REVIEW ARTICLE

The Role of Minimally Invasive Surgery and Outcomes in Colorectal Cancer

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Abstract

For some time now, there has been significant interest in understanding and defining the role of minimally invasive surgery in colorectal cancer. Laparoscopic surgery has been shown to have similar or better outcomes compared with open surgery. Recently, prospective randomized trials have demonstrated oncologic outcomes of laparoscopic colon surgery equivalent to those for open surgery. However, the technical challenges of performing laparoscopic resection of rectal cancers and the uncertainty of the oncologic quality of the surgical resection have hindered the growth of minimally invasive rectal surgery. Robotic rectal surgery has recently emerged as an attractive alternative to laparoscopic surgery because it allows for superior visualization within a narrow pelvic field and more precise dissection. Studies of robotic rectal resection have suggested similar or potentially improved short-term oncologic outcomes when compared with laparoscopic rectal resection. Ongoing randomized studies will provide additional insight into the role of laparoscopic and minimally invasive robotic surgery for rectal cancer.

History of Robotic Surgery

Since the introduction of robotic surgery in 1985 when a robotic flexible arm (PUMA 560) was used to orient a needle for a brain biopsy,[1] there has been extensive research on and growth in the use of robot-assisted surgery. One of the many reasons for the growing interest in robotic surgery stems from the shortcomings of laparoscopic minimally invasive surgery (MIS), including suboptimal optics, loss of dexterity, need for experienced assistants, and inability to provide fixed retraction. A number of robotic systems were first introduced in the 1990s, all touting several advantages over conventional laparoscopic surgery, including enhanced dexterity, three-dimensional field of vision, and more intuitive instrument manipulation,[2] reducing the difficulty associated with complex laparoscopic procedures, particularly for nonlaparoscopic surgeons.[3,4]

In 2000, the US Food and Drug Administration approved the first commercial robotic device for general laparoscopic surgery, and soon thereafter, many reports surfaced, suggesting that cases once considered technically too difficult or previously unfeasible to treat by laparoscopy could now be performed with the assistance of a robot.[5] Early proponents of robotic surgery highlighted shorter learning curves for performing MIS, better depth perception from three-dimensional stereoscopic vision, increased freedom of instrument movements (degrees of freedom), and tremor filtration from the console to the patient.

When robotic surgery was in its infancy and general surgeons were struggling to define the utility of robotic MIS in complex abdominal surgery, urologists quickly embraced commercially available robotic surgical systems. With the exception of high-volume centers, few centers were performing laparoscopic radical prostatectomy (LRP), because the procedure was known to be very challenging, with the greatest difficulty being in performing urethrovesical anastomosis. The technical limitations of a confined and narrow pelvis hindered optimal visualization and prevented maneuverability of laparoscopic instruments. The technical difficulty of LRP combined with uncertainty regarding the oncologic adequacy of the procedure prevented its rapid adoption. However, the improved dexterity of the robotic interface overcame many of the technical limitations.

Initial reports on robot-assisted prostatectomy highlighted the fact that many of the aforementioned disadvantages associated with LRP—namely, the inability to perform precise movements within the

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tight confines of the male pelvis—could be overcome with the robot. The first large case series highlighting the effective and efficient use of robot-assisted surgery was reported by Menon,[6] revolutionizing the role of robot-assisted surgery in urology.

Soon thereafter, many centers began to perform and document the feasibility of robot-assisted surgery in a variety of surgical subspecialties. General surgeons in particular began examining the utility of robotic surgery, and many case series documented its feasibility for cholecystectomies and even complex pelvic surgery.[7–11] However, it was never clear where robotic surgery fit into general surgery. Opponents of robotic surgery argued that surgeons alone can perform many laparoscopic procedures more efficiently than with a robot. In addition, the increased costs, loss of haptic feedback, and inability to perform multiquadrant surgery were prohibitive to the rapid adoption of robotic surgery. Proponents of robotic surgery argued that the superior three-dimensional visualization and the ability to perform articulated and precise movements in tight confines such as the pelvis were better than conventional laparoscopic surgery.

One arena of gastrointestinal surgery where robotic assistance for MIS has gained considerable favor has been in colorectal surgery. In multiple trials, laparoscopic colectomy has been shown to have similar or better short-term outcomes compared with open surgery,[12,13] with a lower risk for perioperative morbidity, including surgical-site infection, urinary tract infection, and pulmonary complications, as well as shorter hospital stays. In view of such information, MIS is routinely being performed for colorectal disease. More recently, surgeons have also looked to the robot to facilitate performance of more complex operations.

Minimally Invasive Surgery and Oncologic Outcomes

There were initial reservations regarding the oncologic safety and adequacy of MIS for colon cancer; however, several prospective randomized trials have demonstrated that the oncologic outcomes of laparoscopic colon surgery are equivalent to open surgery.[14–16] These results led the American Society of Colon and Rectal Surgeons and the Society of American Gastrointestinal and Endoscopic Surgeons to support laparoscopic resections for curable colon cancer by suitably experienced surgeons in selected patients.[17] However, the technical challenges of laparoscopic rectal resection, along with the potential for functional and oncologic hazard, have limited the expansion of MIS for rectal cancer. Studies are under way to evaluate the role of laparoscopic resection for locally advanced rectal cancer.[18]

Although the feasibility of laparoscopic pelvic surgery has been demonstrated, there are little data regarding oncologic outcome. However, some lessons can be learned from the experience with minimally invasive prostatectomy. A study of 4702 patients who underwent laparoscopic prostatectomy performed by 29 experienced surgeons at 7 high-volume centers demonstrated a steep learning curve for the procedure, based on 5-year risk for recurrence after resection as determined by serum level of prostate-specific antigen.[19] The risk was elevated until a surgeon had performed $\geq$250 laparoscopic prostatectomies. Another meta-analysis, reported in 2009, compared published results of 1067 LRPs with results for 973 open radical retropubic prostatectomies (RRPs) and 1034 robot-assisted laparoscopic radical prostatectomies (RALPs) regarding perioperative, functional, and oncologic outcomes.[20] Although the analysis observed no statistically significant difference in stage-stratified rates of positive surgical margins in those patients undergoing open RRP or LRP (relative risk, 1.02; 95% CI, 0.83–1.26; p = 0.85), there was a significant difference in rates of positive surgical margins favoring RALP (relative risk, 2.23; 95% confidence interval [CI], 1.36–3.67; p = 0.002) over open RRP. These data are in keeping with the technical challenges of LRP and the potential advantages afforded by the robotic interface.

One of the factors hindering the growth of minimally invasive rectal cancer surgery has been the lack of adequately powered randomized studies of oncologic and functional outcomes. The uncertainty of the oncologic quality of the surgical resection, including factors such as mesorectal dissection and circumferential resection margin, combined with the technical difficulty of the procedure, have made it difficult for surgeons to readily adopt this technique. Although observational studies have suggested that MIS for rectal surgery may be similar to open rectal resection regarding oncologic outcomes,[21–24] there are little data from prospective randomized trials comparing outcomes. Analysis of the rectal cancer subgroup of the Conventional versus Laparoscopic-Assisted Surgery in Colorectal Cancer (CLASICC) randomized, controlled trial raised concern about a potentially higher risk for positive circumferential resection margin and impaired sexual function in men associated with the laparoscopic approach[25] without differences in three-year rates of local failure or overall survival.[18] However, that study was not specifically designed to address oncologic endpoints of MIS for patients with rectal cancer.

The COREAN (Comparison of Open versus laparoscopic surgery for mid and low REctal cancer After Neoadjuvant chemoradiotherapy) trial randomized patients to laparoscopic or open proctectomy for mid to low rectal cancer.[26] It observed no difference between circumferential resection margin, macroscopic quality of the total mesorectal excision, number of harvested lymph nodes, or perioperative morbidity between the two groups. However, no long-term data are yet available, and the study was not sufficiently powered to address survival outcomes. Currently, there are two ongoing prospective, randomized trials examining the outcomes of MIS for rectal cancer: The COLOR (COlon cancer Laparoscopic or Open Resection) II[27] and ACOSOG (American College of Surgeons Oncology Group) Z6051[28] trials are randomized, international, multicenter studies that will compare the outcomes of laparoscopic (including robotic in ACOSOG Z6051) and conventional resection of rectal carcinoma with curative intent. These studies will test the efficacy of laparoscopic and open surgery with respect to short- and long-term oncologic outcomes, including quality of the mesorectal dissection, risk for local recurrence, and disease-free survival. Other endpoints will include quality of life, sexual function, and costs.

Some of the risk for oncologic efficacy of laparoscopic rectal surgery may come from the technical challenges of performing laparoscopic resection of rectal cancers particularly in patients with bulky tumors or in those who are obese. In an effort to overcome some of these limitations, considerable interest has emerged on robot-assisted colorectal surgery. A number of case series and nonrandomized comparative studies[29,30] from early experiences with robotic colorectal surgery have been reported that demonstrate the feasibility of the robotic approach. Robotic approaches to the rectum are attractive for some of the same reasons that robotic surgery for prostatectomy has been so readily accepted: superior visualization for mesorectal dissection within a narrow pelvic field and improved precision for radical mesenteric vascular dissection for lymphadenectomy.[31]

Most reports of robot-assisted rectal resection, however, have been based on limited numbers of patients.[32-35] A small prospective, comparative trial performed in Korean patients[36] compared laparoscopic to robotic-assisted low anterior resection. Although initially designed as a randomized study, the study had difficulty recruiting patients to accept randomization. However, the patients were similar with respect to demographics and tumor factors. The authors observed that robotic low anterior resection (LAR) of the rectum had superior outcomes versus laparoscopic LAR for the integrity of the mesorectal dissection specimen ($p = 0.033$). Other short-term outcomes were similar, although the robotic surgery group experienced a lower conversion rate (0% robotic vs 10.5% laparoscopic) and a shorter length of hospital stay (4.7 days for robotic vs 5.5 days for laparoscopic).

Short-term outcomes for robotic versus laparoscopic total mesorectal excision for rectal cancer in 50 Italian patients were reported in 2010, and no differences in tumor characteristics, duration of surgery, or morbidity were observed between the groups.[37] In addition, the median number of lymph nodes examined did not differ between the groups. Also in 2010, a larger Korean study reported short-term outcomes of robotic-assisted laparoscopic surgery for low rectal cancer in 113 patients assigned to either laparoscopic or robotic rectal resection.[38] Both groups had similar tumor characteristics, and there were no observed differences in early short-term morbidity, return of bowel function, or length of hospital stay. Again, there was a lower rate of conversion to open surgery in the robotic-surgery group (0%) than the laparoscopic-surgery group (10%). Mean distal and circumferential resection margins were the same in both groups. There was a trend toward an increased number of harvested lymph nodes in the robotic-surgery group (17.3 ± 7.7 vs 14.2 ± 8.9; $p = 0.06$).

One of the only reports of survival outcomes includes 64 patients after robotic total mesorectal excision.[39] All findings for circumferential and distal resection margins were negative, the median number of lymph nodes harvested was 14.5; 32 of 38 mesorectal specimens were deemed complete, whereas 6 of 38 were deemed nearly complete. After a mean follow-up of 20.2 months, there was local recurrence in 3.1% (2 of 64) of patients and distant-only metastases in 6.3% (4 of 64). The mean time to local recurrence was 23 months. The conversion to open surgery in this early experience was 9.4% (6 of 64), which is in line with or better than previously reported conversion rates for laparoscopic rectal surgery.[15,21,24,40]

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Surgical Approach to Robot-Assisted Rectal Surgery

As more data emerge documenting the feasibility and safety of robot-assisted rectal surgery, it is becoming increasingly clear that there are several shortcomings of the robot, including limited working volume and the need for fixed docking. Performing both splenic flexure mobilization and rectal dissection is a challenge for the robotic system. The currently available da Vinci (Intuitive Surgical, Inc, Sunnyvale, CA) robotic system cannot accommodate the large working volume needed to work in multiple abdominal quadrants without repeat docking. Because of this limitation, various techniques for robotic rectal surgery have emerged.

The traditional "hybrid" approach to robot-assisted rectal surgery involves laparoscopic colon mobilization, followed by robotic pelvic dissection. Laparoscopy is first used to isolate and ligate the inferior mesenteric artery and then to mobilize the splenic flexure. Thereafter, the robot is used for the pelvic dissection.[33,41,42] Two shortcomings of this hybrid approach are that it may require additional port placement and that the benefits of the robotic interface are not realized during the lymphovascular dissection. Furthermore, because only the rectal dissection is performed robotically, it is still a prerequisite that the surgeon and assistant have expertise in laparoscopic surgery during the vascular dissection and colonic mobilization.

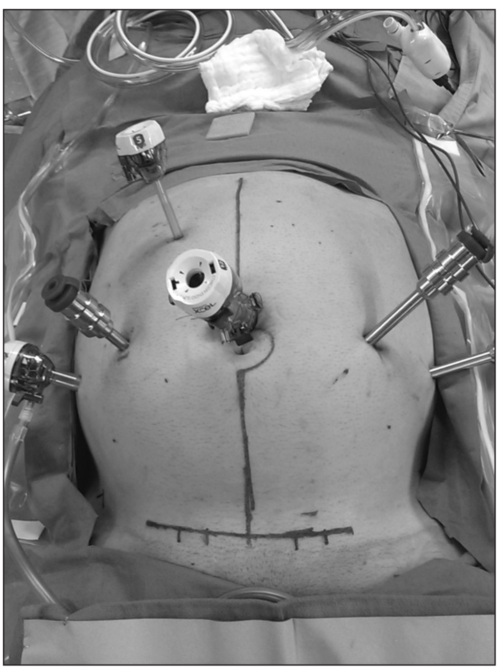

Figure 1. In the "reverse hybrid" approach to robotic rectal dissection, trocar placement is optimized to facilitate the pelvic dissection first, and then laparoscopic splenic flexure mobilization. The specimen is eventually removed via a Pfannenstiel incision or transanally.

These shortcomings led to the evolution of "totally robot rectal surgery" either with the robotic surgical cart, surgical table, and patient's position maintained throughout the operation or with two or more separate dockings. In one of the largest series reported to date, this technique has been described as a six-port system, where five robotic ports and a camera port are used to perform complete rectal surgery from the splenic flexure to the pelvic floor.[43] The surgical procedure consists of two phases. The first phase, the lateral phase, consists of medial-to-lateral dissection from the sacral promontory to the splenic flexure, dissection of lymph nodes around the interior mesenteric artery, ligation of the artery, and splenic flexure mobilization if needed. Thereafter, two of the robot arms are detached and redocked to different ports. The second phase, the pelvic phase, involves dissection of the mesorectum while preserving the pelvic autonomic nerve plexus, division of the mesorectum if needed, and division of the rectum with an endolinear staple when possible. The anastomosis is performed either laparoscopically or under direct open visualization. Another approach has used an over-the-hip single docking to perform these steps without redocking of the robot.[44] Although the entire procedure is performed using the robot, the series reported to date have only rarely performed complete splenic flexure mobilization, perhaps the most difficult aspect of a robot-assisted approach, particularly with a single docking because of external collisions between the robotic arms.[43,44] Even the authors who first reported over-the-hip docking have acknowledged the limitations of this approach to flexure mobilization. Furthermore, in this configuration, the system is limited in its ability to reach the distal rectum. In the US splenic flexure mobilization is generally a requisite step during rectal resection and reconstruction because of the characteristic poor quality of the sigmoid colon as a rectal replacement, and therefore the single-docking technique may often not be applicable.

At the University of Texas MD Anderson Cancer Center, motivated in part by the more distal nature of our rectal cancer practice in a more obese and taller US population, we have developed a "reverse hybrid" approach to robotic rectal resection (Figure 1). It entails performing robotic lymphovascular dissection and pelvic dissection first, and then laparoscopic splenic flexure mobilization (Park I, You Y, Schlette E, et al, unpublished data, 2011). One of the advantages of the reverse hybrid approach is that it requires a single docking of the robotic cart and that the docking is between the patient's legs to allow the robotic system to have maximized instrument range while minimizing the risk for external collisions. After the pelvic dissection is completed, the robot is completely removed from the operating field, and the laparoscopic approach to the splenic flexure is initiated. Thus the robotic phase includes all of the steps for rectal resection with the exception of splenic flexure mobilization, similar to the "totally robotic" approach. Laparoscopic splenic flexure mobilization overcomes the limitations of working volume and fixed docking and permits the optimal use of patient position and gravity to assist with retraction and colonic mobilization. After the splenic flexure is mobilized, the specimen is delivered either transanally or through a small Pfannenstiel incision and the anastomosis is constructed in a standard fashion.

Conclusions

The role of robotic surgery in rectal disease continues to evolve. MIS for colon cancer has been shown to have improved short-term results compared with open surgery.[12,13,45] However, there are still technical challenges that must be overcome, and oncologic efficacy must be established before more MIS for rectal surgery is readily accepted. Ongoing randomized trials should provide additional data regarding the appropriateness of MIS, and the evolution and advancement of technology and techniques of robotic surgery may further enhance the therapeutic applicability of MIS for rectal cancer. ❖

Disclosure Statement

The author(s) have no conflicts of interest to disclose.

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The Slightest Attack

Allow patients to escape with the slightest attack of surgery your skill can supply.

— *Robert Tuttle Morris, 1857-1945, American surgeon and author*