid technique. Operating time for robotic surgery is a combination of the total time to perform the abdominal part of the surgery (the inferior mesenteric artery ligation, colonic mobilisation, splenic flexure takedown when appropriate) either laparoscopically (hybrid technique) or robotically (full robot), the pelvic dissection (robotic TME dissection), laparoscopic rectal transection, anastomosis creation, ileostomy creation when appropriate, docking and undocking time. The most crucial step of robotic rectal cancer surgery is the robotic TME dissection. Because of the heterogeneity of techniques, the true benefits of robot TME may not be apparent in the literature. What would be useful and interesting would be for future studies to perform a subset analysis comparing the time taken to perform the pelvic dissection in (laparoscopic TME vs robotic TME) patients with rectal cancer.

The zero conversion rates for robotic rectal surgery have been consistent with several of the studies in this review. Two studies reported low conversion rates of 4.5% and 4.9% only.[13,14] The overall conversion rates for this review were only 2%. This is very encouraging when considering that reported conversion rates for laparoscopic rectal surgery range from 12% to 20%.[27,28] The conversion rates for the 5 comparative studies were 0% for the robotic group compared to 6.2% for the laparoscopic group. Two of these comparative studies showed a statistically significant difference in conversion rates. Since converted patients may have higher complication rates and poorer oncological outcomes,[29,30] these better results may translate to better postoperative outcomes, superior oncological and functional outcomes. Perhaps the greatest technological advantage of the robotic system is the EndoWrist® function with the stable, 3-dimensional imaging which allows the surgeon to perform fine and precise dissection in the pelvis.

Anastomotic leaks is one of the key surgical complications for any bowel surgery. The overall leak rate for robotic rectal cancer surgery in this study is 8.3%, while the leak rate for the robotic and laparoscopic groups in the 5 comparative studies were 7.6% and 7.3%, respectively. This compares favourably with that reported in previous large series of laparoscopic rectal resection.[31-33] Other surgical complications after robotic rectal surgery have been reported but the evaluating methods are varied between the studies, making direct comparison difficult. Nevertheless, the overall complication for robotic rectal cancer appears to be similar to laparoscopic rectal surgery. In general, the length of stay and blood loss for robotic rectal surgery is similar to conventional laparoscopic surgery, with any difference being non-significant. Baik et al[11] however, showed that robot rectal surgery had a significantly shorter length of stay when compared with conventional laparoscopic surgery.

These studies are based on data accrued from highly skilled and experienced laparoscopic colorectal surgeons. However, there is a difference in the surgeon's experience between the 2 procedures as robotic surgery is a relatively novel procedure. The apparent similarity in outcome between these 2 procedures may be due to an attenuation of the benefits from the technological superiority of robotic surgery. Based on the results achieved so far, robotic rectal cancer surgery is safe and feasible when performed by the experienced and skilful laparoscopic colorectal surgeon.

Several factors regarding the resected specimen have been known to impact outcome. The College of American Pathologists recommend a minimum of 12 nodes for colorectal resection.[34] Only one study in our review had a less than 12 lymph nodes harvested.[16] Other parameters known to impact outcome, such as distal resection margin length and circumferential resection margin (CRM) positive rate, can also be an index of surgical quality. TME is widely accepted as the gold standard for rectal cancer surgery and is one of the most important factors in reducing local recurrences. Distal resection margin length and CRM positive rates were no different between the 2 groups. CRM may be positive despite a perfect TME dissection if the tumour extends up to or through the mesorectal fascia. Baik et al[35] suggested introducing TME completeness as a marker of surgical quality in rectal cancer surgery. Therefore, macroscopic evaluation of TME completeness should be an additional parameter for assessing surgical quality especially in cases with CRM involvement.[19]

Currently, the evidence of oncological outcomes for robotic rectal cancer surgery is limited.[14,16,19] The biggest case series multicentre study by Pigazzi et al,[14] involving 143 patients in 3 centres had a 97% 3-year overall survival, a 77.6% 3-year disease free survival, with no isolated local recurrence detected over a mean follow-up period of 17.4 months. Such excellent results are very encouraging and suggest that robotic rectal cancer surgery may improve local disease control. Patriti et al[16] reported a mean follow-up of 29.2 months and 18.7 months for robot and laparoscopic assisted rectal cancer surgery, respectively. They reported 1 death in each group during the follow-up and a local recurrence rate of 5.4% and 0% for laparoscopic and robotic groups, respectively. Kwak et al[19] performed a case matched controlled study comparing robot vs laparoscopic rectal cancer surgery, which was well matched and had sufficient numbers in each group (59 in each arm). The mean follow-up period was 17 months and 13 months for robot and laparoscopic surgery respectively. During this short follow-up period, the appearance of cancer recurrence was no different between the 2 groups.

Bladder and sexual dysfunction are well known complications of rectal cancer surgery. These complications are related to avulsion or direct injury to pelvic autonomic nerves during rectal resection. Despite the autonomic nerve-preserving techniques in TME, bladder and sexual dysfunction can be up to 12% and 35%, respectively.[36-40]Whether robotic rectal surgery with its technological superiority can result in a more precise pelvic dissection, which will ultimately translate to improved bladder and sexual function compared to the laparoscopic surgery is of great interest to the colorectal surgeons. To the best of our knowledge, there is no high level of evidence evaluating bladder and sexual function after robotic rectal cancer surgery. Patriti et al[16] mentioned that during the follow-up period, there were no differences between the groups in the incidence of erectile dysfunction and faecal incontinence. There was no mention of any evaluation techniques, such as standardised questionnaires.

Currently, an international, multicentre randomised controlled trial of robot-assisted versus laparoscopic resection for rectal cancer (ROLARR trial) is underway to assess whether robot assistance facilitates rectal cancer resection, as measured by the need to convert to open surgery. Secondary aims of this trial include an analysis of the surgical accuracy, safety profile, quality of life and preservation of pelvic organ function between the 2 techniques used. Only prospective randomised clinical trials, with long-term follow-ups can determine if the technological advantages of the robotic surgical system can ultimately translate to better surgical/oncological outcomes and function. Hence, we eagerly await the results of this trial.

Conclusion

The current evidence suggests that robot rectal surgery for cancer is safe and feasible. The very low conversion rate for this procedure is the main advantage over the conventional laparoscopy. The majority of published studies are case series and non-randomised comparative studies. The available data seem to show equivalent short-term clinical outcomes. The short- and medium-term oncological outcomes are equivalent or preferable to laparoscopy. Currently, there is no data to evaluate sexual and bladder function after robotic rectal surgery. Therefore, in the absence of prospective randomised controlled trials, no definitive conclusions can be made. The data from the ROLARR trial will provide crucial information on the application of this novel surgical technique.

REFERENCES

1. Abraham NS, Young JM, Solomon MJ.Meta-analysis of short-term outcomes after laparoscopic resection for colorectal cancer. Br J Surg 2004;91:1111-24.
2. Heald RJ, Husband EM, Ryall RD. The mesorectum in rectal cancer surgery--the clue to pelvic recurrence? Br J Surg 1982;69:613-6.
3. Hartley JE, Mehigan BJ, Qureshi AE, Duthie GS, Lee PWR, Monson JRT. Total mesorectal excision: assessment of the laparoscopic approach. Dis Colon Rectum 2001;44:315-21.
4. Poulin EC, Schlachta CM, Gre´goire R, Seshadri P, CadedduMO, Mamazza J. Local recurrence and survival after laparoscopic mesorectal resection forrectal adenocarcinoma. SurgEndosc 2002;16:989-95.
5. Scheidbach H, Schneider C, Konradt J Bärlehner E, KöhlerL, WittekindCh, et al. Laparoscopic abdominoperineal resection and anterior resection with curative intent for carcinoma of the rectum. SurgEndosc 2002;16:7-13.
6. Weiser MR, Milsom JW. Laparoscopic total mesorectal excision with autonomic nerve preservation. SeminSurgOncol 2000;19:396-403.
7. Watanabe M, Teramoto T, Hasegawa H, Kitajima M. Laparoscopic ultralow anterior resection combined with per anumintersphincteric rectal dissection for lower rectal cancer. Dis Colon Rectum 2000;43(10 Suppl):S94-7.
8. Pigazzi A, Ellenhorn JD, Ballantyne GH, Paz IB. Robotic-assisted laparoscopic low anterior resection with total mesorectal excision for rectal cancer. SurgEndosc 2006;20:1521-5.
9. D'Annibale A, Morpurgo E, Fiscon V, Trevisan P, Sovernigo G, Orsini C, et al. Robotic and laparoscopic surgery for treatment of colorectal diseases. Dis Colon Rectum 2004 ;47:2162-8.
10. Giulianotti PC, Coratti A, Angelini M, Sbrana F, Cecconi S, Balestracci T, et al. Robotics in general surgery: personal experience in a large community hospital. Arch Surg2003 ;138:777-84.
11. Baik SH, Kwon HY, Kim JS, Hur H, Sohn SK, Cho CH, et al. Robotic versus laparoscopic low anterior resection of rectal cancer: short-term outcome of a prospective comparative study. Ann SurgOncol 2009;16:1480-7.
12. Ng KH, Lim YK, Ho KS, Ooi BS, Eu KW. Robotic-assisted surgery for low rectal dissection: from better views to better outcome. Singapore Med J 2009;50:763-7.
13. deSouza AL, Prasad LM, Marecik SJ, Blumetti J, Park JJ, Zimmern A, et al. Total mesorectal excision for rectal cancer: the potential advantage of robotic assistance. Dis Colon Rectum 2010;53:1611-7.
14. Pigazzi A, Luca F, Patriti A, Valvo M, Ceccarelli G, Casciola L, et al. Multicentric study on robotic tumor-specific mesorectal excision for the treatment of rectal cancer. Ann Surg Oncol 2010;17:1614-20.
15. Leong QM, Son DN, Cho JS, Baek SJ, Kwak JM, Amar AH, et al. Robot-

assisted intersphincteric resection for low rectal cancer: technique and short-term outcome for 29 consecutive patients. Surg Endosc 2011 Apr 12.

16. Patriti A, Ceccarelli G, Bartoli A, Spaziani A, Biancafarina A, Casciola L. Short- and medium-term outcome of robot-assisted and traditional laparoscopic rectal resection. JSLS 2009;13:176-83.
17. Bianchi PP, Ceriani C, Locatelli A, Spinoglio G, Zampino MG, Sonzogni A, et al. Robotic versus laparoscopic total mesorectal excision for rectal cancer: a comparative analysis of oncological safety and short-term outcomes. Surg Endosc 2010;24:2888-94.
18. Park JS, Choi GS, Lim KH, Jang YS, Jun SH. Robotic-assisted versus laparoscopic surgery for low rectal cancer: case-matched analysis of short-term outcomes. Ann Surg Oncol 2010 ;17:3195-202.
19. Kwak JM, Kim SH, Kim J, Son DN, Baek SJ, Cho JS. Robotic vs laparoscopic resection of rectal cancer: short-term outcomes of a case-control study. Dis Colon Rectum 2011;54:151-6.
20. Wexner SD, Bergamaschi R, Lacy A, Udo J, Brölmann H, Kennedy RH, et al. The current status of robotic pelvic surgery: results of a multinational interdisciplinary consensus conference. Surg Endosc 2009;23:438-43.
21. Mavrich Villavicencio H, Esquena S, Palou Redorta J, Gómez RuízJJ. Robotic radical prostatectomy: overview of our learning curve. Actas Urol Esp 2007;31:587-92.
22. Patel VR, Palmer KJ, Coughlin G, Samavedi S. Robot-assisted laparoscopic radical prostatectomy: perioperative outcomes of 1500 cases. J Endourol 2008;22:2299-305.
23. Zorn KC, Gofrit ON, Steinberg GP, Taxy JB, Zagaja GP, Shalhav AL. Planned nerve preservation to reduce positive surgical margins during robot-assisted laparoscopic radical prostatectomy. J Endourol 2008;22:1303-9.
24. Badani KK, Kaul S, Menon M. Evolution of robotic radical prostatectomy: assessment after 2766 procedures. Cancer 2007;110:1951-8.
25. Jamali FR, Soweid AM, Dimassi H, Bailey C, Leroy J, Marescaux J. Evaluating the degree of difficulty of laparoscopic colorectal surgery. Arch Surg 2008;143:762-7.
26. deSouza AL, Prasad LM, Park JJ, Marecik SJ, Blumetti J, Abcarian H. Robotic assistance in right hemicolectomy: is there a role? Dis Colon Rectum 2010;53:1000-6.
27. Delgado S, Momblán D, Salvador L, Bravo R, Castells A, Ibarzabal A, et al. Laparoscopic-assisted approach in rectal cancer patients: lessons learned from >200 patients. Surg Endosc 2004;18:1457-62.
28. Dulucq JL, Wintringer P, Stabilini C, Mahajna A. Laparoscopic rectal resection with anal sphincter preservation for rectal cancer: long-term outcome. Surg Endosc 2005;19:1468-74.
29. Guillou PJ, Quirke P, Thorpe H, Walker J, Jayne DG, Smith AM, et al. Short-term endpoints of conventional versus laparoscopic-assisted surgery in patients with colorectal cancer (MRC CLASICC trial): multicentre, randomised controlled trial. Lancet 2005;365:1718-26.
30. Rottoli M, Bona S, Rosati R, Elmore U, Bianchi PP, Spinelli A, et al. Laparoscopic rectal resection for cancer: effects of conversion on short-term outcome and survival. Ann SurgOncol 2009;16:1279-86.
31. Morino M, Parini U, Giraudo G, Salval M, BrachetContul R, Garrone C. Laparoscopic total mesorectal excision: a consecutive series of 100 patients. Ann Surg 2003;237:335-42.
32. Leroy J, Jamali F, Forbes L, Smith M, Rubino F, Mutter D, et al. Laparoscopic total mesorectal excision (TME) for rectal cancer surgery: long-term outcomes. Surg Endosc 2004;18:281-9.
33. Laurent C, Leblanc F, Gineste C, Saric J, Rullier E. Laparoscopic approach in surgical treatment of rectal cancer. Br J Surg 2007;94:1555-61.
34. Compton CC, Fielding LP, Burgart LJ, Conley B, Cooper HS, Hamilton SR, et al. Prognostic factors in colorectal cancer. College of American Pathologists Consensus Statement 1999. Arch Pathol Lab Med 2000;124:979-94.
35. Baik SH, Ko YT, Kang CM, Lee WJ, Kim NK, Sohn SK, et al. Robotic tumor-specific mesorectal excision of rectal cancer: short-term outcome of a pilot randomized trial. SurgEndosc2008 ;22:1601-8.
36. Kim NK, Aahn TW, Park JK, Lee KY, Lee WH, Sohn SK, et al. Assessment of sexual and voiding function after total mesorectal excision with pelvic autonomic nerve preservation in males with rectal cancer. Dis Colon Rectum 2002;45:1178-85.
37. Jayne DG, Brown JM, Thorpe H, Walker J, Quirke P, Guillou PJ. Bladder and sexual function following resection for rectal cancer in a randomized clinical trial of laparoscopic versus open technique. Br J Surg 2005;92:1124-32.
38. Havenga K, Enker WE, McDermott K, Cohen AM, Minsky BD, Guillem J. Male and female sexual and urinary function after total mesorectal excision with autonomic nerve preservation for carcinoma of the rectum. J Am CollSurg 1996;182:495-502.
39. Masui H, Ike H, Yamaguchi S, Oki S, Shimada H. Male sexual function after autonomic nerve-preserving operation for rectal cancer. Dis Colon Rectum 1996;39:1140-5.
40. Asoglu O, Matlim T, Karanlik H, Atar M, Muslumanoglu M, Kapran Y, et al. Impact of laparoscopic surgery on bladder and sexual function after total mesorectal excision for rectal cancer. SurgEndosc 2009;23:296-303.