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The technical aspects of rectal cancer surgery

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ABSTRACT

Despite recent advances in perioperative chemoradiation for the treatment of rectal cancer, surgery remains the only curative therapy for most patients. Surgeries for rectal cancer are considered some of the most technically challenging operations for colorectal surgeons due to the anatomy of the pelvis, proximity to critical structures, and the widespread use of preoperative chemoradiation. This review will focus on the technical aspects of surgery for rectal cancer and appraise the current literature on select controversial topics.

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Introduction

Treatment of rectal cancer is fundamentally different from that of colon cancer and relies on a multidisciplinary approach involving chemotherapy, radiation, and surgery. While chemoradiation has been shown to significantly reduce disease burden and improve survival, surgery remains the only curative therapy for most patients and continues to play a primary role in the treatment of rectal cancer.[1] Surgery for rectal cancer is challenging compared to that for colon cancer for several reasons. First, the physical constraints of the pelvic cavity restrict access to the rectum, limiting both physical tissue manipulation and visualization. Second, complications of rectal cancer surgery, such as damage to nearby autonomic nerve fibers or anal sphincter muscles, can be associated with profound changes in patients' quality-of-life. Lastly, the widespread use of preoperative chemoradiation changes tissue integrity within the operative field, produces greater tissue edema, and alters the areolar tissue plane that is the hallmark for total mesorectal excision (TME). This review will identify anatomical structures associated with rectal cancer surgery, discuss general surgical principles that highlight complete oncologic resection and the preservation of quality-of-life, and describe the most common surgeries performed today for the treatment of rectal cancer.

Anatomy

The rectum is a 12–15 cm segment of large bowel located between the sigmoid colon and the dentate line. Within the pelvic cavity, it folds on itself to form 3 convolutions called the valves of Houston. While the proximal margin of the rectum is not clearly defined, the rectum can be differentiated from the colon by the lack of taeniae coli and haustra. The rectum is located mostly in the extraperitoneal space and is embedded within a layer of fascia and fatty tissue known as the mesorectum (Fig. 1). Proctectomies for rectal cancer always involve a TME, where the entire mesorectum is removed intact with the specimen. The fascial borders surrounding the rectum and mesorectum are important to note as these serve as important landmarks for rectal cancer surgery. Visceral peritoneum lies over the anterior surface of the proximal rectum and reflects superiorly to form the rectouterine/rectovesical pouch, or the pouch of Douglas. This point of reflection is variably located. Although it can be visualized on pelvic MRI, wide interpatient variability limits its utility as a reliable landmark intraoperatively. However, it does serve as the origin of Denonvilliers' fascia, a thick band of connective tissue anchoring visceral peritoneum to the pelvic floor. Denonvilliers' fascia is the anterior border of the TME and is sharply divided during distal proctectomy. Posteriorly, the rectum and mesorectum are bordered by rectosacral, or Waldeyer's, fascia. Waldeyer's fascia is sharply divided to enter the avascular plane between the mesorectum and the presacral fascia overlying the sacrum at the lowest level. Failure to remain in this plane can disrupt the presacral venous plexus overlying the sacrum, leading to significant intraoperative hemorrhage.

Blood supply and drainage

The arterial supply of the rectum is derived from three main arteries: the superior, middle, and inferior rectal arteries. The superior rectal artery is a terminal branch of the inferior mesenteric artery, while the middle and inferior rectal arteries originate from the internal iliac artery. The middle rectal artery have been described to travel medially from the pelvic side wall as part of the lateral rectal ligament. However, the middle rectal artery and the lateral rectal ligament are inconsistently encountered intraoperatively. A cadaveric study evaluating 28 specimens found that 10 did not have an identifiable lateral rectal ligament and the others had insignificant structures that would

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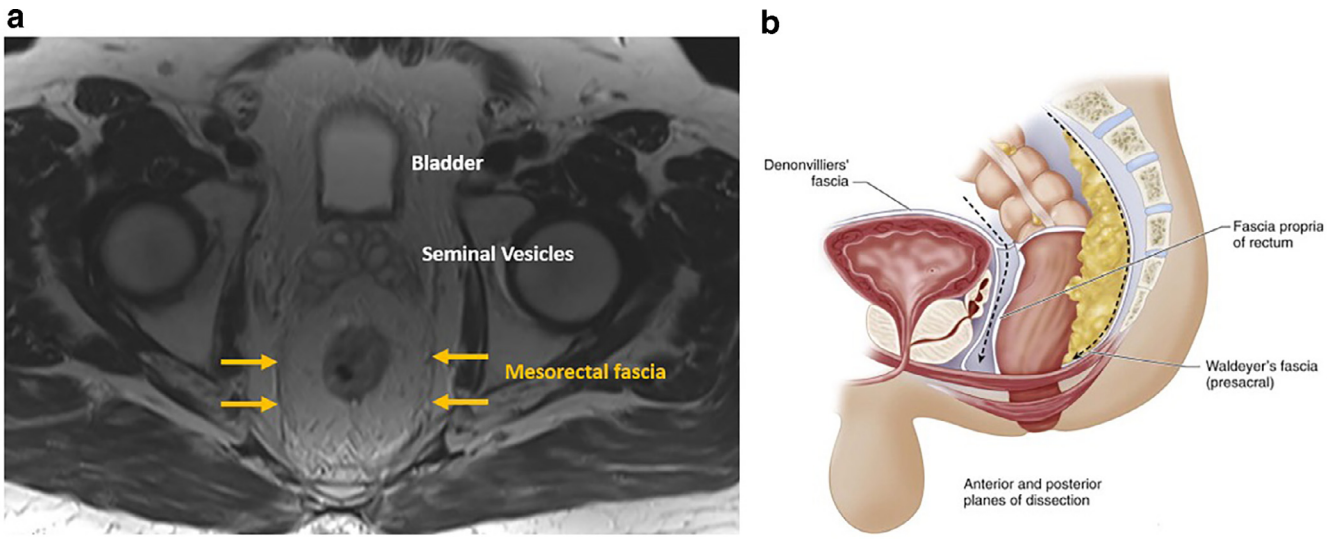

Fig. 1. Surrounding structures and fascial borders of the rectum and mesorectum. a) The rectum and mesorectum are contiguous to the bladder and sexual organs (uterus in females, prostate and seminal vesicles in males). b) Proctectomies for rectal cancer should include a total mesorectal excision, where the rectum and its immediate surrounding tissue are removed en bloc. Dissection is carried out through the avascular plane between the mesorectal fascia and the presacral fascia posteriorly, Denonvilliers' fascia anteriorly, and the pelvic floor inferiorly. (Reprinted with permission from Saunders: *Atlas of Surgical Techniques of the Colon, Rectum, and Anus,* Anne Y Lin, Ch 10 Open Low Anterior Resection, Pg 159 (2013).[66])

not have required ligation.[2] Another study that dissected 30 cadavers confirmed the variable anatomy of the lateral rectal ligament, only identifying this structure in 56.7% of examined bodies.[3] Therefore, in most cases, the rectum can be mobilized with sharp dissection without specific identification and ligation of the middle rectal artery.

Venous drainage generally follows the arterial supply. The superior rectal vein drains into the portal system through the inferior mesenteric vein while the middle and inferior rectal veins drain into the systemic drainage via the internal iliac veins. Since rectal cancer has access to both the portal and systemic venous systems, metastatic lesions to the brain, bone, and lungs are more common than in colon cancer. Lymphatics from the rectum drain into the inferior mesenteric, para-aortic, and internal iliac lymph nodes.

Nerves

The rectum is surrounded by several autonomic nerve fibers that, if injured intraoperatively, can lead to permanent dysfunction. Nerve fibers arise from 2 major plexuses in the pelvis: the superior hypogastric plexus (or preaortic plexus) and the inferior hypogastric plexus. The superior hypogastric plexus resides on the anterior surface of the abdominal aorta and provides sympathetic fibers to innervate the rectum. They are most frequently encountered intraoperatively during ligation of the inferior mesenteric artery. Mixed sympathetic and parasympathetic fibers from the inferior hypogastric plexus connect with fibers from the superior hypogastric plexus to form bilateral hypogastric nerves that run parallel to the rectum. Additional parasympathetic fibers from the nervi erigentes, or pelvic splanchnic nerves, along the lateral walls of the pelvic cavity also contribute to innervation of the rectum. Damage to these nerve fibers can lead to difficulties with bladder emptying and bowel evacuation, as well as sexual dysfunction such as erectile dysfunction and retrograde ejaculation.

Principles of surgical excision

Multiple surgical procedures are available to treat rectal cancer and selecting which procedure to use is based on the stage and location of the tumor. Despite the multitude of options, there are still some basic surgical principles that must be considered for all rectal cancer surgeries.

Adequate margins

Local recurrence is extremely challenging to manage in rectal cancer as treatment options may be limited by prior chemoradiation, presence of distant metastases, and technical feasibility of surgery.[4] Obtaining clear surgical margins during rectal cancer surgery is key to minimizing risk of local recurrence.[5,6] Historically, proximal and distal margins of at least 5 cm were considered adequate. While this can be easy to achieve for tumors located in the proximal 1/3 of the rectum, for patients with low rectal cancer tumors, a 5 cm distal margin may not be reachable within the physical constraints of the pelvic cavity. Moreover, a 5 cm distal margin may require excision of the external sphincter and a permanent colostomy. With the more common use of preoperative therapy, several cohort studies have found that, for patients with low rectal cancer tumors, equivalent oncologic outcomes can be achieved with 1 cm or less distal margins. A systematic review evaluating studies comparing patients with < 1 cm vs > 1 cm distal margins in the setting of pre- or postoperative radiation demonstrated there was no statistically significant difference in local recurrence rate between the two groups; patients in the < 1 cm margin group only had a 1.0% increase in absolute risk of local recurrence compared to patients in the > 1 cm margin group.[7] In conclusion, while a 5 cm distal margin is preferred for more proximal tumors, patients with low rectal cancer tumors can achieve acceptable oncologic outcomes with a distal margin of 1 cm in the setting of multimodal therapy.

In addition to proximal and distal margins, the circumferential resection margin (CRM) is an important prognostic indicator in rectal cancer surgery, serving as an independent determinant of local recurrence and overall survival.[8,9] In the MERCURY trial, rectal cancer patients underwent preoperative high-resolution MRI to assess potential CRM involvement. MRI-determined CRM-involved patients had lower 5-year overall survival compared to CRM-clear patients, 42.2% vs 62.2%, and were 3.5 times more likely to have local recurrence during the follow-up period.[10] Total mesorectal excision (TME) was developed by Heald et al. to address complete excision of the mesorectum in rectal cancer surgery and achieve clear CRM.[11] In short, TME requires complete excision of the mesorectum with the rectal specimen, requiring careful dissection in the avascular plane between the mesorectum and the surrounding presacral fascia and pelvic floor. In a large prospective cohort study comparing proctectomies with TME to proctectomies alone reported by Heald et al., patients with TME had a 10-year local

recurrence rate of 4% compared to 20% in patients who did not undergo TME.[12] TME remains an integral part of local control, even in the setting of perioperative chemoradiation.[13] TME is now a standard part of rectal cancer surgery and, when combined with other treatment modalities, minimizes risk of local recurrence and improves overall survival. The Dutch Colorectal Cancer randomized controlled trial demonstrated the importance of good quality TME through a rigorous selection and certification process for surgeons enrolling patients in their study evaluating the effects of TME with or without preoperative radiotherapy.[1] While there was no difference in overall survival between the two groups (82% vs 81.8%), local recurrence rate at 5-years was significantly lower in patients receiving preoperative radiotherapy than in patients receiving surgery along (2.4% vs 8.2%). Difference in local recurrence remained significantly different after 10 years of follow-up.[14]

The clinical importance of CRM is only significant in high-quality TME specimens. Therefore, CRM evaluation must be coupled with an overall macroscopic assessment of the complete TME specimen. To perform a high-quality TME, the surrounding mesorectum must remain with the rectal cancer specimen and be removed intact during proctectomy. Furthermore, the mesorectum should not be violated as this can lead to intraoperative tumor spillage and increased risk of local recurrence. The overall quality of the TME specimen can be categorized into three groups: complete, nearly complete, and incomplete. Complete specimens are cylindrical and have a smooth mesorectum without any surface defects deeper than 5 mm. Nearly complete specimens have some surface irregularities without any defect exposing underlying muscularis propria. Incomplete specimens have little bulk to the resected mesorectum with significant coning and/or defects reaching the muscularis propria. Nagtegaal et al. evaluated the TME specimens from the Dutch Colorectal Cancer trial and hypothesized categorization of TME specimens into these three groups would add prognostic value to CRM assessment.[15] Out of the 180 patients included in this analysis, 41 patients had CRM involvement; 44% of these patients had incomplete TME specimens while only 11% had complete. Additionally, patients with incomplete TME specimens had a higher risk of local and distant recurrence compared to patients with complete specimens.

Lymph node resection

Inadequate lymph node harvest may contribute to understaging and higher local recurrence rates. Historically, 12 lymph nodes had to be included in a surgical resection for adequate staging and oncologic control, with some groups proposing additional dissection just to retrieve the adequate number of lymph nodes.[16,17] Fujita et al. reported the results of a randomized controlled trial evaluating local recurrence and disease-free survival following TME alone vs. TME with lateral lymph node dissection (removing fatty tissue outside pelvic plexus).[18] The authors found a significant reduction in risk of local recurrence in patients receiving TME and lateral lymph node dissection (LLND) compared to TME alone (7.4% vs 12.6%). However, LLND increases the risk of damage to the pelvic nerve plexus, leading to autonomic dysfunction that can be debilitating. Moreover, the patients included in this study did not receive preoperative chemoradiation. As preoperative chemoradiation can eradicate lymph node metastases, LLND may not be necessary, thus protecting patients from complications associated with more aggressive surgical resection. In the setting of multimodal therapy, the goal of obtaining 12 or more lymph nodes in the surgical specimen may not be as prognostically important. In a small single-center retrospective study evaluating 237 rectal cancer patients, de Campos-Lobato et al. found patients with fewer than 12 lymph nodes retrieved had a lower 5-year local recurrence rate compared to patients with more than 12 lymph nodes, 0% vs 11%; additionally, overall and disease-free survival were not significantly different between the two groups.[19] These findings were confirmed in a larger retrospective study conducted by Kim et al.[20] After analyzing 1332 rectal cancer patients, the authors reported the number of lymph nodes retrieved at the time of surgery was inversely correlated with degree of tumor regression after neoadjuvant chemoradiation; in patients who had a good response to neoadjuvant chemoradiation, those with fewer than 12 lymph nodes retrieved had a higher 3-year disease free survival than those with more than 12 lymph nodes. These findings indicate the number of lymph nodes retrieved appears to be correlated with response to preoperative chemoradiation rather than quality of surgical resection. As lymph node count is no longer an independent predictor of clinical outcomes, more radical surgery such as routine lateral pelvic sidewall dissection in order to sample additional lymph nodes is not recommended based on the current data.

Quality-of-life considerations

While all rectal cancer patients can experience changes to their quality-of-life postoperatively, the proximity of low rectal tumors to autonomic nerve fibers and the anal sphincter place patients with low rectal cancer at increased risk of bowel, bladder, and sexual dysfunction. The most common procedure to treat low rectal cancer is abdominoperineal resection, (APR), which includes removal of the anal sphincter and establishment of a permanent end colostomy. There is great need to identify alternatives to APR that can preserve sphincter function without impairing oncologic outcomes.

One of the most commonly investigated alternative procedures is intersphincteric resection. In intersphincteric resection, the internal sphincter is carefully dissected away from the external sphincter and removed with the specimen.[21] Preliminary data suggest oncologic outcomes of intersphincteric resection are acceptable. Martin et al. conducted a systematic review to evaluate the oncologic outcomes following intersphincteric resection, reporting a local recurrence rate of 6.7% and 5-year overall survival at 86.3%.[22]

Intersphincteric resection can be offered to select rectal cancer patients who have primary tumors within 2–3 cm from the dentate line and no involvement of the external sphincter. Patient selection for APR or intersphincteric resection requires a comprehensive classification system for low rectal cancer. In a retrospective cohort analysis, Rullier et al. classified low rectal cancer patients into four groups based on distance from the anus.[23] Only patients with transanal tumors were treated with APR; all other groups had sphincter-preserving resections with either colo-anal anastomosis or intersphincteric resection. In their cohort of 404 low rectal cancer patients, 79% of patients were able to avoid APR. After a median follow-up of 52 months, there were no differences in disease recurrence and survival in patients treated with colo-anal anastomosis compared to those with intersphincteric dissection. However, patients treated with APR had significantly higher recurrence rates and worse survival compared to either sphincter-preserving group; this was likely due to the higher prevalence of metastatic disease in the APR group compared to the others.

Surgical procedures for rectal cancer surgery

Recent developments in local excision, specifically transanal endoscopic microsurgery (TEM) and transanal minimally invasive surgery (TAMIS), are currently being investigated as surgical therapy for early stage rectal cancer (cT1-3N0M0).[24–26] At this time, there is no consensus on patient selection for these local excision procedures. Therefore, most rectal cancer patients will undergo proctectomy. In this section, we will briefly describe the two most common proctectomy procedures, low anterior resection (LAR) and abdominoperineal resection (APR).

Low anterior resection

Low anterior resections (LAR) are reserved for patients with more proximal rectal tumors that do not involve the external sphincter.

Once the abdominal cavity has been entered and examined for signs of metastatic disease, the left and sigmoid colon are mobilized by incising the white line of Toldt. The left ureter, gonadal vessels, and hypogastric nerve may be in the surgical field and must be carefully identified and protected. Routine mobilization of the splenic flexure and high division of the inferior mesenteric vein allow greater reach of the proximal colon for the planned colo-rectal (or colo-anal) anastomosis. With the colon mobilized laterally, the inferior mesenteric artery is identified and ligated near the ligament of Treitz. Historically, high ligation of the IMA near its origin at the abdominal aorta was promoted to remove para-aortic lymph nodes.[27] However, high ligation of the IMA endangers the superior hypogastric plexus. In a recently published randomized controlled trial conducted by Mari et al., rectal cancer patients treated with LAR were randomized to either low ligation of the IMA (standard technique) or high ligation (within 2 cm of origin). In patients who underwent LAR with high ligation of the IMA, genitourinary and sexual dysfunction were much more prevalent than those who had low ligation of the IMA. There was no difference in oncologic outcomes between the two groups after 1 year. Although this study was not powered to detect differences in oncologic outcomes, the marked difference in quality-of-life measures between the two groups suggest high ligation of the IMA may be more harmful than beneficial.

After the IMA is ligated, the sigmoid colon and its mesentery are then divided with a linear cutting stapler to create the proximal margin; a 5cm margin is ideal. With the sigmoid colon retracted medially, TME is conducted with careful dissection through the avascular plane between the mesorectum and the surrounding presacral fascia; at the most caudal aspect, Denonvilliers' fascia is sharply dissected (Fig. 2). Generally, the posterior dissection is done first, followed by the anterior division of the lowest point of the cul-de-sac, and finally by division of the lateral tissues. Whether the TME is done open, laparoscopically, or robotically, several principles remain unchanged. Adequate lighting and suction are essential. Additionally, traction on the mesorectum permits visualization of the areolar plane through which TME is performed, typically with electrocautery. Once the TME has been completed, the distal margin is created by cutting the rectum with a transverse stapler.

After the specimen is removed, a circular stapler is introduced into the pelvic cavity through the anus to create the anastomosis and restore bowel continuity. The straight anastomosis is the simplest technique; an end-to-end anastomosis is created between the sigmoid colon/proximal rectum and the distal rectal stump or anus. However, this technique does not construct a neorectum reservoir and is associated with LAR syndrome, a term that for postoperative bowel dysfunction characterized by frequent bowel movements and fecal incontinence.[28] To reduce the risk of LAR syndrome, multiple techniques have been developed to create a neorectum. One type of neorectum that can be constructed is the colonic J-pouch. The proximal segment is folded onto itself into a "J" shape and anastomosed to the distal rectal stump. The pouch that is created has a greater volume than a straight anastomosis and can serve as a stool reservoir.[29] In a randomized controlled trial comparing colonic J-pouch with straight anastomosis, patients who underwent reconstruction with a colonic J-pouch experienced fewer bowel movements one year after surgery (2 per day compared to 3.5) and reported fewer and less severe episodes of fecal incontinence.[30] Some patients with J-pouch reconstruction report issues with evacuation and constipation; these patients often have larger pouches, indicating a smaller pouch may be optimal to preserve bowel function.[31] An alternative to J-pouch is the transverse coloplasty. In a transverse coloplasty, a typical straight colo-anal anastomosis is made with a circular stapler. Proximal to the anastomosis, a longitudinal incision is made and then closed transversely, creating a wider segment of large bowel that can serve as a neorectal reservoir.[32,33] Like the colonic J-pouch, the transverse coloplasty is superior to straight coloanal anastomosis, with patients reporting less frequent bowel movements and less fecal urgency.[34] Randomized controlled trials comparing colonic J-pouch with transverse coloplasty have reported similar complication rates and functional outcomes.[35,36] While these techniques may offer some benefits in terms of function (especially in the short term), neorectum constructions are often difficult in patients with narrow pelvis or bulky colonic mesentery. The authors' preference is creation of a colonic J-pouch in patients undergoing colo-anal anastomoses only.

Once the anastomosis is completed and evaluated for leak, a temporary diverting loop ileostomy is created and the abdomen is closed. Diverting loop ileostomies have become more frequently used in the setting of perioperative chemoradiation. In a small retrospective chart review, Buie et al. reported 15% of non-diverted rectal cancer patients treated with neoadjuvant chemoradiation developed pelvic sepsis compared to 4.8% who had surgery only.[37] While creation of a diverting loop ileostomy does require a subsequent surgery to close it, diverting loop ileostomies have been found to minimize the risk of clinically meaningful anastomotic leaks, preventing additional operations or procedures that would need to be performed to address the leak.[38]

Abdominoperineal resection

Abdominoperineal resections (APR) are performed for patients with ultra-low tumors that are adjacent to or involve the external sphincter. The abdominal dissection is performed similarly to that of an LAR, consisting of mobilization of the left and sigmoid colon, separation of the mesorectum from surrounding fascia and pelvic floor, and division of the rectum to create the proximal margin and end colostomy. To completely remove the tumor and mesorectum, the operative field moves to the perineum, where excision begins around the anus and extends superiorly to the join the abdominal dissection.

Despite the inclusion of TME in APRs for rectal cancer, APR patients have overall worse outcomes than those undergoing LAR. Using prospective data from the Dutch Colorectal Group's randomized controlled trial evaluating radiotherapy and TME, Nagtegaal et al. found APR patients had a higher frequency of margin involvement (30.4% vs 10.7%); additionally, margin-positive APR patients had a significantly lower 5-year overall survival rate than margin-positive LAR patients (38.5% vs 57.6%).[39] Achieving a clear CRM is more difficult in an APR than LAR; in an APR, the specimen tends to narrow at the junction between the abdominal and perineal dissections, risking violation of the mesorectum and increasing risk of incomplete resection and intraoperative tumor spillage. For a very distal tumor, the natural mesorectal tapering, or wasp-waist, occurs at the level of the primary tumor. In 2007, Holm et al. described an extended APR, otherwise known as the extralevator or cylindrical APR.[40] Instead of detaching the mesorectum from the levator ani muscles of the pelvic floor, the levators are removed en bloc with the specimen (Fig. 3). The surgeon must consciously widen out the dissection plane from the mesorectum at the lowest point of the abdominal dissection when performing a cylindrical APR. To accomplish this, the patient often is repositioned to prone between the abdominal and perineal dissections. Out of the 28 patients included in this case series, only 2 had a positive CRM and developed local recurrence in the 16-month follow-up period. Further evaluation of the extended APR was done in a meta-analysis performed by West et al. the authors found patients who had extended APRs, compared to those treated conventionally, had lower rates of CRM involvement (14.8% vs 40.6%) and intraoperative tumor spillage (3.7% vs 22.8%).[41]

The perineal dissection of the extended APR will result in a large perineal defect; by definition, tension-free closure of the levators is not possible. Wound size, underlying dead space, proximity to the rectum, history of radiotherapy to the area, and frequent external pressure are all factors that increase the risk of perineal wound dehiscence and infection. Several techniques have been investigated to close the perineal defect, and there currently is no consensus. Primary closure, while the simplest technique, may not be technically

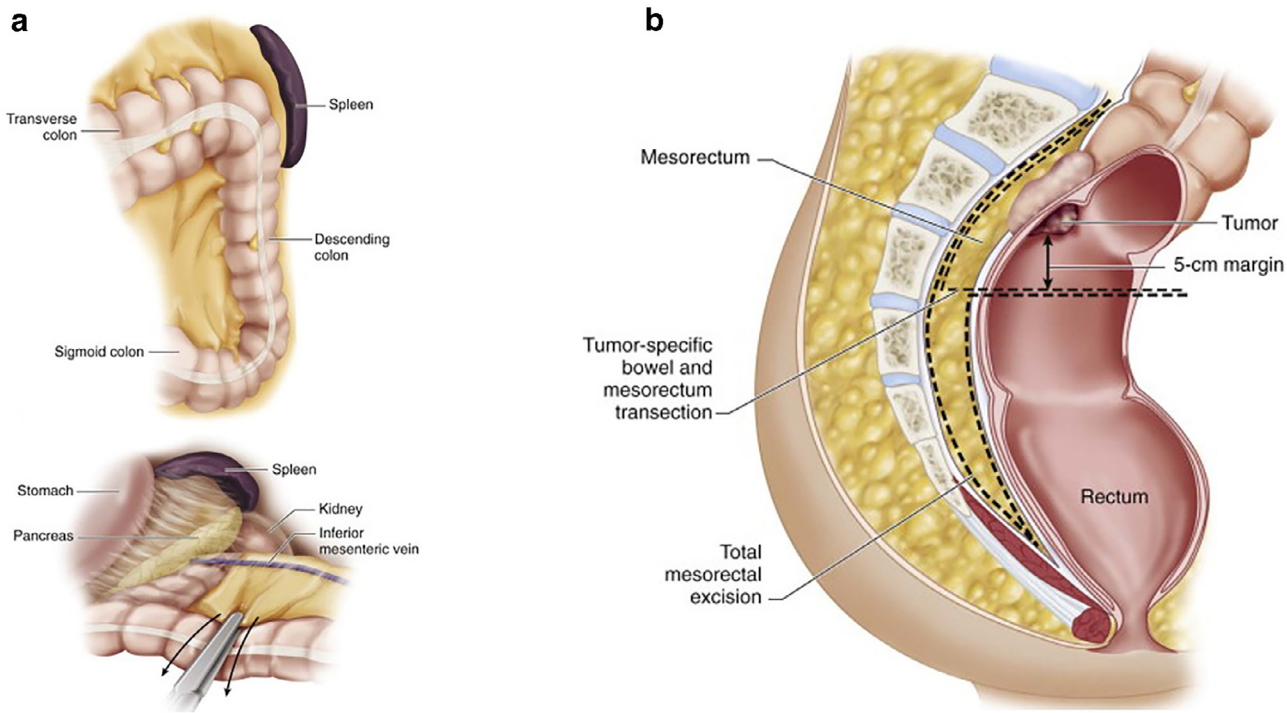

Fig. 2. Low anterior resection (LAR). a) After mobilization of the left and sigmoid colon, the rectum or sigmoid colon is divided 5 cm away from the tumor to create the proximal margin. b) While 5 cm is preferred for the distal margin, shorter distances (< or = 1 cm) have similar oncologic outcomes. A total mesorectal excision (TME) reduces the incidence of circumferential resection margin (CRM) involvement and should be included in all proctectomies for rectal cancer. (Reprinted with permission from Saunders: *Atlas of Colon and Rectal Surgery*, Anne Y Lin, Ch 10 Open Low Anterior Resection, Pgs 163 and 173 (2013).[66])

feasible for large defects. Additionally, several studies have found the rates of wound complications to be unacceptably high, at approximately 25%;[42,43] furthermore, the rate of wound complication increases to 47% in patients who had received preoperative radiotherapy.[44] A few cohort studies have reported moderate improvements with the use of biologic mesh;[45,46] however, the BIOPEX-study, a randomized controlled trial evaluating the use of mesh in wound closure following APR, found no improvement in perineal wound healing with biologic mesh.[47]

As the use of biologic mesh has fallen out of favor, surgeons are increasingly using myocutaneous flap to cover the defect. Donor sites include gluteus maximus, gracilis, and rectus abdominis. In Holm's case series describing the first extended APRs, a gluteus maximus flap was used.[40] However, when these patients were followed for a year, the rate of wound morbidity was not significantly different from primary closure at 41.5%.[48] Alternative donor sites, such as the gracilis and rectus abdominis, are preferred by most surgeons as they are outside the field of radiation.[49] The most common variant is the vertical

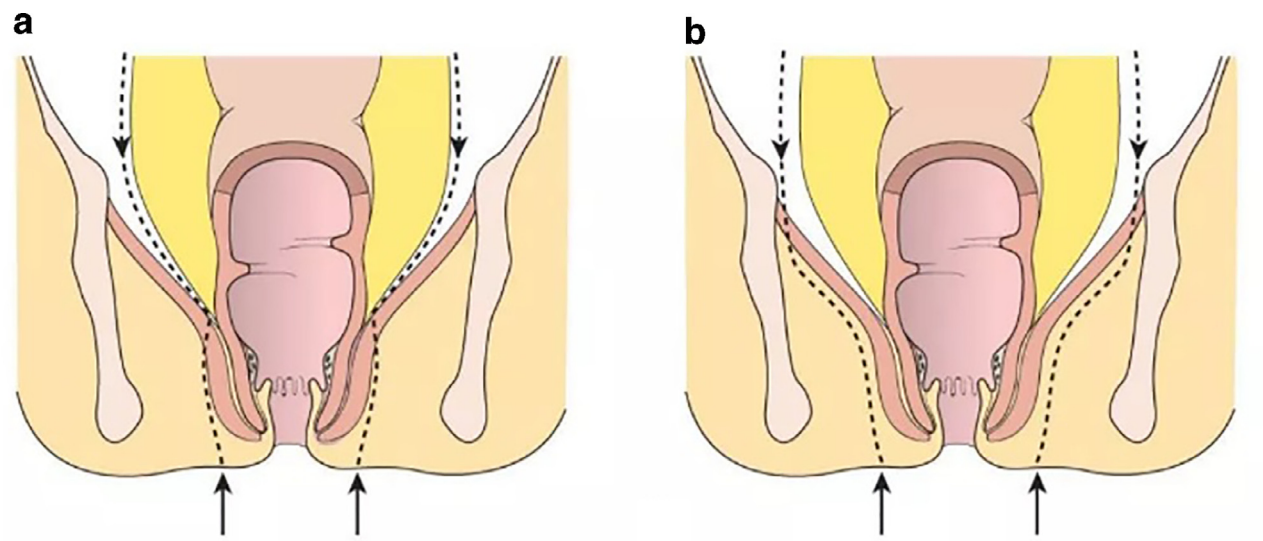

Fig. 3. Perineal dissection of abdominoperineal resection (APR). a) In a conventional APR, the mesorectum is lifted off the pelvic floor and the perineal dissection traverses through the levator ani. This often creates a narrowing at the junction between the abdominal and perineal dissections, increasing the risk of a positive circumferential resection margin (CRM) and/or intraoperative tumor spillage. b) In an extended or cylindrical APR, the levator ani are resected en bloc with the rectum and mesorectum, creating a cylindrical specimen and reducing the risk of local recurrence. (Reprinted with permission from Society of American Gastrointestinal and Endoscopic Surgeons (SAGES), Park EJ, Baik SH, et al.[67])

rectus abdominis myocutaneous (VRAM) flap. A vertical flap of rectus abdominis is incised and intra-abdominally rotated around the inferior epigastric artery to cover the perineal defect.[50] While there have been several studies comparing the various types of flaps, there are currently no prospective randomized trials that can establish a consensus.[51–53]

Minimally invasive rectal cancer surgery

Minimally invasive surgery is associated with shorter length of stay, less postoperative pain, and more rapid return of function compared to open. These advantages have led to increased interest in adopting conventional and robotic-assisted laparoscopic techniques for the treatment of rectal cancer. A series of prospective randomized studies have been conducted within the past decade to evaluate conventional laparoscopic rectal cancer surgery. Initial comparisons with regard to the quality of oncologic resection have been inconclusive. Two of the first randomized controlled trials studying laparoscopic rectal cancer surgery, COREAN and COLOR II, found no significant differences in CRM involvement or TME quality between laparoscopic and open cases;[54,55] however, subsequent non-inferiority trials specifically designed to assess quality of oncologic resection, ACOSOG Z6051 and AlaCART trials, were not able to demonstrate the non-inferiority of surgical specimens collected from laparoscopic proctectomies.[56] Despite these discrepancies in pathologic and histologic measures, mid-term oncologic outcomes from all four trials have found no significant difference in disease recurrence or overall survival after 2 to 3 years of follow-up.[57–60] Thus, conventional laparoscopic proctectomies are now commonly performed by colorectal surgeons proficient in minimally invasive surgery. Nevertheless, laparoscopic rectal cancer surgery remains controversial and studies are needed to select rectal cancer patients who are most likely to benefit from these procedures.

Robotic-assisted laparoscopic surgeries have also been explored and may address the deficiencies of conventional laparoscopy noted by ACOSOG Z6051 and ALaCART. The use of articulating instruments and stereoscopic visualization in robotic surgery may overcome the limitations of rigid instruments in conventional laparoscopy and offer patients a more complete resection.[61] Small cohort studies and meta-analyses have found robotic-assisted resections for rectal cancer to be safe and have comparable perioperative outcomes as conventional laparoscopic techniques.[62–64] To definitively compare robotic-assisted to conventional laparoscopic techniques, the ROLARR trial was initiated in the United Kingdom, enrolling 471 patients with rectal cancer.[65] In their initial report on immediate short-term outcomes, the authors found robotic-assisted surgery did not significantly reduce the rate of open conversion compared to conventional laparoscopic surgery. However, these results do not necessarily indicate the futility of robotic-assisted surgery. Long-term outcomes are currently unavailable. Additionally, as this trial was conducted with surgeons of varying robotic experience, future trials may reveal different results as surgeons become technically more proficient.

Conclusion

While the emergence and optimization of multimodal therapy for rectal cancer have significantly improved outcomes for rectal cancer patients, surgery continues to be the therapy that has the greatest impact on patient survival and quality-of-life. Becoming proficient in rectal cancer surgery is difficult and new techniques remain controversial. However, the general principles highlighted in this review, such as complete oncologic resection and attention to the impact of surgery on patients' functional status, will universally determine the optimal procedures.

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