Robotic versus conventional laparoscopic surgery for rectal cancer: systematic review and meta-analysis

Xi-Yu Sun, Lai Xu, Jun-Yang Lu and Guan-Nan Zhang

Department of General Surgery, Peking Union Medical College Hospital, Chinese Academy of Medical Sciences and Peking Union Medical College, Beijing, China

ABSTRACT

Background: The purpose of this meta-analysis is to evaluate the evidence available on the safety as well as effectiveness of robotic resection as compared to conventional laparoscopic surgery for rectal cancer.

Material and methods: A comparison of laparoscopic and robotic surgical treatments for rectal cancer was collected. Eligible trials that analyzed probabilistic hazard ratios (HR) for endpoints of interest (including perioperative morbidity) and postoperative complications were included in our review.

Results: A total of six studies were included based on the present inclusion criteria. The pooled data showed that R-TME appeared to have association with remarkable reduction in the postoperative morbidity rate as compared to L-TME. Moreover, R-TME was also linked to lower conversion, decreased lymph node number, and longer operation time compared with L-TME. However, there was no difference in hospital stay, positive range of circumferential resection and blood loss between the two study groups.

Conclusions: Robotic rectal cancer surgery provides favorable outcomes and is considered as a safe surgical technique in terms of postoperative oncological safety. Like laparoscopic TME surgery, robotic surgery may be a valid alternative and complementary approach with beneficial effects on minimally-invasive surgery.

Abbreviations: HR: hazard ratio; TME: total mesorectal excision; MIS: minimally invasive surgery; LS: laparoscopic surgery; RS: robotic surgery

Introduction

Colorectal cancer is regarded as one of the most widely occurring malignancies in the world. Rectal cancer accounts for 28% to 35% of the total incidence of colorectal cancer [1]. Surgical techniques and the introduction of total mesorectal excision (TME) [2,3] have led to significant clinical progress and become the major innovations in the treatment of rectal cancer with considerable improvement.

Laparoscopic total mesorectal excision (TME) has been widely accepted and performed as a standard of surgical care [4]. Several randomized trials [5–8] have demonstrated that laparoscopic total mesorectal excision (TME) has short-term oncological safety, less postoperative pain, beneficial results in appearance, quicker recovery, and shorter hospital stay as compared to open surgery. However, in spite of the clinical success as a surgical treatment of rectal cancer, laparoscopic surgery has many potential deficiencies in laparoscopic colorectal technology [6,9], such as the high conversion rate to open surgery, the lack of visualization caused by unstable cameras, and the lack of personalized therapy for selected patients [10–12].

In theory, robotic surgery for rectal cancer has brought on significant clinical progress in an effort to overcome the limitations of laparoscopic surgery. According to several studies that have been published recently, the use of robotic systems in rectal cancer is technically feasible and is a safe surgical option in terms of short-term oncologic outcomes [13,14], including motion filters for use in nonfibrillation surgery. It provides magnified three-dimensional imaging, a camera that is easy for surgeons to control on a stable platform, which makes the rectal dissection more comfortable, and is associated with less fatigue for surgeons [15].

However, a number of descriptive and comparative studies have failed to show superiority of robotic-assisted laparoscopic surgery over conventional laparoscopic surgery.
surgery in long-term follow-up of patients. The quality of technical and oncological results remains controversial in large retrospective studies [16].

Therefore, the aim of this meta-analysis is to evaluate, compare and update the evidence obtained on the true benefits of robotic surgery in the treatment of rectal cancer. We focus on the evaluation of intra- and postoperative outcomes of robotic TME in comparison with laparoscopic TME for rectal cancer.

Material and methods

Search strategy

A systematic literature search was performed using PubMed, Embase, Cochrane library up to December 2017. The process was established to find all articles with the keywords: ‘rectal cancer’ ‘laparoscopic surgery’ and ‘robotic-assisted surgery’. Database searches were conducted with MeSH key words. The reference lists of all articles that dealt with the topic of interest were also hand-searched to check for additional relevant publications.

Eligibility criteria

The inclusion criteria of the present meta-analysis were as follows:

- studies designed as randomized controlled or propensity scores matched trials comparing robotic-assisted versus laparoscopic surgery;
- studies with patients diagnosed with rectal cancer;
- studies providing data on perioperative effectiveness and efficacy for both robotic-assisted and laparoscopic surgery, and providing HRs with its 95% CIs;
- full texts only were included.

If we found duplicated or overlapped data in multiple reports, we only included the one with the most complete information.

Quality assessment

Two investigators separately rated the quality of the retrieved studies. Study quality was assessed using the Newcastle–Ottawa Quality Assessment Scale.

Data extraction

Two authors independently extracted the relevant data from each trial. Disagreement was resolved by consensus. From each of the eligible studies, the main categories were based on the following parameters: first author family name, publication year, study design, study period, sample size, number of male patients, the outcomes of interest including intraoperative parameters (conversion to open, operative time and number of removed lymph nodes), and postoperative parameters (hospital length of stay, positive circumferential resection margin, blood loss, postoperative morbidity).

Statistical analysis

Meta-analysis was performed by pooling the results of reported incidence of intraoperative and postoperative parameters. The results were expressed as the average difference of consecutive results (standards and weightings are determined from existing data) and the appropriate ratio/difference of the bipartite results determined from the available data.

Sensitivity analyses were also performed to examine the effect on overall outcomes, depending on the heterogeneity of the included studies. The $I^2$ statistic was used to test statistical heterogeneity [17], with values of $>50\%$ representing important heterogeneity, then a random-effects model was used to perform the meta-analysis; $I^2$ with a value $<50\%$ suggested low degree of heterogeneity, then fixed-effects model was used [18]. A $p$ values $<0.05$ was considered statistically significant. The statistical analyses were performed using Review Manager version 5.3 software (Revman; The Cochrane collaboration Oxford, UK). Findings of our meta-analysis were shown in forest plots. The Begg test and the Egger test were conducted to evaluate publication bias.

Results

Overview of literature search and study characteristics

A total of 547 studies were retrieved initially for evaluation. Based on the criteria described in the methods, 11 publications were evaluated in more detail, but some did not provide enough detail of outcomes of two approaches. Therefore, a final total of six retrospective cohort studies [19–24] were included in this meta-analysis. The search process is described in Figure 1.

All studies included in this study were based on moderate-strong evidence with high quality. Table 1 describes the primary characteristics of the eligible
studies in more detail. The complications listed in different trials are summarized in Table 2.

Clinical and methodological heterogeneity

Pooled analysis of postoperative morbidity rate comparing robotic-assisted versus laparoscopic surgery

A fixed-effects model was used to pool the postoperative morbidity rate data, since there was no heterogeneity across the three studies. The pooled data showed that robotic-assisted surgery decreased the postoperative morbidity rate (OR =1.67; 95% CI =1.24–2.25; p = .0007) as compared with laparoscopic surgery (Figure 2).

| Study           | Publication year | Study design | Study period          | Sample size | Number of male patients | Age |
|-----------------|------------------|--------------|-----------------------|-------------|-------------------------|-----|
| S. H. Baik      | 2008             | RCT          | 2006.4–2007.2         | 18          | 18                      | 60  |
| Alberto Patriti | 2009             | PSM          | 2004.3–2008.10        | 37          | 12                      | 69  |
| Jin Kim         | 2017             | PSM          | 2007.4–2014.3         | 224         | 141                     | 61  |
| David Jayne     | 2017             | RCT          | 2011.1–2014.9         | 234         | 159                     | 65.5|
| Min Soo Cho     | 2015             | PSM          | 2007.1–2011.6         | 278         | 184                     | 58.3|
| Yong Sok Kim    | 2016             | PSM          | 2010.3–2012.1         | 66          | 46                      | 58.2|

Table 2. Complications in different trials.

| Complications                              | References |
|--------------------------------------------|------------|
| Operative time                             | [19–24]    |
| Rate of conversion to open                  | [19–24]    |
| Rate of dissected lymph nodes               | [19–24]    |
| Blood loss                                  | [20,23,24] |
| Length of hospital stay                     | [19–24]    |
| Positive circumferential resection margin   | [21–24]    |
Pooled analysis of operative time comparing robotic-assisted versus laparoscopic surgery

Pooling the data from six studies showed that laparoscopic surgery increased the operative time (MD = 54.15; 95% CI = 13.02–95.29; p = .01) compared with the laparoscopic group (Figure 3).

Pooled analysis of the rate of conversion to open comparing robotic-assisted versus laparoscopic surgery

The rate of conversion to open was available for six trials. Results showed that there was a lower rate of conversion to open compared with robotic-assisted surgery (odds ratio (OR) = 0.55; 95% CI = 0.33–0.93; p = .003) (Figure 4).

Pooled analysis of dissected lymph nodes comparing robotic-assisted versus laparoscopic surgery

The available data of the dissected lymph nodes rate included six studies (Figure 5). The aggregated results suggested that there was lower incidence of the rate of dissected lymph nodes in the robotic-assisted surgery group (MD = −0.90; 95% CI = −1.82 to 0.02; p = .05).

Pooled analysis of operative parameters comparing robotic-assisted versus laparoscopic surgery

In the analysis of blood loss and the length of hospital stay when comparing robotic-assisted versus laparoscopic surgery for rectal cancer, three studies [20,23,24] (Figure 6) and six studies were included (Figure 7), respectively. The positive circumferential
resection margin was reported in four studies [21–24] (Figure 8), which was not statistically significant.

Discussion

This study reviews the current treatment of rectal cancer based on a multidisciplinary approach that requires surgery, chemotherapy and radiotherapy. The overall aim of surgery is to remove the rectum and mesorectum contained within the intact fascia of the rectum. The correctly performed total mesorectal excision (TME) surgery has been demonstrated to reduce pelvic recurrence, prolongs survival, and preserves postoperative recovery and urinary function by nerve preservation [2,25]. With the development of minimally invasive techniques for rectal cancer in
recent years, the current surgical treatment of rectal cancer is trending towards minimally invasive surgery (MIS) [23].

Laparoscopic surgery (LS) or MIS has been shown to be as safe and effective as open surgery with several advantages [6], including good magnification and illumination of the colorectal region, which can improve the visualization of the pelvic structures [26]. The short-term prevalence of CLS is higher than in open surgery in patients with rectal disease [27]. However, several technical limitations exist including the limited range of motion within narrow pelvic devices, the loss of flexibility, and insufficient vision due to unstable camera vision [9].

Robotic surgery (RS) has emerged as a new promising technique that might overcome the drawbacks of conventional laparoscopic surgery. It provides advanced technologies such as immersive three-dimensional depth of field, improved dexterity, and less tremor. Therefore, it is expected to have superiority in terms of complex procedures or with small spaces in which conventional laparoscopic approaches might be difficult to perform, such as the pelvic cavity [28,29]. However, in spite of the clinical success, robotic surgery still has several potential limitations, such as the loss of tactile feedback, the limited range of movement of the robotic arm, the time requirement and high cost of the system. At present, the clinical application of robotic surgical systems in colorectal cancer resection is still under exploration.

To date, questions remain concerning whether the robotic approach is superior over the laparoscopic approach with regard to the oncologic results and postoperative morbidity in rectal cancer patients [30–34]. Furthermore, it is more difficult to perform RCTs in the surgical field. Therefore, our meta-analysis is based on randomized controlled and propensity scores matched trials.

We found that the conversion rate of rectal cancer in patients with RS was significantly lower than that of patients with CLS, suggesting that RS may better manage complex surgery and was considered as an alternative or compensatory option, allowing more patients to benefit from minimally invasive surgery [35]. Due to the higher incidence of complications in conversion patients and poor oncological outcomes, a lower conversion rate for robotic rectal cancer surgery may lead to better postoperative courses and improved oncological outcomes [6,36]. The reason for the conversion of the R-LAR group is attributed to the superiority of the high-exposure and high-definition surgery in the pelvis due to the stable camera platform that can grasp and manipulate organs and the ability of the surgeon to move the three-dimensional camera as needed [30]. Since the conversion rate is related to technical difficulty, surgical experience and intraoperative complications, assessing the effectiveness of robotic surgery are good indicators [35].

In our analysis, robotic rectal surgery was performed with longer time and higher cost than laparoscopic rectal surgery, which was also considered as the major drawback according to previous studies [32,37]. Longer operative time may be due to additional setup and pause time, and the inherent technical limitations associated with this technique’s steep learning curve [38,39]. The heterogeneity of operative time was very high in both methods ($I^2 = 98\%$). The most common reason for the high heterogeneity is the inclusion of research using a hybrid robotic approach. To clarify this point, consideration should be given to the comparison of subgroup analysis on operative time based on the type of resection in future studies. In addition, the learning curve for R-LAR was more remarkable than that for the L-LAR procedure, and surgeons were relatively unfamiliar with R-LAR techniques [40]. The operative times for R-LAR are expected to be shortened with more practice of the technique.

However, there was no significant difference in hospitalization time between the two groups, indicating that the recovery time was similar between the groups. The 3-D high-definition surgical field provided by robotic surgery and enhanced flexibility can better preserve tissue and reduce complications, which may be related to shorter hospital stay [41].

From an oncology perspective, CRM involvement has been used as a powerful prognostic factor for rectal cancer surgery. According to several reports, CRM involvement in surgical specimens is closely related to local recurrence and distant metastasis of rectal cancer [42]. CRM involvement was defined when there was tumor extension (continuous or discontinuous) or a positive lymph node within 1 mm of the radial nonperitoneal soft tissue edge of the rectal wall [43]. Compared to traditional laparoscopes, robotic systems can complete safe CRM [44]. However, there was no significant difference in the quality of surgery between the R-TME and L-TME groups. Park et al. [14] reported that the rate of CRM involvement was mainly affected by two factors: the location of the rectal tumor and the quality of the operation. More RCTs with larger sample size are needed to further confirm our current findings.
Admittedly, there are several limitations in the present meta-analysis. Considering the small sample size and poor methodology of the eligible studies, potential bias exists due to different characteristics with nonrandom and presurgery baseline in the included studies. The high degree of heterogeneity in some results may have affected the effectiveness of the meta-analysis. In addition, our study did not assess the cost-effectiveness results between the two groups.

The cost of robotic equipment is much higher than that in laparoscopic surgery. Therefore, in order to further assess the need for clinical practice of the new technique, cost-effectiveness trials should be performed using robotic surgery for rectal cancer.

In summary, robotics may be an alternative and promising technique for both surgeons and patients in overcoming the technical difficulties associated with the narrow pelvis and potential functional benefits such as early recovery of voiding function. According to our findings, compared with laparoscopic rectal cancer surgery, robotic surgery has a lower conversion rate, lower lymph node clearance and postoperative morbidity but is associated with longer operative time. There was no difference in hospitalization time, peripheral marginal involvement and bleeding. In agreement with previous studies [21,22], this study showed the potential advantages of the robotic surgical system in oncology. However, different beneficial outcomes were observed in rectal cancer resection by various surgeons based on their experience in robotic surgery. Additional studies on the real benefits of robotic surgery are warranted to evaluate the superiority of R-TME over other methods as a standard surgery for patients with rectal cancer.

Declaration of interest

No potential conflict of interest was reported by the authors.

References

[1] Monson JRT, Weiser MR, Buie WD, et al. Practice parameters for the management of rectal cancer (revised). Dis Colon Rectum. 2013;56:535–550.
[2] Heald RJ, Husband EM, Ryall RD. The mesorectum in rectal cancer surgery—the clue to pelvic recurrence? Br J Surg. 1982;69:613–616.
[3] Heald RJ, Ryall RD. Recurrence and survival after total mesorectal excision for rectal cancer. Lancet. 1986;1:1479–1482.
[4] Senagore AJ. Adoption of laparoscopic colorectal surgery: it was quite a journey. Clin Colon Rectal Surg. 2015;28:131–134.
[5] Clinical Outcomes of Surgical Therapy Study Group, Nelson H, Sargent DJ, Wienand HS, et al. A comparison of laparoscopically assisted and open colectomy for colon cancer. N Engl J Med. 2004;350:2050–2059.
[6] Guillou PJ, Quirke P, Thorpe H, 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;365:1718–1726.
[7] Veldkamp R, Kuhry E, Hop WC, et al. Laparoscopic surgery versus open surgery for colon cancer: short-term outcomes of a randomised trial. Lancet Oncol. 2005;6:477–484.
[8] Kang SB, Park JW, Jeong SY, et al. Open versus laparoscopic surgery for mid or low rectal cancer after neoadjuvant chemoradiotherapy (COREAN trial): short-term outcomes of an open-label randomised controlled trial. Lancet Oncol. 2010;11:637–645.
[9] Sammour T, Kahokehr A, Srinivasa S, et al. Laparoscopic colorectal surgery is associated with a higher intraoperative complication rate than open surgery. Ann Surg. 2011;253:35–43.
[10] Siegel R, Cuesta MA, Targarona E, et al. Laparoscopic extraperitoneal rectal cancer surgery: the clinical practice guidelines of the European Association for Endoscopic Surgery (EAES). Surg Endosc. 2011;25:2423–40.
[11] Huang M-J, Liang J-L, Wang H, et al. Laparoscopic-assisted versus open surgery for rectal cancer: a meta-analysis of randomized controlled trials on oncologic adequacy of resection and long-term oncologic outcomes. Int J Colorectal Dis. 2011;26:415–421.
[12] Ng SSM, Lee JFY, Yiu RYC, et al. Long-term oncologic outcomes of laparoscopic versus open surgery for rectal cancer: a pooled analysis of 3 randomized controlled trials. Ann Surg. 2014;259:139–147.
[13] Baik SH, Kim NK, Lim DR, et al. Oncologic outcomes and perioperative clinicopathologic results after robot-assisted tumor-specific mesorectal excision for rectal cancer. Ann Surg Oncol. 2013;20:2625–2632.
[14] Park EJ, Cho MS, Baek SJ, et al. Long-term oncologic outcomes of robotic low anterior resection for rectal cancer: a comparative study with laparoscopic surgery. Ann Surg. 2015;261:129–137.
[15] Corcione F, Esposito C, Cuccurullo D, et al. Advantages and limits of robot-assisted laparoscopic surgery: preliminary experience. Surg Endosc. 2005;19:117–119.
[16] Sun Z, Kim J, Adam MA, et al. Minimally invasive versus open low anterior resection: equivalent survival in a national analysis of 14,033 patients with rectal cancer. Ann Surg. 2016;263:1152–1158.
[17] Higgins JP, Thompson SG. Quantifying heterogeneity in a meta-analysis. Stat Med. 2002;21:1539–1558.
[18] Higgins JPT, Thompson SG, Deeks JJ, et al. Measuring inconsistency in meta-analyses. BMJ. 2003;327:557–560.
[19] Baik SH, Ko YT, Kang CM, et al. Robotic tumor-specific mesorectal excision of rectal cancer: short-term outcome of a pilot randomized trial. Surg Endosc. 2008;22:1601–1608.

[20] Patriti A, Cecarelli G, Bartoli A, et al. Short- and medium-term outcome of robot-assisted and traditional laparoscopic rectal resection. JSLS. 2009;13:176–183.

[21] Kim J, Baek SJ, Kang DW, et al. Robotic resection is a good prognostic factor in rectal cancer compared with laparoscopic resection: long-term survival analysis using propensity score matching. Dis Colon Rectum. 2017;60:266–273.

[22] Jayne D, Pigazzi A, Marshall H, et al. Effect of robotic-assisted vs conventional laparoscopic surgery on risk of conversion to open laparotomy among patients undergoing resection for rectal cancer: the ROLARR randomized clinical trial. JAMA. 2017;318:1569–1580.

[23] Cho MS, Baek SJ, Hur H, et al. Short and long-term outcomes of robotic versus laparoscopic total mesorectal excision for rectal cancer: a case-matched retrospective study. Medicine (Baltimore). 2015;94:e522.

[24] Kim YS, Kim MJ, Park SC, et al. Robotic versus laparoscopic surgery for rectal cancer after preoperative chemoradiotherapy: case-matched study of short-term outcomes. Cancer Res Treat. 2016;48:225–231.

[25] Junginger T, Kneist W, Heintz A. Influence of identification and preservation of pelvic autonomic nerves in rectal cancer surgery on bladder dysfunction after total mesorectal excision. Dis Colon Rectum. 2003;46:621–628.

[26] Park SY, Choi G-S, Park JS, et al. Short-term clinical outcome of robot-assisted intersphincteric resection for low rectal cancer: a retrospective comparison with conventional laparoscopy. Surg Endosc. 2013;27:48–55.

[27] Arezzo A, Passera R, Scozzari G, et al. Laparoscopy for rectal cancer reduces short-term mortality and morbidity: results of a systematic review and meta-analysis. Surg Endosc. 2013;27:1485–1502.

[28] D’Annibale A, Morpurgo E, Fiscon V, et al. Robotic and laparoscopic surgery for treatment of colorectal diseases. Dis Colon Rectum. 2004;47:2162–2168.

[29] Spinoglio G, Summa M, Priora F, Quaratini R, Testa S. Robotic colorectal surgery: first 50 cases experience. Dis Colon Rectum. 2008;51:1627–1632.

[30] Bianchi PP, Ceriani C, Locatelli 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;24:2888–2894.

[31] Kwak JM, Kim SH, Kim J, et al. Robotic vs laparoscopic resection of rectal cancer: short-term outcomes of a case-control study. Dis Colon Rectum. 2011;54:151–156.

[32] Baek JH, Pastor C, Pigazzi A. Robotic and laparoscopic total mesorectal excision for rectal cancer: a case-matched study. Surg Endosc. 2011;25:521–525.

[33] Memon S, Heriot AG, Murphy DG, et al. Robotic versus laparoscopic proctectomy for rectal cancer: a meta-analysis. Ann Surg Oncol. 2012;19:2095–2101.

[34] Hara M, Sng K, Yoo BE, et al. Robotic-assisted surgery for rectal adenocarcinoma: short-term and mid-term outcomes from 200 consecutive cases at a single institution. Dis Colon Rectum. 2014;57:570–577.

[35] Ortiz-Oshiro E, Sánchez-Egido I, Moreno-Sierra J, et al. Robotic assistance may reduce conversion to open in rectal carcinoma laparoscopic surgery: systematic review and meta-analysis. Int J Med Robotics Comput Assist Surg. 2012;8:360–370.

[36] Rottoli M, Bona S, Rosati R, et al. Laparoscopic rectal resection for cancer: effects of conversion on short-term outcome and survival. Ann Surg Oncol. 2009;16:1279–1286.

[37] Kim NK, Kang J. Optimal total mesorectal excision for rectal cancer: the role of robotic surgery from an expert’s view. J Korean Soc Coloproctol. 2010;26:377–387.

[38] Bokhari MB, Patel CB, Ramos-Valadez DI, et al. Learning curve for robotic-assisted laparoscopic colorectal surgery. Surg Endosc. 2011;25:855–860.

[39] Park EJ, Kim CW, Cho MS, et al. Multidimensional analyses of the learning curve of robotic low anterior resection for rectal cancer: 3-phase learning process comparison. Surg Endosc. 2014;28:2821–2831.

[40] D’Annibale A, Pernazza G, Morpurgo E, et al. Robotic right colon resection: evaluation of first 50 consecutive cases for malignant disease. Ann Surg. 2010;252:988–993.

[41] Sun Y, Xu H, Li Z, et al. Robotic versus laparoscopic low anterior resection for rectal cancer: a meta-analysis. World J Surg Oncol. 2016;14:61.

[42] Wibe A, Rendedal PR, Svensson E, et al. Prognostic significance of the circumferential resection margin following total mesorectal excision for rectal cancer. Br J Surg. 2002;89:327–334.

[43] Nagtegaal ID, Marijnen CAM, Kranenbarg EK, et al. Circumferential margin involvement is still an important predictor of local recurrence in rectal carcinoma: not one millimeter but two millimeters is the limit. Am J Surg Pathol. 2002;26:350–357.

[44] Leonard D, Penninckx F, Fieuws S, et al. Factors predicting the quality of total mesorectal excision for rectal cancer. Ann Surg. 2010;252:982–988.