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Emerging and Evolving Technology in Colon and Rectal Surgery

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Abstract

Minimally invasive surgery has changed the way we manage many colon and rectal pathologies. Multiple techniques, from straight laparoscopic procedures, to hand-assisted and single-port techniques are available, requiring surgeons to go through various learning curves. Robotic surgery is a relatively novel technique in general surgery which appears to hold most promise for rectal resection. Laparoscopic rectal procedures are difficult, and even in experienced hands, conversion rates are around 17%. Robotic surgery may be a point of difference in these cases, despite a long learning curve and higher costs. This article will describe the role of robotics in colorectal surgery. Room set up, port placement, and docking strategies will be described for common procedures, with emphasis on a hybrid robotic low anterior resection.

Keywords
- robotic colectomy
- robotic low anterior resection
- robotic colorectal surgery

More than 20 years ago, reports of the first laparoscopic procedures emerged. Over time, this approach would change the way multiple diseases are managed. However, despite clear advantages in patient care, this technique has faced tremendous resistance among surgeons, especially for colectomy.[1–6] If this statement strikes you as too strong, looking at the percentage of colectomies that were performed laparoscopically in the United States in 2009 should help clarify this point. Database analysis of colon and rectal cases performed in that year across the country reveals that only 39% were performed using a minimally invasive technique.[7] A substantial increase was seen in the following years, with newer data now suggesting that currently approximately 50% of these cases are performed in this fashion. However, with so much scientific literature demonstrating increased benefits to patients, is 50% acceptable?

Multiple barriers may have contributed to the slow adoption of minimal access surgery, such as a significant learning curve, concern over oncologic outcomes, and cost to mention some. Within colon and rectal surgery, both right and left colectomies can nowadays be performed laparoscopically in a very well organized, methodically, step-by-step fashion.[8,9] Patients' characteristics, such as morbid obesity or prior multiple open abdominal surgeries, may still lead to conversion to an open operation. However, for the most part they do not constitute a contraindication, and laparoscopic approaches should be viewed as the gold standard approach. The one area where laparoscopic techniques still lag behind is when dealing with rectal pathology. Adoption of a minimally invasive technique for rectal surgery remains low, and conversion rates high, even when performed by experienced colorectal units, when compared with right or left colectomies.[10] Despite these difficulties, highly selected groups across the country and the world have described even more complex procedure such as single-port laparoscopic colon resections or ultra-low robotic rectal resections, suggesting they may constitute a technical path going forward to extend the minimally invasive boundaries. The question that arises from the current state of the art is: what platform (robotic-assisted, laparoscopic-assisted, single-port, or hand-assisted techniques, etc.) will help achieve the goal of a mass adoption of a

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minimally invasive approach to diseases of the colon and rectum?[11–13]

The goal of this chapter is to share the views of a high-volume colon and rectal surgery unit, experienced in both laparoscopic and robotic surgery and accustomed to performing elective, emergency, and reoperative surgery in a minimally invasive fashion. Technical aspects of common colorectal procedures performed robotically will be described, with an emphasis on those steps that are specific to the robotic platform. At the same time, our perspective on the role of robotics in colorectal surgery is also discussed.

Robotic Colon and Rectal Surgery

Much has been written about the benefits of using the robotic platform: excellent visualization enhanced by 3D images and a steady surgeon-controlled camera, robotic instruments with "human"-wrist functions, improved ergonomics, fine motion scaling; the list can go on and on. However, in colon and rectal surgery, these benefits still need to translate into improved patient outcomes. Laparoscopy changed the landscape dramatically back in the days when procedures to treat colon and rectal pathologies could only be done through open incisions. However, robotic surgery accesses the abdominal cavity in the same way as standard laparoscopy does; therefore, it can be seen as a way of using a "laparoscopic" technique through a different platform. Laparoscopy is exceptionally efficient as a technique in the management of colonic pathology. From our practice standpoint, currently we do not see a substantial advantage to utilizing a robotic platform for colonic diseases. On the contrary, for the great majority of diseases that require a middle-third and lower-third rectal dissection/resection, a combined hybrid laparoscopic-robotic approach is our preferred approach. For the most part, published data on robotic surgery have failed to show improved outcomes in patient care for colonic surgery. Although this comment may also be true for rectal surgery, the adoption of laparoscopy is still limited in rectal pathology, and, as mentioned earlier, conversion rates from laparoscopy to open surgery are high.[14–18] By contrast, the growth of robotic rectal surgery has been impressive in the past few years. Furthermore, robotics may add health benefits to high volume surgeons that may be very difficult to quantify. The number of chronic neck and shoulders problems reported by surgeons is significant and possibly grossly underrepresented. It is too early to say if working from a robotic console may help prevent some of these problems, and institutions may not see it as a real advantage that need to be considered into this equation. However, surgeons should.

What are the disadvantages of adopting robotic surgery on a large scale: the main problem with robotic surgery is, without a doubt, cost. Cost escalates when robotics procedures are performed. As a part of a colorectal unit that regularly performs rectal operations for various diseases (i.e., rectal cancer, rectal prolapse) and has learnt to standardize and optimize instrument utilization, cost is still higher than that of a regular laparoscopic procedure. Using the robot adds approximately $1,200 to $2,000 in disposable per case and thousands of dollars more are charged by the hospital to amortize their capital costs. In our view, the cost currently is justified mostly for patients with middle and lower third rectal cancer or when dealing with rectal prolapse. Male gender, narrow pelvis, obesity, very low rectal lesions, among other characteristics increase conversion rate in laparoscopy. Evidence suggests that robotic surgery may allow the completion of the procedure minimally invasively in these difficult cases, offering patients a better quality operation. Nevertheless, we are eagerly awaiting the results of the ROLARR trial to discern if the preliminary data available to us are the result of surgeons' bias or a true advantage of robotics.[19]

Technical Aspects

The present part of the chapter will describe a robotic right, left, and low anterior resection (LAR). As technology progresses, certain drawbacks of the Da Vinci S and Si such as the ability to place the camera in any robotic arm, or to change patient position without undocking, may have being resolved as hospital incorporate the newer "Xi" platform which will allow greater arm movement and facilitate multiquadrant surgery. For this chapter, and because of the fact that most hospitals are still using the "S" and "Si" platforms, technical description are presented assuming a fix camera port and docking position.

Robotic Right Colectomy

Key Operative Steps

Dissection is performed in a standard medial to lateral fashion under the ileocolic vessels which are divided at their origin below the duodenum. The surgeon should try to minimize grasping the bowel, as the risk of injury because of the lack of haptic feedback and the strength the robotic arms generate is real. Likewise, the dissection proceeds along the mesentery edge and the right branch of the middle colic vessels are also divided. Care is taken to avoid injury to the numerous venous tributaries in this location that make up the so-called trunk of Henle. After medial-to-lateral mobilization, the colon and ileum can be exteriorized for extracorporeal anastomosis or divided inside the abdomen followed by an intracorporeal anastomosis which is our preferred approach.

Room Setup

The robotic cart is advanced from the patient's right flank, and docked in position with the operating table rotated to the left approximately 20 to 30 degrees. The assistant will be standing on the patient's left side.

Patient and Trocar's Positioning

The patient can be placed supine or in a modified lithotomy position. It is our preference to position every patient in lithotomy, as it allows for easy access to the anus should the need to perform an intraoperative colonoscopy arise. At the same time, because we tend to performe intracorporeal anastomosis for our right colectomies, and we use a Pfannenstiel as extraction site, we found lithotomy to be a more ergonomic position for the surgeon.

Five trocars are commonly used. The camera port (C) is a 12 mm laparoscopic trocar placed 2 fingerbreadth to the left of the midline, midway between the xiphoid and the pubic symphysis after insufflation is completed. R1–R3 are 8 mm robotic ports. R1 is placed 4 fingerbreadths (approximately 12 cm) cephalad and lateral to C. R2 is located 4 fingerbreadth inferior to C, almost in the same plane to slightly lateral. R3 is placed in the midline, high in the epigastrium just below the xiphoid. An additional 12 mm laparoscopic port is placed midway C and the anterior superior iliac spine (ASIS). This will be used by the assistant and allows for the introduction of the suction irrigator, a laparoscopic advanced bipolar device and/or staplers, which can be used for construction of an intracorporeal ileocolic anastomosis. If the colon is to be divided extracorporeally, this trocar could be substitute by a 5 mm one.

The procedure itself follows the same principles of a laparoscopic right colectomy. In general, R1 and R2 are the main operating arms; robotic monopolar scissors and a bipolar fenestrated grasper are used through these arms, respectively. A Prograsp (Da Vinci, Intuitive Surgical, Sunnyvale, CA) is used in R3.

If an intracorporeal anastomosis is planned, the transverse colon and terminal ileum are positioned in an isoperistaltic fashion. Enterotomies are then created with monopolar cautery and a laparoscopic stapler is introducer through the 12 mm assistant's trocar. After the side-to-side anastomosis is created, the common enterotomy is suture in two layers. Lapra-tys (Ethicon, Cincinnati, OH) can be used during the second layer to interrupt the thread and spread the tension across multiple points. In this case, the suture of choice is a two "o" Vicryl.

If division of the colon and anastomosis are planned extracorporeally, a small transverse right upper quadrant (RUQ) or a midline suprarumbilical incision is used. The former may have the advantage of being less prone to hernia formation.

Robotic Left Colectomy

General Considerations

Initially, a two-docking technique was used to achieve left colonic dissection and adequate splenic flexure takedown. A single docking technique was later described, as well as a "flip-arm" technique and they may allow the surgeon to complete either a left colectomy or a LAR.[20–22] Regardless of the approach, the dissection is performed in standard medial-to-lateral fashion under the inferior mesenteric artery (IMA) and vein. Once again, minimizing bowel grasping may help decrease the risk of injury because of the lack of haptic feedback and the strength the robotic graspers.

Room Setup

When a double-docking strategy is used, the Da Vinci cart docked via a left shoulder approach facilitates mobilization of the splenic flexure. Redocking at the left hip (central car aligned to the left hip and patient's right shoulder) facilitates the medial to lateral dissection of the left colon. This position allows the surgeon to dissect the rectum as far as needed.

However, a left colectomy can be completed using a single dock strategy via a left hip approach. In this case, a three-trocar robotic technique can be used. Several modifications to this docking strategy have been described, and it is up to the operating surgeon's experience and comfort level with this procedure to use one or another. During the course of a LAR, when mobilization of the left colon and splenic flexure are need, our approach is to combine both techniques in a hybrid laparoscopic-robotic fashion as described later on.

Patient and Trocar Positioning

The patient is in lithotomy, arms tucked, in Trendelemburg and rotated to the left. It is essential to ensure the small bowel is away from the operating field to avoid injuries.

Standard port placement for a left colectomy using a left hip approach is as follows: the C port is a 12 mm trocar placed half way between the xiphoid and the pubis and 3 cm to the right of the midline. A 30-degree camera is usually used. R1 is placed in the RLQ 4 fingerbreadth (12 cm approximately) lateral to C, on an imaginary line that joins C and the ASIS. R2 is placed in the epigastrium, usually approximately 5 cm below the xiphoid, either to the right or left of the midline. Key all along is the distance to C, which should again be 4 fingerbreadths (12 cm approximately). Monopolar scissors and a fenestrated bipolar grasper are introduced through R1 and R2, respectively. A fourth trocar (a laparoscopic 5 or 12 mm port) is placed in the RUQ; it is important to ensure that an adequate distance between ports is maintained. This laparoscopic trocar allows for an entry point for a suction irrigator, advanced bipolar devices, or staplers. It also allows the assistant to provide counter-traction during the case. Surgical steps are described later, under the robotic LAR portion of this chapter.

Robotic LAR: Completely Robotic versus Hybrid Laparoscopic-Robotic LAR

Single-dock completely robotic LAR is feasible and its technique has been published by our group in the past.[20–22] However, having gained significant experience in both laparoscopic and robotic techniques, we have found that we are more efficient when we approach these procedures in a laparoscopic/robotic hybrid manner. It is almost a certainty in our practice that the splenic flexure will need to be mobilized to create a tension-free anastomosis. This may be different in certain geographic parts of the world or when dealing with patients with low BMIs (body mass index), therefore, preferences for a total robotic versus a hybrid laparoscopic-robotic technique may vary depending on surgeon's experience and area of practice.

Hybrid Laparoscopic/Robotic LAR

General Considerations

Surgeons should enter the operating room understanding that a full rectal resection encompasses the following two major stages: (1) an abdominal stage that includes not only the mobilization of the left colon and but also almost constantly the splenic flexure. Division of both the IMA and inferior mesenteric vein (IMV) are also part of this stage and (2) a pelvic stage where rectal dissection needs to adhere to the principles of total mesorectal dissection (TME).

Room Setup

The robotic tower/monitor is located at the level of the feet on the patient's right side, and the assistant is located by the patient's RUQ. The scrub nurse is located between them. A second monitor is on the left side, with the midpoint of the screen just below eye level, positioned by the patient's mid abdomen.

Patient and Trocar Positioning

1. The patient is placed in a modified lithotomy position and secured in such a way that no sliding occurs even with extreme Trendelenburg or lateral positions.
2. The abdominal cavity is accessed and insufflated. It is our preference to use a Veress needle placed at Palmer point, right below the left costal margin at the left midclavicular line. This location is particularly useful in reoperative cases. However, it is up to the operating surgeon's discretion to determine the entry technique.
3. Port placement: we routinely use a six-port technique. We start by placing a 12 mm (mm) laparoscopic port for the camera, a 12 mm (R1) right lower quadrant port (RLQ), and two 5 mm laparoscopic ports located in RUQ and epigastrium. During the robotic part of the procedure, two 8 mm left lower quadrant (LLQ) robotic ports (R2 and R3) are placed as well as an 8 mm robotic port is inserted in a "trocar-in-trocar" configuration inside the 12-mm RLQ port (R1).
4. Robotic ports location: The camera port (C) is placed in the midline halfway between the xiphoid process and the pubis symphysis after insufflation is completed. This means the port could be located at, below or above the umbilicus. Once the camera port is placed, a line from this port to the right and left anterior superior iliac spine is drawn. This line then serves as guide for the three robotic ports (R). It is important to keep in mind that a distance of 8 to 12 cm between ports (4 fingerbreaths) is necessary to minimize the risk of robotic arms collision. R1 (access site for robotic arm 1) is the 12 mm laparoscopic trocar. It is placed on the aforementioned line in the RLQ, 4-fingerbreath away from C. R2 is placed as a mirror image of R1 on the LLQ, while R3 is placed 4 fingerbreaths lateral to R2, approximately 2 cm above the line previously drawn (on a same transversal plane than R2), almost directly above the left ASIS.

In addition, two 5 mm laparoscopic ports (L1 and L2) are routinely used in our practice; these trocars are placed at the beginning of the procedure as follow: L1 is placed in the RUQ, 4 fingerbreaths lateral to C and about 4 fingerbreaths ($\sim$ 12 cm) cranially to R1, while L2 is located in the epigastrium, either to the right or left of the midline, 4 fingerbreaths from L1. L2 is particularly helpful during splenic flexure mobilization.

Laparoscopic Left Colonic Mobilization and Splenic Flexure Takedown

1. After inspecting the abdomen to rule out metastatic disease, dissection starts in a medial to lateral fashion at the level of the IMA. As an alternative, dissection can also start at the level of the IMV just lateral to the ligament of Treitz.
2. The peritoneum is opened from the IMA toward the sacral promontory. Blunt dissection allows for development of that plane, dissecting the mesocolon from the retroperitoneum. The ureter and gonadal vessels should come into view during the dissection. Once these structures are identified, the IMA is then divided.
3. Progressing in a medial-to-lateral fashion cranially, allows for identification of the IMV and subsequent division of this vessel. This allows for length, necessary to construct a tension-free anastomosis.
4. Dissection then transition to lateral to medial, allowing for division of the lateral attachments of the left colon. Dividing the omentum from the colon, allows the surgeon to complete the mobilization of the splenic flexure, a step as we mentioned earlier, done in almost every procedure.
5. Once the colon has been mobilized, the ureters identified and the inferior mesenteric vessels divided, the robotic portion of the procedure begins.

Robotic Low Anterior Resection

1. Docking strategies: our preferred method is a left hip approach. In this case, the Da Vinci cart's central column is in-line with the patient's left ASIS and right shoulder. Docking can also be performed with the cart in between the legs; however, this approach makes intraoperative digital or endoscopic rectal examinations difficult.
2. A 0-degree 12 mm robotic camera is introduced in C. We rarely use the 30-degree camera. Arm 1 is docked to R1 using a "trocar-in trocar" technique as described earlier and monopolar robotic scissors are usually introduced through this port (a robotic hook can sometimes be used). Arms 2 and 3 are docked to R2 and R3, respectively. A robotic bipolar fenestrated grasper is placed in arm 2, while a Prograsp or another instrument with a blunt and fairly long tip can be used in R3. The assistant, located on the right side of the patient, uses an extended-length suction irrigator in L1, and a locking grasper in L2. The suction irrigator is used not only for evacuating smoke, but also for counter traction. L2 is locked in the upper rectum, holding it out of the pelvis and to the right or the left opposing the site where the dissection is being performed.
3. The robotic total mesorectal excision (rTME) starts at the sacral promontory as the avascular plane between the endopelvic visceral fascia that encompasses the mesorectum and the endopelvic parietal fascia is entered. Dissection follows the same principles of open and laparoscopic

TME and is beyond the scope of this chapter. What is important to emphasize though is the role of the robotic arms. As the surgeon controls the camera and three robotics arms, exposure, and visualization are greatly enhanced. Arm 1 is the main operating arm, while arm 2 and 3, controlled by the surgeon's left hand, are key as they provide retraction. In general, we prefer not to grasp the mesorectum as the robotic arms may tear tissues easily. A small step often missed that we found that improves retraction significantly is achieved by placing the instruments (usually ARM 2 and 3) in an "L" or "_I" configuration. This allows for a larger area of contact between instruments and tissues facilitating exposure, therefore, improving dissection.

4. Division of the rectum can be achieved in several ways (with a robotic stapler, a laparoscopic stapler or transanally in the case of very low lesion). Digital rectal examination or flexible endoscopy is used as needed during the procedure to ensure that the dissection has reached the targeted area. In the case a robotic stapler is used, the 12 mm RLQ trocar need to be changed for a 15-mm robotic trocar. Otherwise, R1 is removed and a regular laparoscopic stapler is used under robotic visualization. Once the rectum is divided, the robot is undocked.

Specimen Extraction and Laparoscopically Assisted Colorectal Anastomosis

1. A suprapubic Pfannenstiel incision created 2 fingerbreadth above the pubis is our preferred extraction site. Fascia is opened in a transverse fashion, while the muscle is retracted, not divided, in a vertical manner. A wound protector is placed, the specimen extracted, divided, and the anvil of a circular stapler secured in place.
2. The incision is then closed or the wound-retractor clamped and a circular colorectal anastomosis is created laparoscopically. A flexible endoscopy, as well as, an air-leak test is routinely performed. The endoscopy allows for detection of possible areas of ischemia in an otherwise negative leak-test patient.
3. A loop ileostomy is usually created in high-risk patients or when the anastomosis is located within 5 to 7 cm of the anal verge.

Special Scenarios

Transanal Specimen Extraction

Pathologies such us rectal prolapse associated with constipation, where the rectum is dilated, may allow for transanal specimen extraction. In these cases, bowel clamps are placed at the desired transection points in the descending colon and at the rectosigmoid junction. The colon is then transected sharply using monopolar scissors. A ring clamp is then introduced through the anus and, under direct robotic visualization; the resected segment of bowel is grasped and gently brought out through the anus. This maneuver needs to be performed under direct vision because of the risk of damaging the rectum. At that point, the anvil of a circular stapler is introduced through the anus and advanced into the abdomen. After removing the clamp located on the descending colon, the anvil is placed inside the colon, allowing the lumen to remain "stented" open and a pursue string is constructed robotically. A second pursue string is then performed in the upper rectum, and the pin of the circular stapler advanced before securing it tight. A double pursue string end-to-end circular anastomosis is then created.

Very low rectal tumor may also allow for a transanal extraction. In these cases, whether the rectum is disconnected transanally at the beginning of the case (and suture closed when feasible) or after completely mobilized, an Alexis type wound retractor is placed through the anus and then the specimen is brought out through it. It is important to have completely divided the mesocolon all the way to the colonic wall before bringing the specimen down, to avoid injuring the blood supply to the colon that will be used to create the hand-sewn coloanal anastomosis. This part of the procedure should also be done under direct visualization to ensure that no tension or twisting of the colon occurs.

Rectopexy

Room setup, patient trocar positioning follows the same principles described for a hybrid laparoscopic-robotic LAR. Placing a 12 mm trocar in L1 allows for sutures and mesh introduction without having to dock and undock several times. In many of these patients, R3 may not be necessary, and is placed as needed. We usually performed mesh rectopexy (as long as no resection is performed), with a ventral approach. In this cases, a light-weight macroporous polypropylene mesh cut to measure 18 × 3 × 2 cm is used (further trimming may be performed intra-abdominally once the distal 3 cm in width end is sutured in placed). It is usually feasible to robotically close the peritoneum over the mesh at completion of the case.

Future Directions

The robotic platform allows for completion of multiple procedures in colorectal surgery. It should be viewed as an option, the same way as single incision or hand-assisted surgery. As long as results are in line with a standard laparoscopic approach, there should be no discussion from a medical standpoint about whether it could be used or not. It should be up to each individual surgeon, based on experience and technical expertise, to approach a procedure in one fashion or another. However, cost is what may end up determining whether this technology is here to stay or not. If the cost of robotic surgery continues to escalate without solid evidence justifying its use, then the role of this modality may be limited in the future. In our practice, as mentioned, robotics is chiefly used for rectal procedures because of the perception of superior outcomes in difficult pelvic operations. We hope upcoming studies such as the ROLARR (robotic vs. laparoscopic resection for rectal cancer) randomized trial will help us better determine the precise role of robotic colorectal surgery and its true merits.

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