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Robotic Rectal Cancer Surgery: Current Practice, Recent Developments, and Future Directions

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Abstract

Purpose of Review The robotic surgical platform is increasingly used for rectal cancer surgeries. However, whether the long-term clinical and oncological outcomes are significantly better, considering the high costs of this approach, is still debated.

Recent Findings ROLARR trial did not demonstrate lower conversion rates with robotic compared to laparoscopic rectal cancer surgery, except in a subgroup. Recent large-scale observational studies state otherwise, reporting outcomes favoring the robotic approach. Additionally, functional and long-term oncological outcomes are yet to be thoroughly evaluated. The costliness of robotic surgery is a major concern, however, newer technology and growing experience might improve the cost value in the long-term.

Summary Large-scale, multicenter randomized trials, and comprehensive analyses are needed to form conclusions with the best evidence on clinical, oncological, functional, and economic outcomes of robotic rectal cancer resections. The technical advantages of the platform are well-recognized, therefore, similar to the progressive adaptation of laparoscopy, robotic surgery is expected to become routine. By identifying the right patient populations, implementing cost-conscious strategies, utilizing newer devices and growing the expertise, robotic platform will likely prove its value for rectal cancer surgery.

Keywords Robotic surgery · Rectal cancer · Total mesorectal excision · Proctectomy

Introduction

Laparoscopic platform forever changed the surgical field. Although at the beginning there was considerable hesitation, the prospect of achieving similar clinical results with less surgical incisional trauma started gaining interest [1]. Over the years, as large-scale studies confirmed better overall patient outcomes and decreased costs, the technique was widely adopted by many surgeons [2–4].

Colorectal cancer is the fourth leading cause of cancer-related mortality, and rectal cancers make up approximately 30% of the cases [5, 6]. Management of rectal cancer differs from colon cancer, and with increasing incidence there is considerable interest in this area. Total mesorectal excision is still the mainstay of rectal cancer treatment, and minimally invasive approaches are increasingly utilized, as 52.8% of proctectomies were done laparoscopically in 2016 compared to 9.8% in 2005 [7]. However, multicenter randomized clinical trials (RCTs) comparing laparoscopic to open rectal cancer surgery yielded mixed results in terms of oncological outcomes and conversion rates, causing concern about the utility of minimally invasive surgery for these particular procedures.

Laparoscopic rectal surgery brings numerous challenges to the table. Maneuverability in the deep and narrow pelvic space becomes difficult, due to rigid instruments causing a fulcrum effect and colliding with each other. The lack of tactile feedback is prominent. Surgeons have to adapt to a two-dimensional assistant-controlled camera view, where depth perception is reduced and assistant movement varies.

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These issues with laparoscopy were cited as possible explanations for the poor results in clinical trials [8, 9].

Robotic surgical platform was first introduced in the early 2000s, to address shortcomings of laparoscopy, especially for procedures performed in compact areas of the body [10]. This new technology provided the surgeon with a more stable self-controlled camera and a three-dimensional view, advanced instruments with 7 degrees of freedom, motion scaling, and tremor-filtration features. The system was designed to provide high precision in small fields, allowing access to some difficult anatomical regions such as the pelvis. Additionally, the ergonomic design helped decrease surgeon fatigue, and the two-console settings allowed for assisting and teaching.

Nowadays, the robotic system is increasingly used for rectal cancer resections. The proposed technical advantages, compared to laparoscopy, prompted expectations of better surgical outcomes with the robot. Several trials evaluated this claim, with inconclusive results [11••, 12••]. Recent large-cohort observational studies, however, show a benefit compared to laparoscopy [13••, 14••]. Nevertheless, the discussion is ongoing, and factors such as learning curve, cost, and availability are evaluated to truly decide the value for the patients. This review will discuss the current practice at our institution, particularly referring to the experience of high-volume robotic surgeons, recent developments in the field, and future directions.

Robotic Proctectomy

Patient Selection and Evaluation

For any surgery to be successful, multiple patient factors should be considered. The patient with a rectal mass should be thoroughly evaluated with a cancer-specific detailed history and physical examination. We recommend preoperative flexible sigmoidoscopy and/or colonoscopy, to evaluate the index lesion and identify any synchronous ones. Preoperative rectal MRI with contrast and multidisciplinary tumor board discussion for all rectal cancers are also routine in our practice.

While there are almost no absolute contraindications to choosing the robotic approach, the patient should be medically fit to tolerate the pneumoperitoneum and positioning of minimally invasive surgery. Surgeon experience and preference play a crucial role, as mastery in robotic technique takes time. Therefore, expected complexity of the operation should be taken into account.

Preoperative Interventions and Room Setup

In our institution, compulsory preoperative steps include mechanical bowel preparation and oral antibiotics. Intravenous antibiotics are administered within 30–60 minutes of incision [15]. Deep venous prophylaxis consists of compression devices, and preoperative low-molecular-weight heparin.

In the operating room, an orogastric tube and a urinary catheter are inserted in all cases. Rectal irrigation with saline is done for rectal cancer resection patients. The patient is placed in a modified lithotomy position, the yellowfins are used to prevent peroneal nerve injury. This positioning has the advantages of creating additional space for an assistant, and allowing easy access to the anus for an intraoperative colonoscopy and/or transanal stapler use while forming an anastomosis. Gel pads are used to provide decubitus support and additional stability. The operating table is moved during the procedure into a reverse Trendelenburg. Significant tilting and sliding can occur, therefore, we prefer to further secure the patient with strong tapes around the chest area to prevent injuries.

Operative Steps

Intraoperative flexible sigmoidoscopy can be performed to assess tumor location, if not done beforehand. Two monitors are routinely present in the room, on each side of the operating table, so the entire team has a clear view throughout the operation. The robotic camera is connected to the monitors for the bedside assistant to follow. An incision 1–2 cm above and left of the umbilicus is made, and an 8 or 12 mm port is placed. Pneumoperitoneum is achieved, and the camera is inserted. Video-endoscopy is undertaken first, to assess the abdomen, especially for metastatic disease. With this camera port in place, other ports are placed under direct intraabdominal vision.

Port-site selection is a crucial step and can be highly variable depending on the anticipated operative technique [16]. Operating surgeon's personal experience and skill level will affect this choice. Totally robotic and hybrid techniques can be performed with similar safety profiles. However, operative times are usually longer with hybrid approaches. As a general rule of thumb, instrument clashing should be kept in mind for port-site placement, especially for earlier robotic systems. Maintaining a minimum distance of "one-hand's breadth" between ports should be the goal [17].

Until recently we employed a different approach which required double-docking for left colonic mobilization and pelvic dissection. However currently, with the Da Vinci Xi robotic system (Intuitive Surgical, Sunnyvale, USA), we perform the procedure with one-docking. For this, we place three additional 8 mm ports along a diagonal line from right anterior superior iliac spine (ASIS) and left lower costal margins as shown in Fig. 1.

The robot is on the left-side setting, and the patient is placed in a right-tilted, slight Trendelenburg position, so the small bowel and cecum are displaced out of the field. We start our dissection from the left side, with medial-to-lateral mobilization of the left colon. The avascular dissection plane and the vessels are identified. Usually, we start with inferior mesenteric artery (IMA), and once identified high ligation is performed with Hem-o-Lok clips or a vessel sealer. The inferior mesenteric vein (IMV) is identified and ligated next. Gastrocolic and splenocolic ligaments are divided for access to the lesser sac.

Typically, the medial-to-lateral dissection is completed and left colon is mobilized. After that, we continue with the pelvic mesorectal dissection, starting at the sacral promontory, below the superior hemorrhoidal artery plane. We follow the avascular plane between the mesorectal envelope and endopelvic parietal fascia. Importance of the mesorectal envelope completeness should be kept in mind, and dissection carried out carefully [18]. Hypogastric nerve plexuses should be identified while carrying out the dissection down towards levators.

Rectum is divided with articulating endoscopic stapling devices. We then come back to proximal colon, and inject indocyanine green (ICG) to evaluate tissue perfusion. This built-in intraoperative fluorescence angiography ability is another advantage of the robotic platform. After confirming the proximal site with good blood flow, the specimen is transected with staplers and extracted from the Port 3 or 4 depending on the choosen ileostomy site (Fig. 1). Anastomosis is typically created by using a 31 mm circular stapler. Flexible sigmoidescopy is performed to check the anastomotic ring, for active bleeding and the leak test. Sometimes, a diverting loop ileostomy is brought up, port incisions closed, and stoma matured if present, to conclude the procedure.

Minimally Invasive Rectal Cancer Surgery: Clinical, Oncological, and Functional Outcomes

Management of rectal cancer changed significantly in the last two decades. Expanded screening efforts and modern treatment modalities such as neoadjuvant chemoradiation improved survival. However, total mesorectal excision is still the mainstay in rectal cancer treatment for curative intent [19]. As for many other procedures, a minimally invasive approach is increasingly utilized for rectal cancer resections. However, results from prospective RCTs comparing laparoscopic and open approaches raised concerns about high conversion rates, as those patients also had worse outcomes than open surgery arm [8, 9]. Therefore, despite widespread use of laparoscopy, there is still a debate on the utility of minimally invasive surgery for rectal cancer.

Oncological and Clinical Outcomes: Laparoscopic vs. Open Surgery

Laparoscopic approach was found to have better short-term patient outcomes and similar oncologic results for colon cancer resections [8]. However, the same multicenter randomized MRC CLASICC trial failed to demonstrate non-inferiority of laparoscopy for rectal cancer surgery. Patients undergoing laparoscopic resections were found to have similar short-term postoperative outcomes, but longer operative times and more circumferential margin positivity

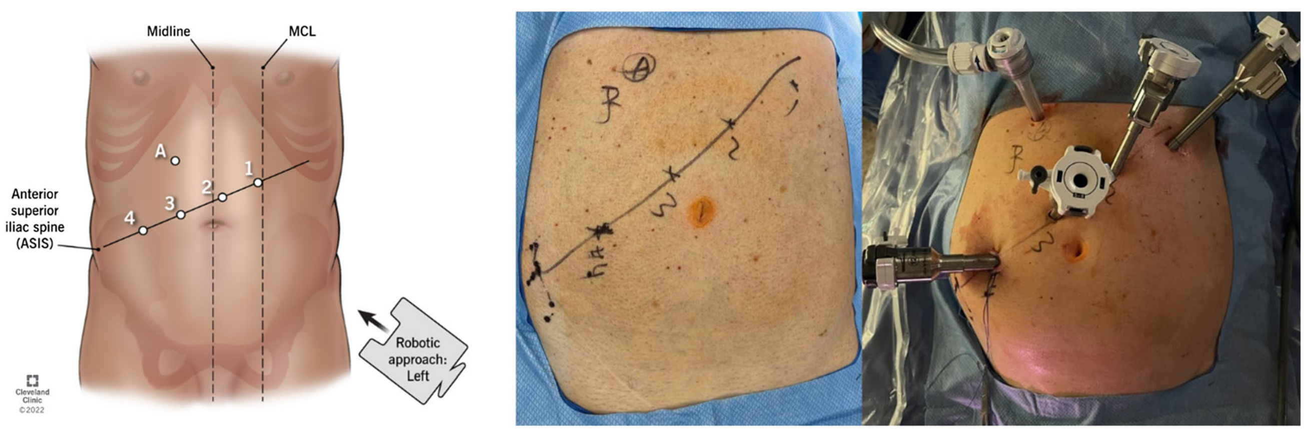

Fig. 1 Port placement for robotic proctectomy. A supra-umbilical 8 or 12-mm balloon port is placed for pneumoperitoneum which becomes the camera port (2). Three additional 8-mm ports are placed along the diagonal line between anterior superior iliac spine (ASIS) and left lower costal margins (1, 3, 4). A 5-mm assistant port (**A**) is placed in right upper quadrant. *MCL:* Midclavicular line

compared to open (12% vs. 6%), with a conversion rate of 34%. Although the margin positivity metric did not reach statistical significance, combined with a high conversion rate, these findings raised concerns and warranted further investigation on rectal cancer resections specifically.

ACOSOG Z6051 randomized trial, on laparoscopic versus open resection for stage II and III rectal cancer, did not reach non-inferiority criteria for the pathologic outcomes in the laparoscopic group [9]. The rate of successful resection, defined by negative distal and circumferential margins, and completeness of mesorectal excision, occurred in 81.7% of laparoscopic vs 86.9% of open cases. The similarly designed ALACART trial reached a similar conclusion, failing to demonstrate non-inferiority [20]. Although these results do not imply inferiority, their inconclusive nature led to questions among clinicians.

On the other hand, the 10-year follow-up of the MRC CLASICC trial showed similar disease-free and overall survival results, and local and distant recurrence rates for patients in both arms [21]. The COLOR II trial recruited patients with stage I or II rectal cancer, and found shorter hospital stay and similar pathological outcomes for the laparoscopy group compared to open [22]. COREAN trial, conducted with mid or low-rectal cancer patients, demonstrated better clinical and similar pathological specimen outcomes for the laparoscopy group [23]. The 3-year disease-free and overall survials, and local recurrence rates were also not different [24].

In a recent meta-analysis, Schietroma et al. looked at 15 RCTs and showed no difference in postoperative pathological outcomes and local and distal recurrences between laparoscopic and open rectal cancer resections [25]. However, they found better 4 and 5-year disease-free survival for patients in the open surgery cohort, adding to the conflicting results on this matter. The paper also looked at reported reasons for conversions, with most common explanations cited as narrow pelvis, extensive adhesions, and obesity. Of note, as the ACOSOG Z6051 trial involved surgeons experienced in laparoscopy, instead of the learning curve, one proposed explanation for their findings was the inability to perform the challenging maneuvers in the narrow pelvis with the rigid laparoscopic instruments.

Oncological and Clinical Outcomes: Robotic vs. Laparoscopic Approach

Robotic platform was designed to provide better access, maneuverability, and higher precision in small surgical fields. Although there has been some hesitation about utilizing minimally invasive surgery for rectal cancer resections, the robot might in fact address the limitations of laparoscopy, while keeping the clinical benefits over open surgery. Investigations were conducted with this idea in mind, therefore most studies compared the robotic approach to laparoscopy, and much less so to the open surgery.

First RCT by Baik et al. demonstrated similar short-term clinical and pathological specimen outcomes for robotic rectal cancer resections comparing to laparoscopy, establishing the safety of the technique [26]. The multicenter international randomized Robotic vs Laparoscopic Resection for Rectal Cancer (ROLARR) trial showed no difference in conversion rates, circumferential margin positivity, and complication rates between robotic and laparoscopic groups [11]. Conversion to open is associated with worse clinical outcomes [22], and was therefore the primary endpoint of this study. The robotic approach was found not superior to laparoscopy in this regard.

On the subgroup analysis, however, there was a statistically significant difference in conversion rates for male patients in favor of the robotic group. This was explained by the possible added benefit of the robotic system, for the more challenging operation in the narrower male pelvis. Similarly, the robotic group had a lower conversion rate for patients with obesity undergoing low anterior resections (LARs). Although the finding was not statistically significant, this observation helps to identify patients who might benefit from the robotic approach the most. A follow-up study from the trial also explored learning effects on outcomes, and demonstrated a potential benefit of robotic surgery over laparoscopic if done by experienced surgeons, highlighting a possible factor impacting results [27••].

Since ROLARR, only a few single-center RCTs compared laparoscopic and robotic rectal cancer surgery, reporting good clinical outcomes for both groups [12, 28]. Kim et al. similarly found no difference in conversion rates. However, Tolstrup and collegues showed a statistically significant advantage for the robotic approach. Findings of numerous observational studies were reported after ROLARR, with results of the bigger cohorts included in this review. The three studies with significant patient numbers by Ackerman et al., Crippa et al., and Myrseth et al. demonstarted significantly lower conversion rates with the robotic approach [13, 14, 29]. Clinical and oncological findings of the recent works are summarized in Tables 1 and 2.

Interestingly, Crippa and colleagues found robotic approach was associated with significantly less postoperative complications. On further analyses, patients in the robotic group had less postoperative anemia and need for tranfusion, suggesting the advantage of a more precise dissection. Notably, Tolstrup et al. and Ackerman et al. did not report pathological specimen findings in their studies, as they focused on specific clinical outcomes in their respective designs. However, this further shows the lack of abundant high-quality evidence and comprehensive data in this area.

Table 1 Clinical outcomes from recent studies comparing laparoscopic and robotic rectal cancer resections

Author	Study Design	# of Pts		Type of Operation (%)			Mean Op Time (SD), min		Mean LOS (SD), day		Conversion rate (%)			Postoperative Complications (%)		
		Lap	Rob		Lap	Rob	Lap	Rob	Lap	Rob	Lap	Rob	*p*	Lap	Rob	*p*
Jayne (ROLARR)[11]	RCT	234	237	LAR: APR:	71.7	64.4	261 (83.24)	298.5 (88.71)	8.2 (6.03)	8 (5.85)	12.2	8.1	0.16	31.7	33.1	0.84
					19.6	22										
Kim[12]	RCT	73	66	LAR:	95.9	98.5	227.8	339.2 (80.1)	10.8 (7.4)	10.3 (3.4)	0	1.5	0.475	23.3	34.8	0.133
				APR:	2.7	1.5	(65.6)									
Tolstrup[28]	RCT	25	26	LAR:	–	–	170	152 (43)	9.5 (7.7)	8.9 (5.6)	38.4	4	0.005	38	40	0.90
				APR:	–	–	(57)									
Ackerman[29]	PSM	533	533	LAR:	–	–	–	–	–	–	29.5	11.6	.0001	29.5	28.7	0.778
				APR:	–	–	–	–	–	–						
Crippa[13]	RS	283	317	LAR:	78.8	66.6	214.6	324.1 (108.4)	5 (4–7)*	3 (3–5)*	13.8	5.05	.0001	51.2	37.2	.0001
				APR:	21.2	33.4	(71)									
Myrseth[14]	PCD	909	375	LAR:	60.7	50.9	–	–	6	5 (3–7)*	9.6	2.1	.0001	12.3	11.5	0.669
				APR:	30.8	40.5	–	–	(4–9)*							

RCT Randomized controlled trial, *PSM* Propensity-score matching, *RS* Retrospective study, *PCD* Prospectively collected data, *Pts* Patients, *Lap* Laparoscopic, *Rob* Robotic, *LAR* Low anterior resection, *APR* Abdominoperineal resection, *Op time* Operative time, *SD* Standard deviation, *LOS* Length of stay

*Median

Table 2 Pathologic specimen outcomes from recent studies comparing laparoscopic and robotic rectal cancer resections

Author	Study design	# of Pts		CRM positivity (%)			DRM (median and range), cm		Mesorectal completeness (%)			LN harvest (mean/median)	
		Lap	Rob	Lap	Rob	*p*	Lap	Rob		Lap	Rob	Lap	Rob
Jayne (ROLARR)[11]	RCT	234	237	6.3	5.1	0.56	–	–	Complete:	75.2	75.4	24.1 (12.91)	23.2 (11.97)
									Near-complete:	16.5	14		
Kim[12]	RCT	73	66	5.5	6.1	0.999	0.7 (0–2.5)	1.5 (0.04–6.7)	Complete:	78.1	80.3	15 (4–40)	18 (7–59)
									Near-complete:	21.9	18.2		
Crippa[13]	RS	283	317	1.3	0.3	0.379	–	–	Complete:	–	–	–	
									Near-complete:	–	–	–	
Myrseth[14]	PCD	909	375	4.6	4.8	0.885	3 (1.8–4.0)	3.5 (2.0–4.5)	Complete:	–	–	16 (12–21)	13 (11–17)
									Near-complete:	–	–		

RCT Randomized controlled trial, *PSM* Propensity-score matching, *RS* Retrospective study, *PCD* Prospectively collected data, *Pts* Patients, *Lap* Laparoscopic, *Rob* Robotic, *CRM* Circumferential margin, *DRM* Distal resection margin, *LN* Lymph node

In conclusion, the utility of minimally invasive surgery for rectal cancer is still a topic of debate. Robotic surgery is a recent novelty, and as with any new technique, time and experience are needed to optimize the outcomes. Furthermore, the robotics technology is constantly improving, allowing for shorter operations and better results. Therefore, multicenter randomized trials taking these factors into account are needed to determine the value of the robotic system in rectal cancer surgery.

Oncological and Clinical Outcomes: Robotic Approach vs. Open Surgery

Robotic surgery is frequently grouped with laparoscopy, and provides similar short-term clinical benefits of a minimally invasive surgery [22, 23]. Therefore, most observational studies and clinical trials focused on comparing the two, in order to reveal the benefits of robotic approach specifically. There are no prospective trials comparing open and robotic rectal cancer resections.

Jimenez-Rodriguez et al. retrospectively evaluated outcomes of robotic and open surgical rectal resections at a single high-volume center and found longer operative times, lower complication rates, shorter hospital stay, and similar oncologic outcomes for the robotic group [30]. In our institution, we similarly found longer operative times and shorter hospital stay in the robotic group, with equivalent pathologic specimen outcomes [31••]. Additionally, on the 33 month follow-up, the local recurrence rates and disease-free survival were comparable, further validating the oncologic feasibility of robotic proctectomy. A recent meta-analysis similarly found equivalent oncological results for both approaches [32]. As there is still a lack of consensus on the long-term oncological feasibility of laparoscopic rectal cancer resections, it is useful to compare the robotic approach to open surgery separately, and further establish oncological safety and clinical benefits with more studies.

Benefits of the Robot

Long-Term Functional Outcomes

Total mesorectal excision is associated with significant morbidity. Approximately 80–90% of patients undergoing sphincter-sparing surgery report symptoms of low anterior resection syndrome (LARS) [33]. High-quality data on the prevalence and management of LARS are scarce, and even rarer for the outcomes with minimally invasive approaches. Urinary and sexual dysfunction are commonly reported, with more studies available evaluating these issues [34]. One proposed benefit of the higher precision robotic dissection is the increased likelihood of nerve plexus preservation and potentially better functional outcomes for patients.

ROLARR trial did not find any difference in the bladder and sexual function between robotic and laparoscopic groups at 6-month follow-ups. On long-term evaluation, with a median follow-up of 35 months, the overall incidence of LARS was 82.6%, with major symptoms in 62.9% and minor in 19.7% of patients [35••]. There was no difference in terms of surgical approach.

Two recent RCTs, since ROLARR, compared robotic and laparoscopic rectal resections for functional outcomes. Kim et al. demonstrated better sexual function after 12 months in the robotic group [12••]. Wang et al. included only male patients, and similarly found better sexual and urologic function with the robot [36]. A sizeable single-center series by Rouanet et al. did not find any difference in quality of life, sexual or urinary function between robotic and laparoscopic arms of their study [37]. However, two other cohorts found favorable outcomes for the robotic approach, in some quality of life metrics, male sexual function [38••], and rate of low anterior resection syndrome [39].

Long-term consequences of rectal cancer surgery affect a significant number of patients. Therefore, possible benefits of the robotic approach need to be explored thoroughly, as the population-level effects can be tremendous. The multidimensional discussion on the cost-effectiveness of the robotic approach should take functional outcomes into account, as improvement in this area would likely result in less overall healthcare utilization.

Patients with Obesity

Obesity is prevalent in the United States, therefore it is a frequently encountered challenge during surgery. Advantages of the robotic system are particularly pronounced for the patients with obesity. A recent retrospective analysis from the ACS-NSQIP database showed obese patients were more likely to need conversion, however, the rate was significantly lower in the robotic compared to laparoscopic rectal resections, suggesting a potential benefit for this patient population [40]. Similarly, we previously reported better postoperative recovery with a robotic approach for obese patients in our institution [41]. This is another area where more research is needed, to further identify specific populations that can benefit from robotic surgery. Especially in light of value-based care discussions and cost considerations.

Learning Curve

Minimally invasive colorectal surgery has multiple challenging aspects. Learning curve for laparoscopy is steep, becoming proficient takes significant time and training [42]. Average cases needed to reliably produce standardized results are 40–90 [43–45]. Initially, operative times were significantly longer and the technique seemed too complex [46]. However, when surgeons acquired enough expertise, a trend of improvement in patient outcomes and a decrease in conversion rates was seen [9, 43].

Previous experience with laparoscopy is suggested to decrease the learning curve for robotic surgery [47]. Colorectal surgeons using the robotic platform will likely have prior laparoscopic experience, therefore it is difficult to extrapolate a robotic-specific learning curve. Some initial studies suggested 15–35 surgeries are needed to learn the technique [48, 49], while another reported a learning curve ranging from 23 to 114 cases for five different surgeons with various levels of experience in laparoscopy [45]. Robotic surgery is a relatively new approach, therefore, an ongoing period of expertise building is expected. It is plausible that with the technical and instrumental advantages of the robot, movements and maneuvers are learned faster. More data is needed to create a standard curriculum and accreditation metrics, to ensure good outcomes for patients.

Surgeon experience should be considered when measuring and interpreting outcomes. One important example is the results of the ROLARR trial: When later explored for learning effects, the results demonstrated a potential benefit of robotic surgery over laparoscopic if done by experienced surgeons [27]. As with any innovation, growing experience, exploration of possibilities and limitations with the platform, and efficient training programs can lead to an overall decrease in operative times and improvement of postoperative outcomes.

Cost-Conscious, Value-Based Care: Robotic Surgery for Rectal Cancer

Robotic surgery has been associated with higher direct costs [11••, 50]. Major drivers are identified as the capital acquisition of the robot, equipment maintenance fees, limited-use instruments, and increased operative time, especially during double-docking [10]. This issue is routinely brought up as a significant disadvantage, especially considering lack of high-quality evidence supporting superiority of the approach. However, some recent studies report different results, when new developments in robotics and the broader outcomes metrics are considered for the calculations [51–53].

Robotic rectal cancer resections are associated with less blood loss, pain, and shorter hospital stay [11••–14••]. Some studies report benefits for long-term quality of life and functional outcomes [12••, 38••, 40, 41]. Justiniano et al. evaluated 90-day cost and hospital utilization of all Stage I-III colorectal resections in New York State, they found no cost difference between open, laparoscopic, and robotic rectal resections [51]. When clinical benefits of the robotic approach are taken into account, the upfront direct cost might be offset by the improved patient outcomes and decreased healthcare utilization.

In our institution, we assessed the laparoscopic and robotic abdominoperineal resections (APRs), and demonstrated comparable costs in the two groups [52••]. This is explained by similar operative times of the two approaches, as APRs rarely require double-docking and splenic flexure mobilization. Additionally, the new Da Vinci Xi robot allows LARs to be performed with one-docking, which substantially reduces operative time. Morelli et al. reported a significant decrease in the overall variable, personnel and consumable costs with the Xi robot compared to Si [53••]. Furthermore, they found a significant reduction in operative times and costs with growing experience.

We also compared open and robotic proctectomies by high-volume surgeons employing cost-conscious strategies [31••]. This approach consisted of avoiding extra cost when applicable, such as using the cautery and scissors instead of vessel sealing devices. We found longer operative time, but less estimated blood loss and transfusions, and decreased length of stay. The costs were comparable between groups, after the first five robotic cases.

Robotic devices and the market evolve constantly, as hospitals become more interested in acquiring the system. Other companies are investing in this technology and new robots are being developed, with promising initial safety results [54, 55]. The market competition is likely to draw the costs down for the systems and the instruments. Although there is a justified debate on the cost-effectiveness of robotic rectal cancer surgery, recent findings are encouraging.

Future Directions

A robotic platform allows integration of the modern technology into the operating table, and numerous inventions are coming out constantly [56]. These have various functions that ultimately claim to improve clinical outcomes, maneuverability, or learning experience. For example, intraoperative fluorescence angiography with indocyanine green shows promising results in decreasing anastomotic leak rates [57, 58]. Clinical trials are underway to evaluate this prospect [59, 60]. The Da Vinci Xi model robot came with a table motion function, which decreased operating time [61].

Augmented reality (AR) and artificial intelligence (AI) can be utilized to enhance visualization, which might improve port placement and recognition of essential vascular structures and nerves, once enough data is collected to refine the technology [62–65]. Additionally, 3D reconstruction of masses can be done, which might increase the precision of dissection in the future. Remote robotic surgery is another recent idea that can be possible, even with current devices [66–68]. Remote surgeon training can happen, accelerating the growth of experience, increasing overall patient access to specialty care.

The implications and possibilities are vast, and it is clear that the field is only in its beginnings. We expect further advancements in the technology and increased integration of the robotic platform in rectal cancer surgery, as with many other procedures.

Conclusions

Currently, the robotic platform is increasingly utilized in colorectal surgery, as the technical advantages of the platform are well-recognized in practice. More large-scale, multicenter randomized trials and comprehensive analyses are needed, to reach a definitive conclusion and establish practices based on good quality evidence, especially on the oncological outcomes of minimally invasive rectal cancer surgery. By identifying the right patient population, implementing cost-conscious strategies, better technology, and growing expertise, the platform is likely to prove its value for rectal cancer surgery.

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Declarations

Conflict of İnterest Dr. Emre Gorgun is a consultant for Boston Scientific Corporation, Intuitive Surgical, Inc and Olympus America Inc. Other authors do not have any conflicts of interest of financial ties to disclose.

Human and Animal Rights All reported studies/experiments with human or animal subjects performed by the authors have been previously published and complied with all applicable ethical standards (including the Helsinki declaration and its amendments, institutional/national research committee standards, and international/national/institutional guidelines).

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Council CLASICC trial of conventional versus laparoscopically assisted resection in colorectal cancer. Br J Surg. 2013;100(1):75–82. https://doi.org/10.1002/bjs.8945 (Epub 2012 Nov 6 PMID: 23132548).

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the robotic apparoch in some quality of life outcomes, and male sexual funciton.

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