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REVIEW ARTICLE

Robotic Colorectal Surgery

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ABSTRACT

Aim: Studies reporting outcomes of robotic colorectal surgery were identified by systematic searches of electronic databases. Outcomes examined included operating time, length of stay, blood loss, complications and cost and conversion rates.

Results: Fifteen studies (nine case series, four comparative studies, two randomized controlled trial) describing 420 procedures were identified and reviewed. Robotic procedures tend to take longer and cost more, but may reduce the length of stay, blood loss and conversion rates. Complication profiles and short-term outcomes are similar to laparoscopic surgery.

Conclusion: Robotic colorectal surgery is a promising field and may provide a powerful additional tool for optimal management of more challenging pathology, including rectal cancer. Current evidence suggests that the safety and feasibility of robotic colorectal surgery has been established. The advantages conferred by the robot are particularly useful for rectal dissection. Although the majority of published studies are case series or nonrandomized comparative studies, data show equivalent clinical short-term outcomes except for longer operating times and lower conversion rates compared with laparoscopic surgery. However, the lack of prospective randomized studies precludes definitive conclusions. Multicenter, prospective randomized controlled trials designed to evaluate safety, feasibility, cost-effectiveness and long-term outcomes will provide crucial information on the practice of robotic colorectal surgery.

Keywords: Robotic surgery, Laparoscopy, Colorectal.

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INTRODUCTION

Over the last 30 years, minimally invasive techniques have revolutionized general surgical practice, above all impacting surgery of the gastrointestinal (GI) tract. Benefits of such an approach have been observed in almost all surgical subspecialties and include reduced postoperative pain, shorter hospital stay and an improved cosmetic outcome.[1] Though slower to gain acceptance, laparoscopic colorectal surgery has gained in popularity, and in experienced hands is now regarded as a safe and feasible alternative to open surgery. Early concerns over oncological outcomes have been addressed by several large randomized studies, demonstrating comparable results between laparoscopic and conventional surgery.[2-5] Nevertheless, the long learning curve, together with inherent difficulties such as two-dimensional imaging, limited dexterity and diminished tactile sense have meant that the application of laparoscopic surgery to technically demanding. Colorectal procedures continue to present a challenge, in particular for restorative resection of mid and low rectal cancers.[6,7] Robotic surgical systems may offer a solution in overcoming these difficulties. A number of systems have been reported and offer several advantages overconventional laparoscopic surgery including; first, it has a magnified full high definition 3D camera that is under the control of the surgeon. Second, the instruments have a free articulating endowrist. The full articulating robot arms facilitate the dissection and retraction of the specimen in these complex surgeries and enhanced dexterity. Third, the movements of the robotic arms are precise with complete elimination of the tremors produced by the surgeon's hand. Fourth, the ergonomic position of the surgeon while working in the console reduces the muscle strain on the surgeon that is seen with conventional laparoscopy.

Although surgical robots have been successfully applied to a number of disciplines, most notably urological and cardiac procedures,[8,9] robotic colorectal surgery remains in its infancy. The first two cases of robotically assisted colectomy were performed in 2001[10] and since then there have been a number of publications on the use of robotic systems in colorectal surgery.

The da Vinci surgical robot has been used for general surgery procedures, and there has been an increase in the last few years in colorectal surgery but there is still no standardized technique (Figs 1A and B). For left colon resection and LA procedures, it has been described in several procedures:

1. *Hybrid technique:* Technique that mainly consists of laparoscopic mobilization of splenic flexure followed by robotic docking for the dissection of the pelvis and completion of the procedure.
2. *Single-docking technique (described by Kim SH):* Technique that incorporates mobilizing the second and third robotic arm for the different parts of the procedure utilizing single docking at the left lower quadrant (splenic flexure mobilization and for the pelvic dissection).
3. *Double-docking technique (described by KY Lee and BS Min):* Technique that incorporates docking from the left hemiabdomen for dissection of the splenic flexure and then changing the docking to the left lower quadrant and placing an extra port at the right hemiabdomen for the pelvic dissection.

AIM

The aim of this review is to provide a comprehensive and critical analysis of the available literatures on the use of robotic technology in colorectal surgery.

METHODS

Google, SpringerLink and HighWire Press search engines had been gone through using the following keywords: robotic colorectal surgery. Fifteen recent (> 2005) articles had been deliberately reviewed. This review will concentrate upon the following main points: Operative time, blood loss conversion rate, hospital stay and complication.

RESULTS AND DISCUSSION

The first robotic-assisted colectomies were reported in 2002 by Weber et al[10] who performed successful robotic-assisted laparoscopic sigmoidectomies and right hemicolectomies for diverticulitis. Since then, wide range of colorectal operations have been performed, including right and left hemicolectomies, sigmoid resections, rectopexies with/without resection, anterior resections, abdominoperineal resections and total colectomies.[10,15,20,23,25-28]

Table 1 shows chronologically how robotic surgery has been applied in the field of colorectal surgery. In the beginning, robotic surgery was performed in a variety of types of operations and embraced a wide range of diseases including both benign and malignant.[26,27] It appears to be a process of verifying the safety and feasibility of this new technology and it was a process for finding where we could achieve maximum benefits from the robotic surgical system. The indications for its use are still evolving and many colorectal surgeons are passionately adopting the robot and trying to discover the boundaries where the robot can be applied. Spiniglio et al[20] reported their initial 50 cases of robotic colorectal surgery, comparing them with 161 conventional laparoscopic cases during the same time periods. The types of operation were evenly distributed from right colectomy to anterior resection and these operations

Figs 1A and B: (A) Operation theater with the da Vinci surgical system, and (B) an operator at the master console

Table 1: Clinical application of robots in colorectal surgery

Reference	*Year*	*Country*	*Study type*	*Number*	*Platform*	*Procedure(s)*
Braumann[11]	2005	Germany	Case series	5	da Vinci	RHC(1) SC(4)
Woeste[12]	2005	Germany	Comparative	6	da Vinci	SC(4) RP(2)
Ruurda[13]	2005	Holland	Case series	23	da Vinci	RP(16) ICR(5) SCS(2)
Sebajang[14]	2006	Canada	Case series	7	da Vinci	RHC(3) SC(3) AR(1)
Pigazzi[15]	2006	USA	Comparative	6	da Vinci	AR(6)
DeNoto[16]	2006	USA	Case series	11	da Vinci	SC(11)
Hellan[17]	2007	USA	Case series	39	da Vinci	AR(33) PRC(6)
Rawlings[18]	2007	USA	Comparative	30	da Vinci	RHC(17) SC(13)
Baik[19]	2008	Korea	Randomized	18	da Vinci	AR(18)
Spinoglio[20]	2008	Italy	Comparative	50	da Vinci	RHC(18), LHC(10), AR(19), APER(1), TRC(1) TC(1)
Fabrizio et al[21]	2009	Italy	Case series	55	da Vinci	LHC(27) AR(17) APR(7) TRS(4)
Kim et al[22]	2010	Korea	Case series	15	da Vinci	RHC(13) SIG(5) PEXY(2) AR(125) APR(9)
Zimmern et al[23]	2010	USA	Case series	131	da Vinci	APR(11) TPRRHC(42) SIG(16) PEXY(8) AR(47)7
Ragupathi et al[24]	2011	USA	Case series	24	da Vinci	AR(24)

RHC: Right hemicolectomy; ICR: Ileocecal resection; TRC: Transverse colectomy; LHC: Left hemicolectomy; SC: Sigmoid colectomy; AR: Anterior resection; TP: Total proctocolectomy; APR: Abdominoperineal resection; TRS: Transsphincteric resection were performed mainly on malignant diseases (88%). Zimmern et al[23] presented a retrospective review of 131 cases from their 4-year experiences of robotic colorectal surgery (Fig. 2). They reported that the robotic procedures included 42 right colectomies, 16 anterior resections for benign disease, eight anterior resections with rectopexy for prolapse, seven total proctocolectomies, 47 low and ultralow anterior resections for rectal cancer and 11 abdomino-perineal resections. Fourteen percent of a total of 954 colorectal resections were performed by robotic procedures. Although they did not present details, the indication for robotics seems to be diverse and its application broad.

At present, application of the robotic surgical system for total mesorectal excision (TME) seems to have the greatest potential for benefit, as it is expected to prove its ability when the operation is performed within a confined pelvis. The majority of recent studies have been focusing on robotic TME for rectal cancer.[29-36] According to kim et al[22] (Table 1), types of procedure are heavily weighted in favor of rectal cancer resection. In their institution, more than half of all rectal cancer patients have had robotic rectal resection since its introduction in their institute; 117 cases were performed by robotic surgery and 102 cases by laparoscopic surgery during the study period.[36]

Other procedures like right hemicolectomy or sigmoid resection are relatively straightforward procedures for the colorectal surgeon and can be effectively and safely performed using conventional laparoscopy.[37] Furthermore, after considering the higher medical cost and longer operating time, it is less attractive to implement robotic colorectal surgery except for TME in rectal cancer.[25,18,38] Some authors suggest alternative roles for the robot in the field of colon surgery, such as intracorporeal anastomosis, easier taking down of the splenic flexure, natural orifice specimen extraction or as a training tool.[20,26,35,38] It would be more appropriate to wait for more data from large randomized studies before a definite recommendation can be made.

Short-term clinical outcomes for robotic colorectal surgery such as operating time, conversion rate, length of hospital stay, morbidity and mortality are reviewed and compared with laparoscopic colorectal surgery.

In general, longer operating time is widely considered to be one of the disadvantages of robotic surgery, along with higher cost and lack of tactile sense, compared with conventional laparoscopic procedure. The robotic surgical system is still complex and bulky, and therefore a large operating room is needed and it takes significantly longer to prepare the device. Woeste et al[12] commented that the robot setup time has the tendency to remain long even after the initial learning curve. Because, some studies included setup time in the operating time.[20] The gap will be decreased if the robot setup time is considered. The operating time will also depend on whether the hybrid technique or totally robotic technique is utilized. Notably, although it is just a numerical difference, some authors have reported even shorter operating times for robotic rectal cancer resections using a hybrid technique.[30,31] Badani et al[17] reported their experience with 2,766 robotic-assisted radical prostatectomies and compared the results of their first 200 cases with their last 200 cases. The mean surgical and console times were 160 and 121 irrespectively in the first 200 cases; in the last 200 cases, they were 131 and 97 minutes respectively ($p = 0.05$). Since there is no large series in robotic colorectal surgery, we cannot be certain if the same conclusion can be reached. As we ascend the learning curve, achieving the prevention of any collisions with proper port placement and the standardization of every step of the procedure, the operating time can be expected to decrease further.

The excellent conversion rate has been reported consistently in several series of robotic rectal cancer surgery.[30,31,34-36] Although no statistically significant

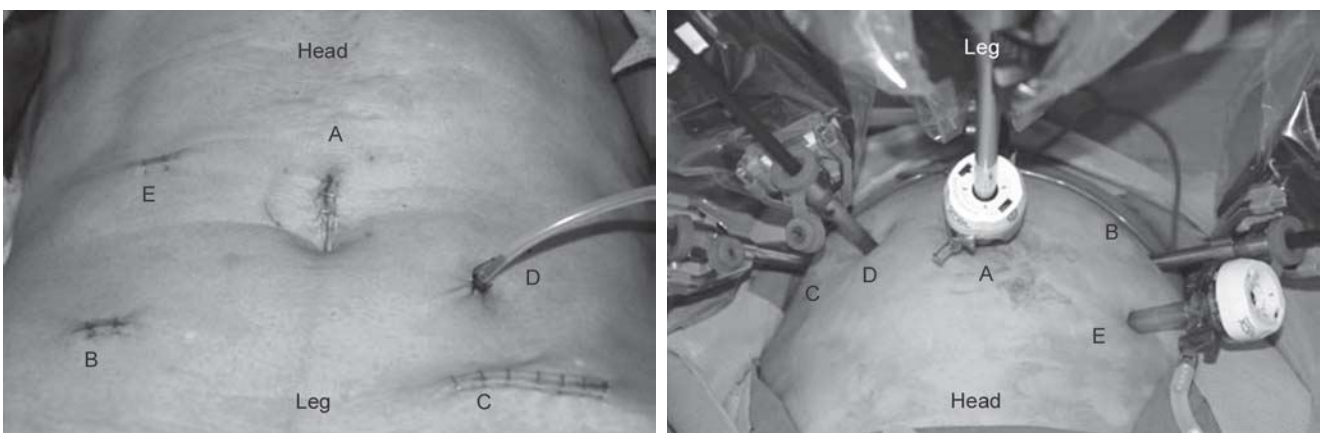

Fig. 2: Position of the working port for robotic low anterior resection. A: 12 mm camera port; B: 8 mm robot port. This port was exchanged with a 12 mm trocar to allow use of an Endo-GIA, C: 8 mm robot port; used for specimen delivery; D: 8 mm robot port; E: 11 mm port for assistance

differences were noted between the two groups in these studies, the zero conversion rates in robotic rectal cancer surgery are promising and encouraging when considering that reported conversion rates in laparoscopic rectal cancer surgery range from 12 to 20%.[39,40] Since, converted patients may have higher complication rates and worse oncologic outcomes,[41,42] these results can lead to better postoperative course and improved oncologic and functional outcomes.

The most frequent cause of conversions difficulty in pelvic dissection, which can cause bleeding from the lateral pelvic wall, rectal perforation and unintended injury to an adjacent organ. The most important technological advantage of the robotic surgical system is the ability to perform a fine dissection in a narrow pelvic cavity due to a stable, three-dimensional image and a freely articulating EndoWrist (Intuitive Surgical, Sunnyvale, CA, USA).

Similar outcomes of postoperative recovery between robotic and laparoscopic colorectal surgery were reported in most of the available publications.[18,20,26,27,32,35,36] Park et al[35] compared postoperative course in their case-matched analysis and showed no differences in first flatus passage (2.9 *vs* 2.7 days, $p = 0.487$), time to resume diet (6.7 *vs* 6.6 days, $p = 0.924$) and postoperative hospital stay (9.9 *vs* 9.4, $p = 0.527$). By contrast, Baik et al[30] in their nonrandomized comparative study of 56 robotic and 57 laparoscopic low anterior resections, reported shorter time to resume diet (4.7 *vs* 5.5 days, $p = 0.008$) and postoperative hospital stay (5.7 *vs* 7.6 days, $p = 0.001$). They presumed that the lower serious complication rates in the robotic group would influence the patients' recovery.

Surgical complications after robotic colorectal surgery have been documented in various previous studies but evaluating parameters also varied between the studies.[20,26,27,30,31,34-36] Nevertheless, robotic colorectal surgery seems to be equivalent to laparoscopic surgery in terms of overall operative complications. To the best of our knowledge, there was no report of postoperative mortality from robot-related complications.

As most studies are based on data from highly experienced laparoscopic colorectal surgeons, there is a definitive difference in the surgeon's expertise between the two operative techniques. We hypothesize that this difference may attenuate the benefits of robotic surgery, resulting in similar clinical outcomes rather than superior results due to its technological advantages. In view of the results achieved so far, robotic colorectal surgery can be performed safely and feasibly by the skillful laparoscopic surgeon.

Intraoperative blood loss has been reported in nine studies[13,17,20,25,26,43-45] with losses ranging from 21 to 400 ml. In one series, an instance of severe intraoperative hemorrhage following injury of a pelvic vein during a robotically assisted abdominoperineal resection is described, although it was considered unrelated to the robotic technique.[17] Conflicting results on blood loss have been found in studies comparing laparoscopic and robotic colorectal surgery. Delaney et al[25] and Woeste et al[44] both noted a nonsignificant increase in blood loss with robotic surgery. Rawlings et al found blood loss to be reduced in robotic right hemicolectomy, but increased in sigmoid colectomy when compared with laparoscopic resections. Other groups have also reported reduced blood loss with robotic colorectal procedures.[13,26,44,45] Biak et al[19] compared the mean change in hemoglobin concentration as a surrogate marker for blood loss. In their randomized study, they identified a nonsignificant reduction in blood loss in the robotic group.

SUMMARY

Current evidence suggests that the safety and feasibility of robotic colorectal surgery has been established. The advantages conferred by the robot are particularly useful for rectal dissection. Although the majority of published studies are case series or nonrandomized comparative studies, data show equivalent clinical short-term outcomes except for longer operating times and lower conversion rates compared with laparoscopic surgery. However, the lack of prospective randomized studies precludes definitive conclusions. Multicenter, prospective randomized controlled trials designed to evaluate safety, feasibility, cost-effectiveness and long-term outcomes will provide crucial information on the practice of robotic colorectal surgery.

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