Ovunc Bardakcioglu
Editor

Advanced Techniques in Minimally Invasive and Robotic Colorectal Surgery

Second Edition

Springer

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Editor
Ovunc Bardakcioglu
University of Nevada, Las Vegas
Las Vegas, NV, USA

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To my father, my first mentor and most talented surgeon I know

Ovunc Bardakcioglu

Foreword

Numerous textbooks line our shelves, fill our memory devices, and are available in our clouds. Each of these learned works includes facets of our practice which offer value to the practitioner. While some of these scholarly works focus upon disease, others focus upon technique. The styles of the textbooks range from recitation of results to management of complications to diagnostic methodology to illustrated atlases. I congratulate Dr. Ovunc Bardakcioglu upon the second edition of his outstanding scholarly volume *Advanced Techniques in Minimally Invasive and Robotic Colorectal Surgery*. Within his 18 chapters, he has captured the essence of the major advances in our specialty including advanced laparoscopic and endoscopy, robotic, and transanal minimally invasive surgical techniques. He has selected from among a myriad of renowned experts some of the most accomplished, respected, and innovative individuals. He and his colleagues have deftly woven a volume in which virtually every new important advance is lucidly described in a meaningful clinically relevant manner. I am particularly delighted to see several of our Cleveland Clinic Florida colorectal surgery alumni including Brooke Gurland and Dana Sands as contributors to this volume. As minimally invasive surgery continues to move forward, as new and better techniques are described and implemented and current ones are improved upon, I have no doubt that Dr. Bardakcioglu and his colleagues will continue to lead the forefront of implementation, introduction, and advancement of these paradigm-changing techniques. Perhaps much to the surprise of the readers of this foreword, I am not focusing upon comparing laparoscopic and robotic colorectal surgery. I think that the essence of offering patients the benefits of minimally invasive surgery is to avoid placing one or more hands in the abdominal cavity. Whether the benefits are conferred by laparoscopy, transanal techniques, or laparoscopic or endoscopic methods, those benefits are realized by a combination of the skill of the surgeon, the nature of the pathology, and other circumstances such as the individual patient and the working environment. I have ceased espousing that it is more important to perform laparoscopy instead of robotics. My current mantra is that only instruments rather than any hands should be used within the abdomen and pelvis to manipulate, dissect, resect, and anastomose intra-abdominal organs. The orifice of introduction and the platform selected are of less relevance provided that the operator and team are appropriately skilled, the resources are available, the patient understands the other operations through an extensive informed consent, and the reason for employment of the given method is with the evidence-based expectation of optimizing the patient's outcome. I thank Dr. Bardakcioglu for having bestowed upon me the honor of authoring this foreword for his outstanding textbook *Advanced Techniques in Minimally Invasive and Robotic Colorectal Surgery,* second edition. I highly commend this volume to all practitioners within our specialty.

October 2018

Steven D. Wexner, MD, PhD, FACS, FRCS, FRCS, FRCSI
Digestive Disease Center
Department of Colorectal Surgery
Cleveland Clinic Florida
Weston, FL, USA

Preface

The first edition of *Advanced Techniques in Minimally Invasive and Robotic Colorectal Surgery*, which was published in 2015, received tremendous feedback as a first textbook introducing and systematically describing robotic colorectal surgical procedures in addition to laparoscopic techniques. Since the first edition, the use of robotic surgery in our field significantly increased, and many new advances in equipment and new approaches are becoming more popular.

The first edition laid out the foundation with laparoscopic and robotic surgery utilizing the Da Vinci SI platform. Transanal minimally invasive techniques were introduced.

The second edition is expanding on laparoscopic and endoscopic techniques and more advanced robotic colorectal procedures, including the use of the new Da Vinci XI platform. A new innovative approach, transanal total mesorectal excision (TaTME), is introduced, which is dramatically changing the surgical approach to rectal resections. This volume therefore complements the first edition with all new topics.

These two books bridge the gap between the practicing community of surgeons and the surgical innovators and provide a foundation for all classic and new techniques in minimally invasive colorectal surgery. By enhancing the surgical toolbox, the surgeon will be able to progress from the novice to the master. Rather than describing the entire operative procedure by a single individual author, the guide compares operative steps of various technical difficulties throughout the different chapters, thereby allowing the surgeon to tailor surgery to patient and surgeon's own comfort level and experience.

I hope this new book will help increase the adaption of these new innovative approaches to minimal invasive colorectal surgery for the benefit of all our patients. I am excited to see where the future will take us with new robotic platforms on the horizon and further advances in endoluminal surgery.

Las Vegas, NV, USA — Ovunc Bardakcioglu

Contents

Contributors

Ahmed Al-Khamis, MD, MSc (Epi), FRCSC Department of Colon and Rectal Surgery, Advocate Lutheran General Hospital, Park Ridge, IL, USA

Elliot G. Arsoniadis, MD Department of Colorectal Surgery, Cleveland Clinic Florida, Weston, FL, USA

Deniz Atasoy, MD Department of General Surgery, Acibadem Mehmet Ali Aydinlar University, School of Medicine, Istanbul, Turkey

Bilgi Baca, MD Department of General Surgery, Acibadem Mehmet Ali Aydinlar University, School of Medicine, Istanbul, Turkey

Atakent Acibadem Hastanesi, Kucukcekmece/Istanbul, Turkey

Ovunc Bardakcioglu, MD, FACS, FASCRS Division of Colon and Rectal Surgery, UNLV School of Medicine, Las Vegas, NV, USA

Amir Bastawrous, MD, MBA Swedish Medical Center, Swedish Colon and Rectal Clinic, Seattle, WA, USA

Richard C. Baynosa, MD, FACS Department of Plastic Surgery, University of Nevada, Las Vegas School of Medicine, Las Vegas, NV, USA

Patrick Berg, MD Department of Surgery, UNLV School of Medicine, Las Vegas, NV, USA

Manish Chand, MBBS, FRCS, FASCRS, MBA, PhD Division of Surgery and Interventional Sciences, University College Hospital, London, UK

Robert K. Cleary, MD Department of Surgery, St Joseph Mercy Hospital, Ann Arbor, MI, USA

Samuel Eisenstein, MD Department of Surgery, UC San Diego, La Jolla, CA, USA

Phillip Fleshner, MD Division of Colon and Rectal Surgery, Cedars-Sinai Medical Center, Los Angeles, CA, USA

Garrett Friedman, MD University of Nevada Las Vegas, Las Vegas, NV, USA

Joshua J. Goldman, MD Department of Plastic Surgery, University of Nevada, Las Vegas School of Medicine, Las Vegas, NV, USA

Emre Gorgun, MD, FACS, FASCRS Department of Colorectal Surgery, Cleveland Clinic, Cleveland, OH, USA

Aimee Gough, MD Department of Surgery, Wyoming Medical Center, Casper, WY, USA

Brooke Gurland, MD Department of General Surgery, University of Stanford, Palo Alto, CA, USA

Eric Haas, MD Division of Colon and Rectal Surgery, Houston Methodist Hospital, Houston, TX, USA

Ismail Hamzaoglu, MD Department of General Surgery, Acibadem Mehmet Ali Aydinlar University, School of Medicine, Istanbul, Turkey

Cristina R. Harnsberger, MD Department of Colon and Rectal Surgery, University of Massachusetts Medical School, Worcester, MA, USA

Craig S. Johnson, MD Department of Surgery, Oklahoma Surgical Hospital, Tulsa, OK, USA

Tayfun Karahasanoglu, MD Department of General Surgery, Acibadem Mehmet Ali Aydinlar University, School of Medicine, Istanbul, Turkey

Shawna R. Kleban, MD Department of Plastic Surgery, University of Nevada, Las Vegas School of Medicine, Las Vegas, NV, USA

Kunal Kochar, MD Department of Colon and Rectal Surgery, Advocate Lutheran General Hospital, Park Ridge, IL, USA

David W. Larson, MD Division of Colon and Rectal Surgery, Mayo Clinic, Rochester, MN, USA

Sang W. Lee, MD Division of Colorectal Surgery, University of Southern California, Keck School of Medicine, Los Angeles, CA, USA

Amy L. Lightner, MD Division of Colon and Rectal Surgery, Mayo Clinic, Rochester, MN, USA

Shanglei Liu, MD, MAS Department of General Surgery, University of California San Diego, San Diego, CA, USA

Joshua MacDavid, MD Department of Surgery, UNLV School of Medicine, Las Vegas, NV, USA

Slawomir Marecik, MD, FACS, FASCRS Department of Colon and Rectal Surgery, Advocate Lutheran General Hospital, Park Ridge, IL, USA

Department of Colorectal Surgery, University of Illinois at Chicago, Chicago, IL, USA

Rachel Martin, MD Department of Colorectal Surgery, Colon and Rectal Clinic of Orlando, Orlando, FL, USA

Justin A Maykel, MD Department of Colon and Rectal Surgery, University of Massachusetts Medical School, Worcester, MA, USA

Erik R. Noren, MD Department of General Surgery, University of Southern California, Keck School of Medicine, Los Angeles, CA, USA

John J. Park, MD Department of Colon and Rectal Surgery, Advocate Lutheran General Hospital, Park Ridge, IL, USA

Kristen Rumer, MD, PhD Department of General Surgery, University of Stanford, Palo Alto, CA, USA

Dana Sands, MD Department of Colorectal Surgery, Cleveland Clinic Florida, Weston, FL, USA

Ipek Sapci, MD Department of Colorectal Surgery, Cleveland Clinic, Cleveland, OH, USA

António S. Soares, MD, MSc Division of Surgery and Interventional Sciences, University College Hospital, London, UK

Mark Soliman, MD Department of Colorectal Surgery, Colon and Rectal Clinic of Orlando, Orlando, FL, USA

Karen Zaghiyan, MD Division of Colon and Rectal Surgery, Cedars Sinai Medical Center, Los Angeles, CA, USA

Laparoscopic-Assisted Polypectomy

1

Erik R. Noren and Sang W. Lee

Introduction

This chapter presents a historical overview of laparoscopic-assisted polypectomy and detailed description of surgical technique. We will a additionally describe several variations and advanced maneuvers that extend the application of the technique to more difficult lesions. Tips and tricks will be highlighted to help navigate the procedure throughout the chapter. Finally, we will discuss special considerations in challenging cases and provide guidance for management of complications.

Background

Adoption of colorectal cancer screening has been effective in reducing the overall incidence and mortality from the disease. Concurrently, there has been an increase in the detection of large and complex polyps not amenable to simple endoscopic resection alone. Traditionally, these patients were referred for surgical management by segmental colon resection. In fact, surgery for benign colorectal polyps has increased significantly from 5.9 per 100,000 patients in 2000 to 9.4 per 100,000 patients in 2014, which represents more than 28,000 colectomies performed every year in the United States for benign lesions [1]. Although the development of laparoscopic colorectal surgery and deployment of enhanced recovery protocols has markedly reduced the surgical trauma, cost, and complication rate associated with colon resection, there remains significant morbidity for patients undergoing colectomy.

Innovative combined endoscopic and laparoscopic surgery (CELS) approaches have been developed that leverage the capabilities of each technology for removal of difficult polyps without colon resection [2–6]. Laparoscopic-assisted polypectomy was first described in 1993 as a method for complete excision of moderate-sized sessile polyps that avoided colon resection in select patients [3]. Subsequently described techniques include laparoscopic-assisted colon wall excision and full-thickness CELS [7]. In the following decades, several retrospective series have confirmed the safety and effectiveness of the procedures for management of such difficult lesions [8–11]. A systematic review of CELS experiences found low complication rates and high (74–91%) rates of successful resection with colon preservation [12]. In studies with long-term follow-up, there were no cases of malignant lesions developing in patients with completely resected histopathologically benign polyps [8, 10].

Cost analysis demonstrates that utilization of CELS benefits the healthcare system in addition to the benefits for patients. The majority of CELS patients will be discharged on the day of surgery or the following day, so while CELS has slightly higher equipment costs, this is more than surpassed by the savings from substantial reductions in inpatient hospital utilization. Sharma et al. identified the total cost per CELS procedure at $6554 compared with $12,585 per laparoscopic segmental resection and $18,216 per open resection [13].

Current indications for CELS encompass benign-appearing polyps not amenable to simple endoscopic resection. Often this is the result of polyp size or location on a luminal fold, colon flexure, proximity to the appendiceal orifice, or ileocecal valve. Eligible polyps may be pedunculated or sessile, appear soft with regular contours, have no central depression or ulceration, and lift with submucosal injection.

E. R. Noren
Department of General Surgery, University of Southern California, Keck School of Medicine, Los Angeles, CA, USA
e-mail: Erik.Noren@med.usc.edu

S. W. Lee (✉)
Division of Colorectal Surgery, University of Southern California, Keck School of Medicine, Los Angeles, CA, USA
e-mail: sangwl@med.usc.edu

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Polyps with irregular vascular or pit pattern when viewed with narrow-band imaging are suspicious for invasive malignancy and may not be appropriate for CELS.

Preoperative Planning

Evaluation of the patient referred for an endoscopically unresectable polyp begins with a thorough history and physical exam with particular attention paid to the medical and surgical history as well as family history of colorectal cancer and inflammatory bowel disease. Patients should undergo appropriate preoperative cardiopulmonary evaluation for their age and existing comorbidities. Review of the colonoscopy report with relevant images and pathology report confirming a benign lesion is necessary to determine if a patient is indeed a candidate for CELS. In-office evaluation of left-sided lesions by flexible endoscopy allows verification of polyp location, size, and the absence of concerning characteristics.

It is necessary to counsel patients that, in the event that a lesion cannot be removed by CELS or if the lesion is found intraoperatively to have features concerning for malignancy, the operating surgeon will proceed with a laparoscopic colon resection. Additionally, patients should understand the possibility that a successfully removed polyp may be found on pathologic evaluation to contain malignancy which may necessitate a subsequent formal resection.

Full mechanical bowel preparation the day before surgery is necessary for utilization of the endoscope during the procedure. Subcutaneous heparin and prophylactic parenteral antibiotics are administered within 1 hour prior to surgical incision.

Room Setup and Positioning

After induction of general anesthesia, the patient is placed in a modified lithotomy position to allow simultaneous access to the anus and abdominal approach. Both arms are tucked at the patient's side with care to ensure adequate padding of the hands, wrists, and all pressure points as the operating table position is often adjusted throughout the case. Nasogastric drainage tube and Foley catheter are placed and pneumatic compression devices are applied to the bilateral lower extremities.

Positioning of the laparoscopic viewing monitors is dependent on the anticipated lesion location. Right colon lesions will require the laparoscopic surgeon, often with an assistant, to stand on the patient's left side with the monitor off the right side and slightly biased toward the shoulders and head (Fig. 1.1). The opposite for left colon lesions with monitors on the patients left biased toward the waist and feet. Monitors for transverse colon lesions should be positioned at the head of the bed. The endoscopist will work from between the patient's legs. The endoscopy cart, including high-definition monitor and CO_2 insufflator, is usually positioned on the same side of the patient as the laparoscopic monitor, though this is adjustable for strong surgeon preference or better comfort.

It is important to have all equipment required for a laparoscopic colon resection available in the room in addition to that required for the CELS procedure in the event a formal resection is required.

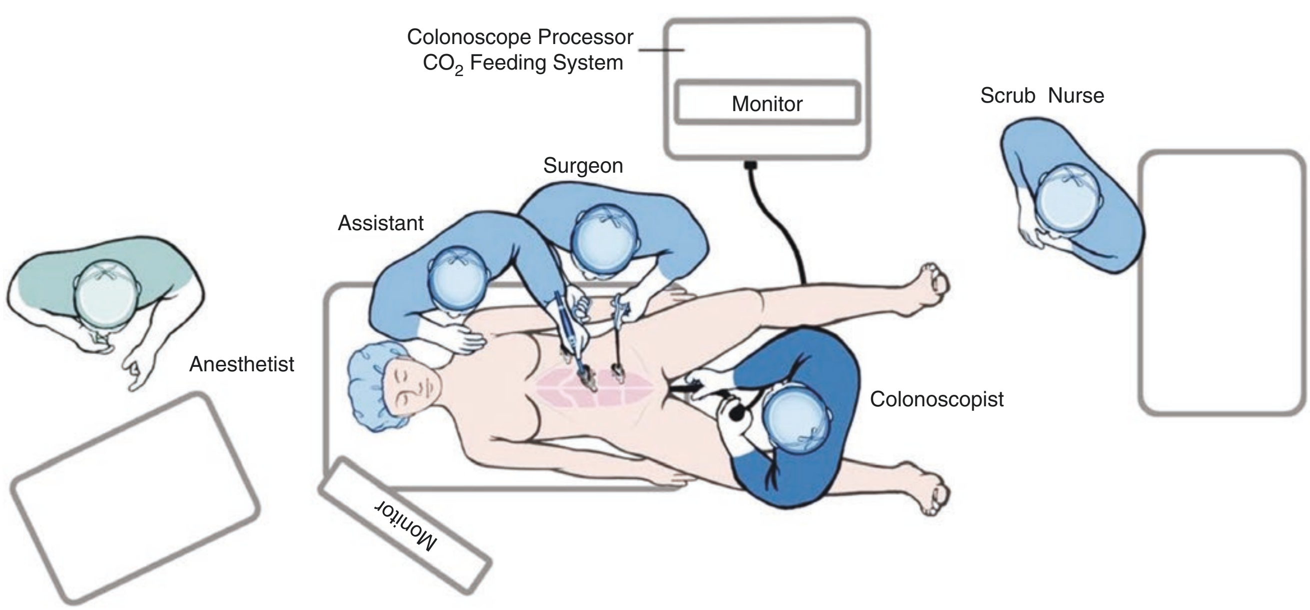


Fig. 1.1 Operating room setup and positioning for excision of right colon lesion by laparoscopic-assisted polypectomy

Port Placement

Placement of abdominal trocars is typically deferred until the target lesion has been identified by intraoperative endoscopy and confirmed to be amenable to CELS resection. Trocar placement necessarily depends on the location of the lesion.

Abdominal access is achieved with placement of a 5 mm periumbilical trocar by standard technique and pneumoperitoneum established. Insertion of a laparoscope allows identification of the target lesion, either by tattoo identification or endoscopic transillumination of the colon wall. We recommend using a high-definition flexible-tip laparoscope for enhanced visualization and adaptability during mobilization. A pair of 5 mm working trocars is placed with intent to triangulate on the target lesion, though 3 mm microlaparoscopic trocars may be substituted if available. Place trocars in the right lower quadrant and suprapubic positions for left-sided lesions and in the left lower quadrant and suprapubic positions for right-sided lesions. Transverse colon lesions may be accessed by placement of bilateral 5 mm working trocars in the upper or lower quadrants.

Operative Steps

Operative steps	Degree of technical difficulty (scale 1–10)
1. Colonoscopy	1
2. Mobilization	2–4
3. Polypectomy	3
4. Full-thickness CELS	7
5. Colonoscopy-assisted laparoscopic cecectomy	3
6. Leak test	2

Colonoscopy

The use of CO_2 insufflation is decidedly superior to room air when performing CELS procedures. More rapid absorption of CO_2 minimizes unnecessary colon distention and allows for optimal simultaneous laparoscopic and endoscopic visualization [14].

The endoscopist begins the procedure with insertion of the colonoscope and advancement to identify the target lesion. It should be examined to confirm the location, size, and absence of concerning features such as hardness, fold convergence, expansile growth, and depression or ulceration. Having confirmed the lesion is amenable for CELS resection, the surgeon may proceed with incision and port placement as described in the previous section.

Mobilization

The great advantage CELS provides over solitary endoscopic approaches is the ability to externally manipulate the colon. The location of the polyp will dictate the degree of manipulation and in many cases mobilization of the colon that is required.

Polyps located along the edge or back side of folds are difficult to approach endoscopically. Directed laparoscopic manipulation repositions the colon wall exposing the lesion for endoscopic resection (Fig. 1.2). Polyps located behind flexures and kinks from scarring often will not respond to simple manipulation of the colon wall and will require mobilization of the corresponding segment of colon to straighten out the tissue and expose the polyp. Additionally, polyps located on the mesenteric or retroperitoneal side of the colon lumen require laparoscopic mobilization of that segment of the colon. This is performed with a similar technique as for a laparoscopic colon resection, utilizing an energy device to divide attachments along the embryologic tissue planes. It is helpful to have an assistant piloting the flexible-tip laparoscope to free the surgeon to work with both hands.

Polypectomy

Submucosal injection to lift the polyp is performed with an endoscopic injection needle through the working channel of the colonoscope. Dilute solution (50/50) of indigo carmine or methylene blue and either saline or albumin is used to both mark the location of the lesion and elevate the mucosal-based lesion. Injection into the submucosal space forms a broad smooth cushion barrier between the polyp and the underlying muscular layer. Failure to create this effect likely indicates injection into a deeper layer of the colon wall; slowly pull back the injection needle while slowly injecting to find the correct plane. It may be necessary to repeat injection later in the procedure if the elevated cushion has dissipated.

Be cautious with a lesion that does not elevate with submucosal injection as this may be an indication of an invasive tumor. Evaluate for additional concerning signs as mentioned previously. If there is concern for an invasive lesion, laparoscopic colectomy should be performed. If the polyp truly appears benign, the failure to lift may be the result of scarring from previous biopsies, and endoscopic removal may proceed. Overall the incidence of cancer found in benign-appearing lesions after CELS resection is low (~2%) [8], and those patients are able to undergo a subsequent resection as necessary.

The target polyp is removed by electrosurgical snare polypectomy. The laparoscopic instrument is utilized to

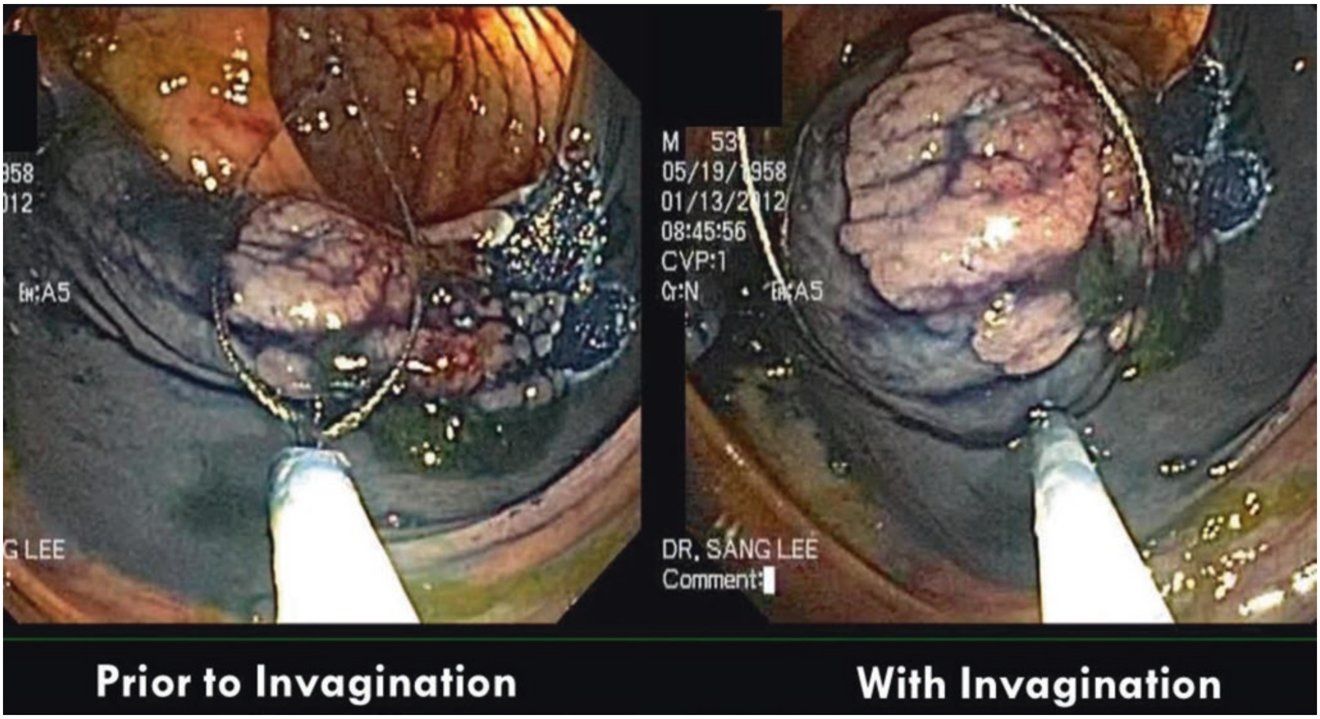
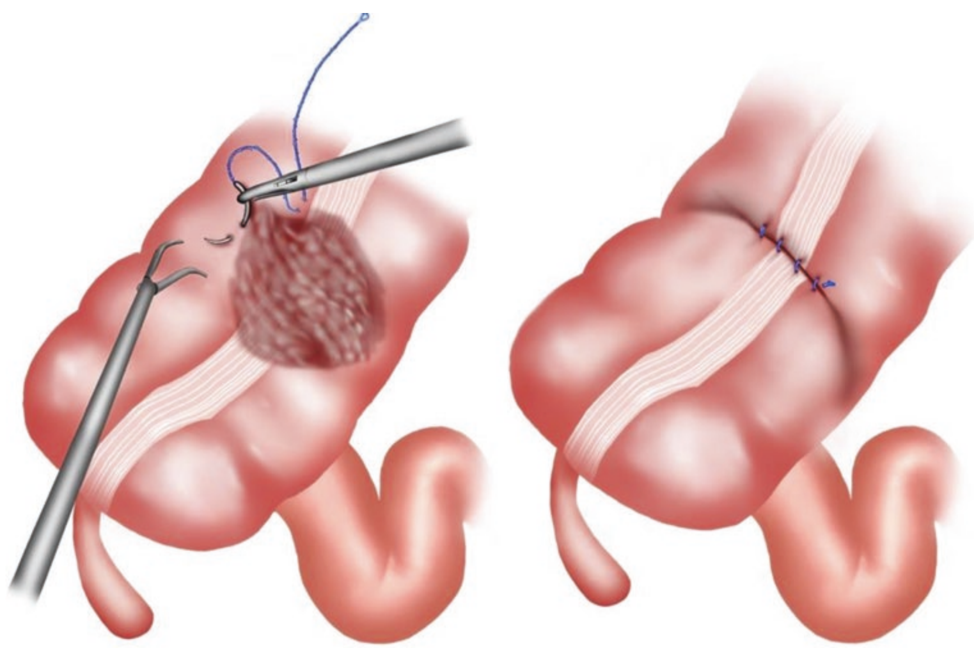


Fig. 1.2 Laparoscopic instrument positions a difficult polyp for snare polypectomy

Fig. 1.3 Laparoscopic suture reinforcement for thermal colon injury



position and deliver the polyp into the snare loop. Large or complex lesions may need to be removed in several piecemeal snare excisions. Do not lose track of the specimens prior to collection. Specimens removed by polypectomy are typically removed endoscopically with a Roth Net. However, specimens that are small (<5 mm) or excised in a piecemeal fashion can be removed by colonoscope suction with a specimen trap attached in line to the suction device.

The laparoscope is used to monitor the serosal side of the polypectomy site for any sign of thermal injury or weakness created by the procedure. Such areas can immediately be reinforced or repaired with a laparoscopic imbricating suture (Fig. 1.3).

Full-Thickness CELS

An extension of the CELS technique allows for full-thickness excision of polyps that may be difficult to remove with snare polypectomy, particularly large serrated adenomas and polyps with significant scarring due to prior biopsies [15].

Submucosal dilute dye injection is utilized, as described in the prior section, to elevate and mark the polyp (Fig. 1.4). Once the entire area of the lesion is elevated with dye, the circumference of the resection area is marked on the serosal surface from the laparoscopic approach using monopolar cautery. The seromuscular layer is then divided along the circumference of the marked resection, taking particular care not to cause a full-thickness perforation by injuring the mucosal layer (Fig. 1.5). The dissected resection area can now be invaginated into the colon lumen with the assistance of a laparoscopic instrument. The formerly flat and adherent lesion is now visualized endoscopically protruding into the lumen and can be delivered into a polypectomy snare (Fig. 1.6). The snare is carefully closed, without dividing, pulling together the edges of the serosal dissection. The seromuscular defect is closed with a running 3-0 vicryl laparoscopic suture, an additional layer of imbricating sutures may additionally be placed (Fig. 1.7). Once the defect is closed, the snare polypectomy is completed and the lesion collected in a Roth net and removed from the colon (Fig. 1.8).

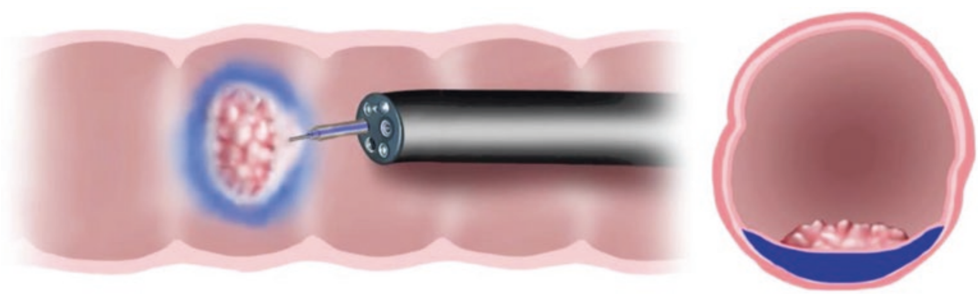


Fig. 1.4 Submucosal dilute dye injection elevates the target polyp

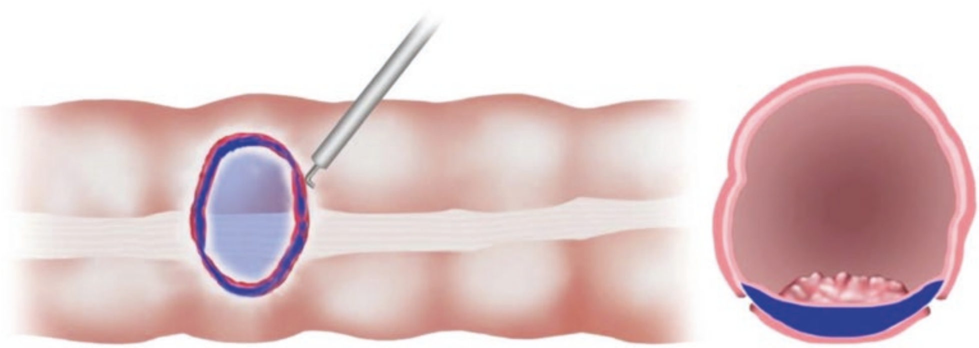


Fig. 1.5 Division of the seromuscular layer of the colon during full-thickness CELS technique

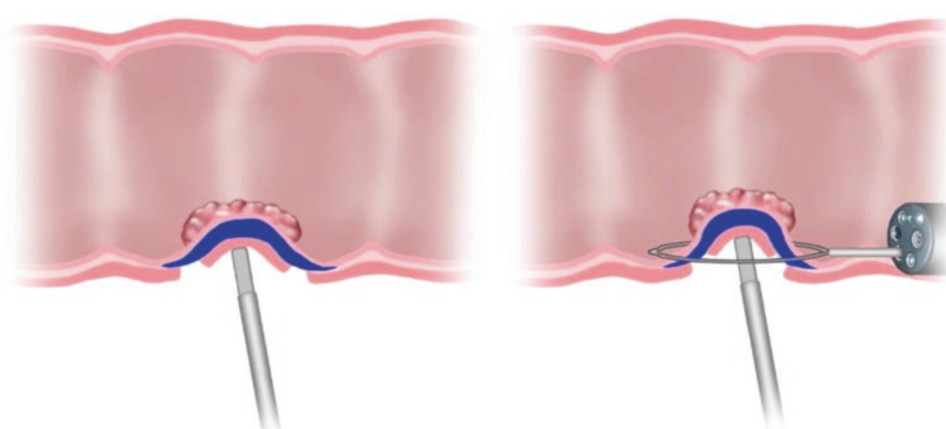


Fig. 1.6 Laparoscopic instrument used to invaginate the polyp for endoscopic snare placement

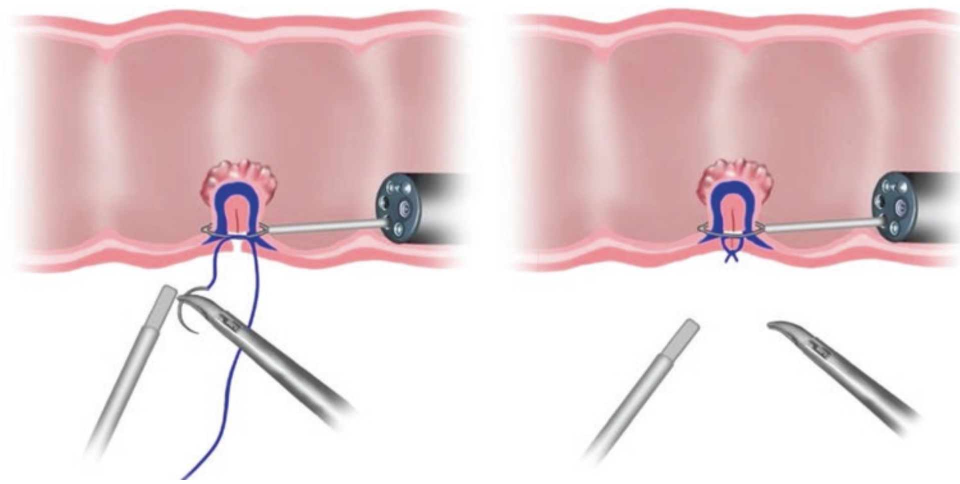


Fig. 1.7 Laparoscopic suture repair of the seromuscular defect prior to transection of the polyp

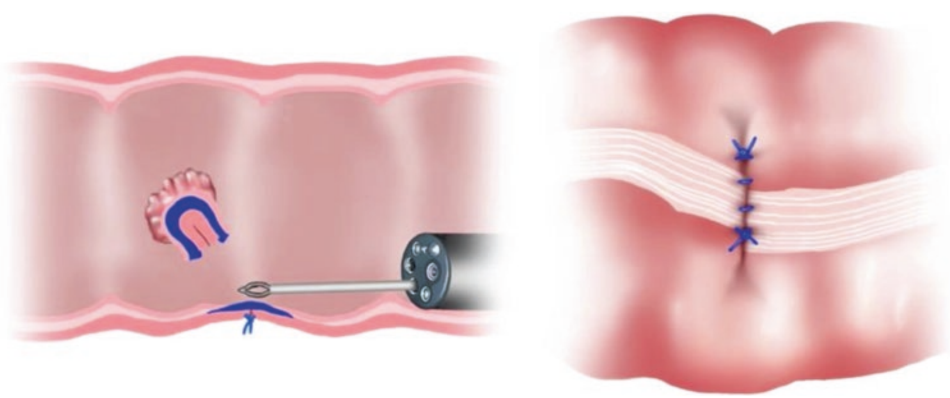


Fig. 1.8 Energy is applied to the snare for full-thickness excision of the lesion. The repaired seromuscular defect

Colonoscopic-Assisted Laparoscopic Partial Cecectomy

Polyps located in the thin-walled cecum and proximal ascending colon are effectively managed with laparoscopic stapled wall excision or partial cecectomy performed under colonoscopic guidance. These polyps are often located within close proximity of the ileocecal valve or appendiceal orifice. This technique ensures complete full-thickness excision of even wide sessile polyps while protecting the aforementioned structures from damage [16].

The polyp is identified by colonoscopy as previously described. A 12 mm trocar is substituted for the usual 5 mm in the left lower quadrant to accommodate a laparoscopic linear cutting stapler. It may be necessary, in some cases, to mobilize the cecum and proximal ascending colon by dividing the peritoneum and lateral attachments using electrocautery. Placing the patient in Trendelenburg position with the right side elevated is also helpful. While positioning the stapler, the colonoscope is used to confirm the line of resection including the entire lesion. Intubation of the terminal ileum allows the colonoscope to function as a mechanical barrier, like a Bougie, when positioning the stapler for resection of a lesion in close proximity to the terminal ileum. The resected specimen is withdrawn from the abdomen in a laparoscopic Endo Catch bag.

Leak Test

An air leak test can be performed using CO_2 colonoscope insufflation and laparoscopic irrigation. Adjust the operating table to place the tested colon in a dependent position, irrigate the abdomen and submerge. The absence of bubbles indicates a negative leak test.

Postoperative Care

The majority of patients who undergo CELS laparoscopic-assisted polypectomy can go home the same day as their procedure. Patients that undergo full-thickness excision, colonoscopic-assisted laparoscopic wall excision, or partial cecectomy or in cases in which a full- or partial-thickness injury was noted intraoperatively, patients will have a short hospital stay. The diet is advanced as tolerated, though we recommend monitoring until there is return of bowel function prior to discharge.

The importance of diligent surveillance colonoscopy must be emphasized, as there is a known incidence of polyp recurrence, reported at 10% over the course of a 10-year series [8]. We perform a follow-up colonoscopy at 3 months. The majority of detected recurrent polyps are managed endoscopically.

Special Considerations and Complications

The overall complication rate in multiple series reporting on CELS cases is low, 4–13% [2, 17, 18], and consists primarily of ileus and wound complications. Lee et al. report a complication rate of 4.2% over 10 years, most commonly consisting of urinary retention and wound hematoma [8].

Contraindications

Laparoscopic-assisted polypectomy should not be performed in patients with a known malignancy or for management of lesions with high risk features. Biopsied polyps demonstrating high-grade dysplasia but absent any other concerning features may be amenable to CELS. It is important to obtain tissue slides for review and diagnosis confirmation by your institution's own pathologist. Patients with a known polyposis syndrome or patients with additional polyps that cannot be removed endoscopically or by CELS should not undergo this procedure. Adhesive disease in patients with a history of multiple prior abdominal operations makes manipulation and mobilization of the colon difficult and increases the likelihood that a patient will require a surgical resection.

Morbid Obesity

Morbid obesity is not a contraindication for CELS procedures. Placement of laparoscopic trocars may need to be adjusted nearer to the target lesion to maintain triangulation with increased abdominal girth, and in patients with super-morbid obesity, bariatric trocars and instruments may be required.

Perforation

The rate of iatrogenic colon perforation during purely endoscopic procedures is reported as less than 1% [19]. A primary advantage of CELS over totally endoscopic resection techniques is the continuous laparoscopic monitoring and leak testing during the procedure. This allows intraoperative detection of perforation or partial-thickness injury and immediate suture repair. Suture placement was reported in 10% of laparoscopic-assisted polypectomy cases by Franklin et al. [2] and in 43% of cases by Yan et al. [5]; however, in both series there were no reported incidences of full-thickness perforation. Rather, intraoperative suture placement in these cases represented detection of partial-thickness injury or colon wall weakness following polypectomy and prophylactic measures to reinforce the area.

Bleeding

Post-polypectomy bleeding has not been reported with significant incidence in the available series of CELS patients, likely because the majority of bleeds are detected and managed during the procedure. However, it is a known complication of polypectomy and endoscopic interventions, and thus the surgeon performing CELS procedures should be prepared to manage it.

Immediate bleeding from polypectomy sites can be controlled using the polypectomy snare to deliver electrocautery. In rare cases injection of epinephrine or placement of endoscopic clips may be required. Delayed bleeding may occur up to a month after the procedure. Management consists of resuscitation followed by repeat endoscopy with epinephrine injection or clipping in most cases [20].

Summary

Techniques for combined endoscopic and laparoscopic surgery (CELS) including laparoscopic-assisted polypectomy have demonstrated safety and effectiveness for management of benign polyps not otherwise amenable to endoscopic removal. Since initial description well over a decade ago, utilization of CELS has allowed a great number of patients to avoid the substantial morbidity of colectomy with faster recovery and lower cost.

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2 Endoscopic Submucosal Dissection

Ipek Sapci and Emre Gorgun

Abbreviations

EMR Endoscopic mucosal resection
ESD Endoscopic submucosal dissection
HES Hydroxyethyl starch

Introduction

This chapter will review the advanced endoscopic resection technique of endoscopic submucosal dissection. The steps of this novel method will be described in detail accompanying brief literature review on this approach. Equipment, tips, and key points for endoscopic submucosal dissection will be summarized with supplementary images and video clips.

Background

Colorectal cancer is the second most common cause of cancer death in the US population and was estimated to result in 50,260 deaths in 2017 [1]. Screening colonoscopy with polypectomy has been shown to decrease the incidence of colorectal cancer and its related mortality [2]. Most colorectal polyps are suitable for snare or cold forceps removal; however, some lesions may not be fit for conventional resection. For these lesions, advanced oncological resections are performed frequently, and a recent study reported that it can be an overtreatment for 92% of the patients [3].

Advanced polypectomy techniques such as endoscopic mucosal resection (EMR) and endoscopic submucosal dissection (ESD) were developed to fill the gap in-between to prevent overtreatment and achieve complete resection of difficult lesions. EMR resulted in insufficient piecemeal specimens in the upper gastrointestinal tract, and this lead to the development of endoscopic submucosal dissection [4].

ESD became popularized mainly in Asia, and it is still not commonly performed in Western countries. In fact, 87% of the published literature is from Asia [5]. Regardless of the growing interest for ESD around the world, acceptance levels remain low. Recently, it became an integral part of the clinical practice for colorectal lesion removal in Japan [6]. In spite of reports of this procedure to be safe and feasible for colorectal lesions by a wide array of studies, a standardization is yet to be accomplished [5, 7].

ESD was developed to facilitate excision of the lesions that are difficult to remove with regular snaring [8, 9]. The main goals of ESD are to achieve an R0 resection for early cancerous lesions and accomplish an en bloc resection suitable for meticulous histopathological examination [6]. A recent meta-analysis reported R0 resection rates of 13,833 lesions as 83% with en bloc endoscopic resection rate of 92% for ESD. When R0 resection is achieved, risk of recurrence was reported to be 4 in 10,000 [5].

Widespread use of this novel method in the colon has also been restricted due to technical difficulties resulting from the anatomy and physiology of the colon [6, 10]. The colon is anatomically challenging to perform ESD in the sense that it consists of folds and flexions and exhibits peristalsis [6]. In addition, the colonic wall is thinner in comparison to other locations of the alimentary tract which places a greater risk for perforations during the procedure.

ESD was reported to have higher perforation rates and longer procedural time when compared with EMR but also had higher en bloc resection rate and a lower recurrence rate when compared with EMR [11]. Size, localization, morphology, granularity, and experience level of the endoscopist are the factors that affect the decision to either perform simple snaring, EMR, ESD, or oncological resection [9].

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I. Sapci · E. Gorgun (✉)
Department of Colorectal Surgery, Cleveland Clinic, Cleveland, OH, USA
e-mail: sapcii@ccf.org; gorgune@ccf.org

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The basic principle of ESD consists of generating a plane between the mucosa and the submucosa by injecting a solution material that works as a cushion and subsequently dissect the mucosa from the underlying submucosa using this newly formed plane. Cautious dissection in this plane is the crucial step to accomplish an adequate specimen without defects through the submucosa.

Recently, new injection materials and dissection techniques are being developed, and efforts are continuing to establish ESD as a standard of care [6]. In the following sections, key steps of this procedure will be explained in detail with emphasis on the technique.

Indications

ESD is indicated (as recommended by Japan Gastroenterological Endoscopy Society) for lesions that are larger than 20 mm and not suitable for endoscopic en bloc removal with snaring, lesions with underlying fibrosis, local residual carcinomas, and sporadic localized lesions in patients with chronic colonic inflammation [10] (Table 2.1).

In the United States, ESD has not been standardized yet; however, a proposed management algorithm can be used for appropriate patient selection (Fig. 2.1).

Table 2.1 Indications for colorectal endoscopic submucosal dissection (ESD)

1. Large (>20 mm in diameter) lesions that are indicated for endoscopic resection and in which en bloc endoscopic mucosal resection is difficult
Laterally spreading tumor-nongranular: particularly of the pseudodepressed type
Lesions showing Kudo type-V invasive pit pattern
Carcinoma with submucosal infiltration
Large depressed-type lesion
Large elevated lesion suspected to be a cancer
2. Mucosal lesions with fibrosis
3. Local residual early carcinoma after endoscopic resection
4. Sporadic localized tumors in chronic inflammation, such as ulcerative colitis

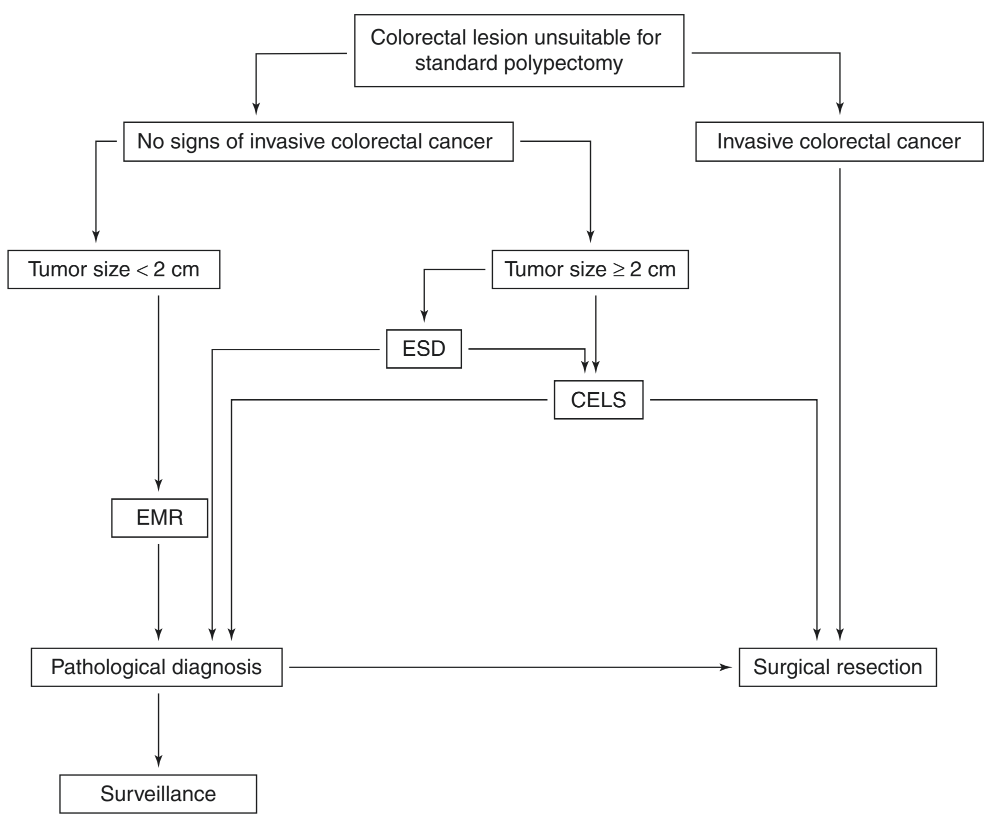

Fig. 2.1 Endoscopic submucosal dissection algorithm for mucosal/submucosal tumors

Preoperative Planning

Principles of care for colonoscopy are followed for patients undergoing ESD. ESD can be performed both in the outpatient setting and in the operating rooms. Operating room setting should be preferred for high-risk patients with comorbid conditions and low functional status. Patients who undergo ESD are observed for at least 4 hours after the procedure and can be discharged the same day after tolerating oral intake [12].

Room Setup and Positioning

Room setup is different for the operating room setting and the endoscopy suites (Fig. 2.2). An adjustable bed is vital to ensure the ease of dissection and ergonomic efficiency for the endoscopist. In the OR, the endoscopist typically stands in the middle of the legs, and initially, the colonoscope is introduced, and a complete colonoscopy is performed to locate the lesion.

After locating the lesion, the position of the patient can be changed along with abdominal pressure application by an assistant as needed to provide the endoscopist with the best angle for visualization and ease of dissection. Typically the lesion is aimed to be located at 6 o'clock [12].

External pressure application and maneuvers can be beneficial during procedure especially for lesions in locations that are difficult to reach such as flexures and ileocecal valve and retroflexion can be used for these locations [13].

Operative Steps

Operative steps	Degree of technical difficulty (scale 1–10)
1. Identification and injection of lesion	2
2. Circumferential incision and submucosal dissection	5–9
3. Retraction	4
4. Excision and clip application	3

Identification and Injection of Lesion

Lesion identification prior to colonoscopy may be necessary especially for nongranular laterally spreading lesions. The referring physician can tattoo the lesion to enable timely identification and to avoid omitting the lesion. Advanced endoscopic imaging techniques can also be beneficial for predicting the risk of the invasion. Narrow-band imaging and

Fig. 2.2 Room setup for endoscopic submucosal dissection in the operating room

chromoendoscopy can be used to identify the surface pits of the lesion which correlates with the invasion risk [13, 14].

Localization of the polyp is essential for determining the injection technique. The shape of the lesion is equally imperative for the method of injection and amount of the injected material. The endoscopist must ensure that the injection material is distributed evenly in the submucosa to form adequate planes and facilitate safe dissection.

Injection of a durable material is vital to perform an effective excision with negative margins. The solution works as a submucosal cushion and creates a surgical plane for dissection. Adjusting the concentration of the injection material is crucial to permit visibility of blood vessels and to correctly identify the submucosal layer [6].

If the polyp is situated on a fold, primary injection site should be along the far aspect of the lesion to allow the polyp to fall forward into view [13]. If the submucosal injection is commenced first along the distal portion of the polyp (anal side), it can potentially fall backward, away from the view of the scope and make the procedure challenging.

The first step is advancing the injection needle into the mucosa when the assistant is injecting the solution. Instant swelling and elevation of the mucosa indicate access to the accurate dissection plane, the submucosal space. The injection needle can be repositioned to confirm entry into correct area. If the endoscopist observes an inadequate elevation in the presence of correct injection which is also known as the “non-lifting sign,” this may point to a high degree of fibrosis or submucosally invasive disease. These lesions may not be suitable for ESD and should be re-evaluated for surgical resection [9] (Video 2.1).

A variety of injectable solutions are available for use in ESD. In regular practice, the injectate can contain glycerol, hyaluronic acid, and sterile saline, and it should be effective and inexpensive [9, 13]. Normal saline disperses quickly and is reported to stay for 1–10 min [15, 16]. Solutions used and investigated for efficiency in ESD include glycerol, dextrose, and hydroxypropyl methylcellulose (hypromellose). Hypromellose can be preferred as an inexpensive alternative when diluted 6–8 times with sterile saline [9, 17]. A dye, most commonly methylene blue or indigo carmine, is generally used to demonstrate the lifted mucosa.

Recurrent injections increase the total duration of the procedure and hence increase the duration of anesthesia for the patient. Therefore, there is ongoing research to develop the ideal solution with minimal complications and maximum duration of stay that would decrease the needed repeat injections. A recent randomized controlled trial in an animal model compared 0.4% hyaluronic acid, 6% hydroxyethyl starch (HES), hydroxypropyl methylcellulose and Eleview®, reported Eleview®, and 6% HES as the solutions with the greatest performance in terms of speed and ease of procedure for ESD [17].

Currently, Eleview® is the single ready-to-use solution for submucosal injection approved by the Food and Drug Administration in the United States. It is a premixed solution that contains saline, methylene blue, and colloid agents. In a randomized controlled trial, it was compared with normal saline for endoscopic mucosal resection and was found to be safe and feasible with comparable complication rates [18]. It was reported to last up to 45 min with lifting up to 15 mm.

Circumferential Incision and Submucosal Dissection

The next step after achieving a cushion with the injectate is incising around the lesion prior to proceeding with deeper dissection and if necessary ultimately snare resection. Borders of the lesion can be delineated prior to incision. Following the incision of the initial half, submucosal dissection is fashioned and deepened as necessary. This step is repeated until the lesion is completely dissected from the underlying submucosa.

For this step of the procedure, multiple endoscopic knives are available for use in ESD [7, 9]. The DualKnife™ (Olympus America Inc., Center Valley, PA), HookKnife™ (Olympus America Inc., Center Valley, PA), and the HybridKnife® (ERBE, Tübingen, Germany) can be used for this step of the procedure [9, 19]. The HybridKnife® can facilitate injection of solution and dissection in a single instrument. It can be beneficial as both injection and dissection instrument is introduced through the same channel which is useful for maintaining the location and refraining from unnecessary withdrawal of the scope and instrument change [19].

The HookKnife™ was suggested as the safest instrument for dissection in ESD; however, a recent study with over a thousand patients reported there was no difference between the dissection knives in terms of safety and post-procedural complications [6, 20]. A recent development is the water-jet system that uses pressured saline injection for dissection. Decreased dissection time with reduced perforation rates in animal models was reported when the procedure was performed by an experienced endoscopist [19]. Determining the instrument for dissection depends on its cost and availability and familiarity of the endoscopist with the instrument.

Retraction Methods

During the dissection step, once a half of the circumference is incised, submucosal dissection proceeds in this half of the lesion. Conventionally, submucosal dissection continues along the borders of the lesion until sufficient dissection reveals the submucosa and complete dissection is achieved.

Performing ESD is more challenging in the colon, especially due to peristalsis, angulation, and lack of stable operative exposure. These difficulties resulted in development of various techniques to stabilize and retract the procedure area and improve exposure [21]. Decrease in mean procedural time of 15 min was reported by Yamada et al. by using clip and snare technique [22].

Current improvements in technology allow the lumen to be stabilized using balloon inflation over the scope. A balloon overtube can be used for standard ESD when paradoxical movements make dissection challenging. After reaching the lesion, the balloon overtube can be fixed with the balloon attached to the distal end.

Another advantage of this method is balloon-assisted retraction (Video 2.2). After the initial half of the lesion is incised and submucosa is appreciated, an endoclip can be applied to the side of the lesion and to the balloon. This method provides a stable environment for the endoscopist and retraction with continuous exposure of the submucosal layer.

Excision and Clip Application

When the dissection is completed, the seperation of the lesion from the underlying layers should be achieved. En bloc resection is the key step that is crucial for successful endoscopic submucosal dissection. It is ideal to achieve an en bloc resection; however, when the lesion is not suitable for en bloc removal due to a difficult location or other factors, snaring could be done piecemeal by performing hybrid EMR-ESD [9].

After excising the lesion, the submucosal defects can be observed which can occur due to thermal injury or minimal trauma [13]. Surgical intervention should be preferred for large defects, yet smaller defects can be suitable for closure with endoclips or over-the-scope clips (Video 2.3) [13, 23]. Over-the-scope clips were reported to have a success rate of 100% for prophylaxis of perforations and 90% for the treatment of acute perforation [24]. Clips can remain in place up to 6 months, and no side effects have been described due to clips (Videos 2.3 and 2.4).

Special Considerations and Complications

When performing ESD, studies show that complication risk decreases as the number of procedures performed increases. Overall complication rate was reported to be higher in institutions with lowest total number of cases, and complication risk was independently higher for tumors larger than 50 mm [20]. Most common complications after ESD are perforation and bleeding. These complications can occur during the procedure or later in the post-procedural period. A recent study from our institution published the US experience with ESD on 110 patients. A successful endoscopic resection rate of 88% with 9% of patients having invasive cancer on final pathology were reported. Perforation and delayed bleeding rates were 2.7% and 3.6%, respectively [25].

Perforation

Due to the relatively thin wall of the colon with scarce muscular layers, it is probable to come across a perforation. It is challenging to manage a perforation in the colon due to the risk of fecal residue leakage and peritonitis [6]. It is diagnosed based on symptoms of abdominal pain, fever, and an inflammatory response. Immediate and delayed perforation rates were reported as 4.2% and 0.22% in a recent meta-analysis [5]. In cases with suspicion of delayed perforation, advanced imaging with CT should be performed if feasible. Due to high risk of peritonitis, surgical treatment may be necessary.

Bleeding

Management of bleeding is determined by the amount of bleeding and the time interval. Bleeding during the procedure can be managed with hemoclips, soft coagulation with snare tip, or coagulation forceps. Delayed bleeding after ESD may require exploratory operation and subsequent resections. A meta-analysis reported immediate and delayed major bleeding rates as 0.75% and 2.1% [5]. Complaints of pain can be common after ESD. Unremitting pain may warrant advanced radiologic assessment, especially if accompanying symptoms are present.

The Elderly Patient

ESD also allows lesion removal in patients who are not suitable to undergo oncological resection due to general condition, age, or any other factors. Especially in older populations, it may be of value. Application of ESD in elderly population has raised a concern, however a study reported similar outcomes between the older group and younger group patients with a cutoff age of 65 years. Outcomes of the procedure and complication rates were found to be similar, proposing a safe and feasible application of ESD in elderly patients [26].

Learning Curve

Success of ESD depends largely on the experience and skill set of the endoscopist. Previous training and experience in performing colonoscopy is of high significance. Endoscopists are recommended to start performing ESD on smaller lesions and are advised to proceed to larger lesions as they gain experience [20].

Recently, learning curve for ESD was evaluated using porcine models, and when endoscopists with experience on gastric ESD are to perform colonic ESD, at least nine ex vivo procedures are suggested before practicing this procedure on live animals or proctored clinical ESDs [27].

Cost and Quality of Life

In addition to technical and clinical benefits, ESD was found to be advantageous in terms of costs. A recent case-matched analysis from our institution investigating the cost of ESD matched 48 patients undergoing ESD with 48 undergoing laparoscopic resection. The cost of ESD was found to be 64% of that of laparoscopic resection for left-sided lesions and 59% of laparoscopic resection for right-sided lesions. Differences of cost were noted in surgical services and supplies in the operating room. When all lesions were compared, ESD was 60% of the cost of laparoscopic resections. Submucosal dissection was reported to be less costly in terms of ancillary resource areas and anesthesia. When both groups were evaluated for complications, they were found to be comparable [12]. Validation of these results with further research may help widespread acceptance of this technique in the United States.

Quality of life of patients undergoing ESD was also compared with laparoscopic-assisted colectomies in a study. Patients undergoing ESD had higher quality of life scores on the postoperative day 1 and also 2 weeks after the operation. Patients undergoing ESD can easily start ambulating after the procedures and preserve their organ function [28].

Summary

Key Points

- Endoscopic submucosal dissection (ESD) is an advanced endoscopic resection method that can be used to prevent overtreatment with oncological organ resection and achieve complete “en bloc” resection of difficult non-malignant lesions.
- Localization of the polyp is essential for determining the injection technique. The shape of the lesion is equally imperative for the method of injection and amount of the injected material.
- The endoscopist must ensure that the injection material is distributed evenly in the submucosa to form adequate planes and facilitate safe dissection.
- Dissection should be performed in the newly formed plane, and retraction methods can be used when available.
- After snaring and removing the lesion, any immediate bleeding should be coagulated, and perforations should be sealed with endoclips.
- Patients are recommended to undergo a follow-up colonoscopy at 6 months.

Endoscopic submucosal dissection is a newly developed technique that is not yet accepted as a standard of care. Its application on superficial neoplasms in the gastrointestinal tract has shown promising results. It has the potential to revolutionize the treatment of superficial lesions that are difficult to remove with conventional snaring techniques. Increased experience and practice will lead to standardization, and this is expected to result in lower complication rates.

ESD is a favorable technique with satisfying results when performed by experienced endoscopists for the correct indications. In order to accept this method as a standard of care in the United States, centers should be established that offer this technique and extensive education about this technique, and correlation of surface morphology and submucosal invasion risk of lesions should be described. There is ongoing research to explain these topics in detail, and ESD may become more widespread in the United States as research continues.

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3 Fluorescence in Colorectal Surgery

António S. Soares and Manish Chand

Fluorophores

Optical and haptic cues have been the main tools used by surgeons to assess disease intraoperatively since the advent of modern surgery. Fluorescence-guided surgery is an evolution of intraoperative assessment of patient anatomy and physiology. This technology has the potential to radically change current practice and enhance precision surgery [1–3]. A fluorophore is a substance that emits energy as fluorescence after being excited by light at a specific wavelength [4]. This enables detection of the distribution of the fluorophore not only if the tissue is isolated but also through variable thickness of overlying tissues, ranging from 5 to 10 mm [5–7]. By allowing a better anatomical resolution, fluorescence-guided surgery enhances the surgeon's ability to discriminate different tissues. The optimal wavelengths for intraoperative use are the near infrared spectra (650–900 nm). Wavelengths shorter than this interval lead to natural haemoglobin fluorescence and therefore make detection of other fluorophores difficult. For wavelengths above 900 nm, it is the water's fluorescence that represents an obstacle. There are several different clinically approved fluorophores available in the market [8]. Each one has a specific wavelength for excitation and for emitted fluorescence to which the devices must be adapted or be adaptable.

Indocyanine Green

Indocyanine green (ICG) is the most commonly used fluorophore in clinical practice. It is a heptamethine cyanine fluorophore and has a peak excitation wavelength of 807 nm and a peak emission wavelength of 822 nm. It is a hydrophobic molecule, and therefore, after intravenous injection, it binds to albumin and is confined to the intravascular space. This characteristic makes this an ideal fluorophore for perfusion assessment through fluorescence angiography [8]. Its half-life in plasma is around 3–5 min and is eliminated via hepatic excretion. This pharmacokinetic profile allied to rapid distribution makes ICG ideal for repeated intraoperative administrations. The hepatic excretion allows hepatic lesion identification. Tumours have a disorganised capillary network that enables the so-called enhanced permeability and retention effect (EPR). This is caused by preferential leakage of intravascular contents in the areas of neoplastic tissue [9]. This effect can be used to non-specifically detect cancers such as ovarian cancer and metastases, pancreatic cancer or peritoneal metastases. ICG has historically been used in clinical practice for ophthalmologic angiography, cardiac output measurement and functional liver assessment with a great safety and very favourable adverse effect profile [10, 11]. Care must however be exercised in patients allergic to iodine or iodine-based contrasts, as the commercially available formulations contain a small percentage of sodium iodide.

Methylene Blue

Methylene blue is widely used as an antidote for methemoglobinemia and in conjunction with a radiotracer to localise sentinel lymph nodes in breast cancer and melanoma. Its use as a fluorophore is growing as it exhibits favourable photophysical properties with an excitation wavelength of approximately 668 nm and an emission wavelength of approximately 688 nm [8]. Care must be exercised in its administration in patients with G6PD deficiency as it may precipitate a haemolytic reaction and in patients on antidepressants, as it has dangerous interactions [12].

A. S. Soares · M. Chand (✉)
Division of Surgery and Interventional Sciences, University College Hospital, London, UK
e-mail: antonio.soares.17@ucl.ac.uk; m.chand@ucl.ac.uk

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Equipment

The use of fluorescence requires the use of a fluorophore, a light emitter and a receptor. Specific characteristics of fluorescence detection devices also vary, and it is important to be acquainted with their specifications [7]. It is important to ensure that the wavelengths for the excitation and emission of the fluorophores used are encompassed by these devices. The display for visualisation can comprise visible light image as the standard; a near infrared image and an overlay of both images to provide real-time visualisation of fluorescence (Fig. 3.1).

This technique of intraoperative fluorescence can be used without posing additional constraints to the theatre workflow as the additional steps required have a short duration and make use of the equipment employed for minimally invasive surgery.

Applications

Perfusion Assessment with Fluorescence Angiography

Anastomotic leaks (AL) are one of the most challenging complications in colorectal surgery associated with significant morbidity and even mortality. They have been associated with increased incidence of cancer recurrence and reduced long-term survival [13]. AL are associated with longer lengths of stay and increased intensive care unit admission, incurring additional annual costs of £1.1–35 million in the United Kingdom alone [14]. The additional cost per patient with AL is between £3372 to £10,901 (approximately 4777–15,443 USD). Despite advances in perioperative care and surgical technique, the risk of anastomotic leak is still up to 19% in colorectal anastomosis [15]. For anterior resection of the rectum, the perfusion of the left colon and anastomosis is most commonly reliant on the marginal artery. Inadequate bowel perfusion is widely regarded as the most common contributing factor for AL through ischaemia [16–18], possibly caused by a failure in normal tissue regeneration. Traditional assessment of colonic extremity perfusion is performed through a combination of the detection of palpable pulses in the mesentery, absence of bowel discolouration, and pulsatile bleeding from the cut ends of the anastomosis. Using an intravenous injection of ICG is a more objective method of perfusion assessment and may be used at different timepoints during bowel transection and subsequent anastomosis, e.g., following inferior mesenteric artery ligation and/or following anastomotic construction. Fluorescence emission occurs only in the perfused bowel, whereas a notorious absence of fluorescence is present in non-perfused areas of the colon.

Utilisation of fluorescence angiography (FA) with a minimally invasive (laparoscopic or robotic) approach can result in a change in management, mostly leading to a more proxi-

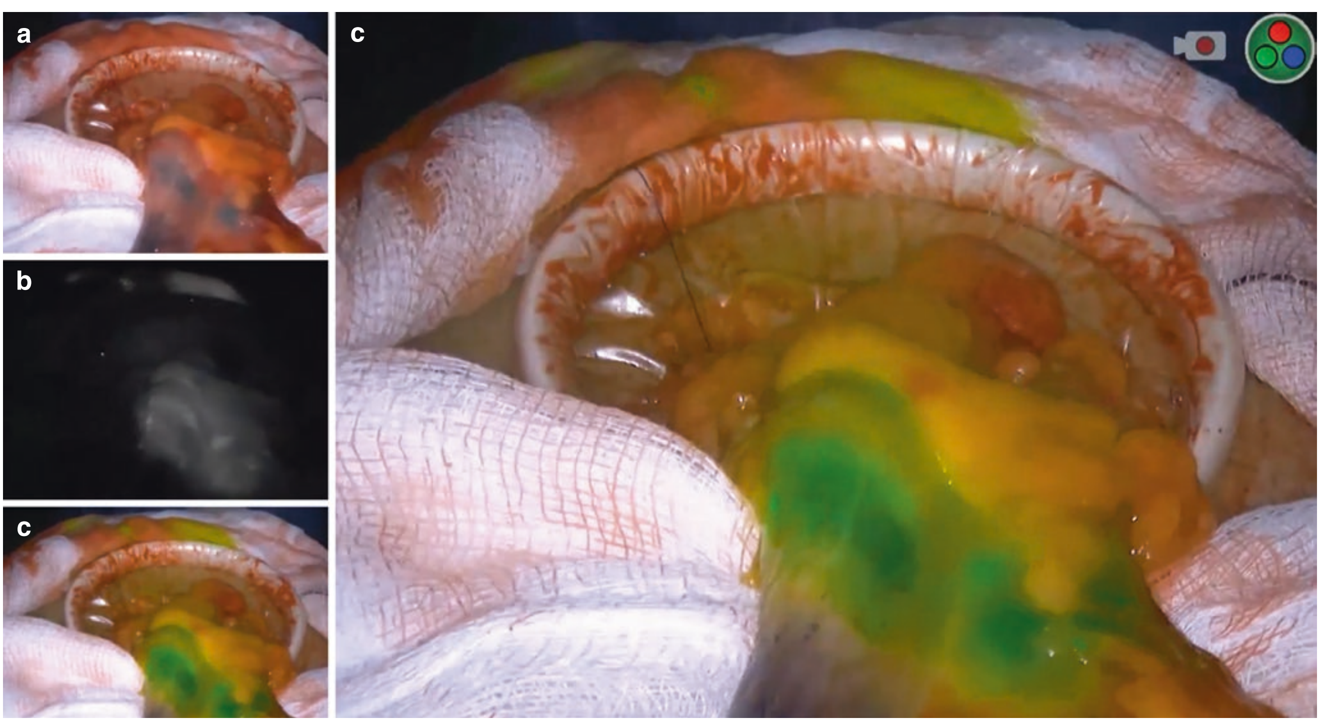

Fig. 3.1 Intraoperative image display with (**a**) normal vision, (**b**) NIR mode and (**c**) overlay mode

mal transection of the colon [19–24]. The percentages of cases in which change occurred vary between studies but are situated between 3.7% and 28%.

Ris and colleagues [24] have demonstrated high levels of success rate for fluorescence angiography after right hemicolectomy, left hemicolectomy and anterior resection, with a median added time of 5 min per case. In this group of 30 patients, no leaks occurred.

In the PILLAR II trial [19], 147 patients submitted to left hemicolectomy or anterior resection for benign and neoplastic causes underwent fluorescence angiography, with 99% technical success rate. This included two assessments: before transection of the proximal part of the colon and after the colorectal anastomosis. In this study, surgical decision of the point of transection was altered in 7%. The overall leak rate in this study was 1.4%, and no leaks occurred in the group where surgical decision was changed.

Recently a phase II study has assessed the impact of fluorescence angiography in elective colorectal surgery in 504 patients [25]. This study included patients from three European centres, submitted not only to left hemicolectomy and anterior resections but also to right hemicolectomies, either with an open or with a laparoscopic approach. Fluorescence angiography was employed before proximal colon transection and after the anastomosis, resulting in a median of 4 min additional operating time. This assessment changed the operative plan in 5.8% of cases. The leak rate was 2.4% overall, with 2.4% in right-sided resections, 2.3% in high anterior resection and 3.0% in low anterior resection. In patients where fluorescence angiography caused a change in operative plan, no leaks occurred. The authors compared these results to historical controls, showing a reduction in leak rate in left-sided resections (6.9–2.6%).

A recent meta-analysis examined the results from 1302 patients from five non-randomised studies [26]. The authors found a significantly lower odds ratio (OR 0.34; CI 0.16–0.74; $p = 0.006$) for leakage in colorectal surgery when fluorescence angiography was used. There was also a significantly lower leak rate in rectal cancer surgery (1.1 vs. 6.1%, $p < 0.05$) when fluorescence angiography was used. Data regarding the benefit of ICG fluorescence is accruing. However, at the moment there are no results from randomised trials on the effect of fluorescence angiography.

The PILLAR III trial was started in 2015 in the United States, aiming to assess anastomotic leak rate through a randomised design. However, it was terminated due to slow recruitment in May 2017 [27]. The IntAct (intraoperative fluorescence angiography to preve*nt* *A*nastomotic leak in re*ct*al cancer surgery) is a European trial on the use of fluorescence angiography in this context [28]. This trial will assess the clinical anastomotic leak rate at 90 days after anterior resection for rectal cancer. Both high and low anterior resections will be included. The protocol includes two assessments with fluorescence angiography: before proximal transection and after anastomosis. Participants will be randomised on a 1:1 basis to receive either surgery with or without fluorescence angiography.

The creation of a diverting ileostomy has a protective effect on colorectal anastomoses and has been shown to reduce the frequency and severity of an anastomotic leak, should it occur [15]. The use of fluorescence angiography may provide an important contribution to the decision to divert [29]. After perfusion assessment, the lower risk of leak may provide enough certainty to avoid diversion ileostomy [24]. This needs to be documented in larger studies.

Perfusion assessment with ICG in colorectal surgery has been more extensively studied in the context of left hemicolectomies and anterior resections of the rectum. However, the technique has expanded to other uses such as in transanal total mesorectal excision (TaTME) and pouch surgery in inflammatory bowel disease. In *TaTME* the general principles of FA apply as in anterior resections if the specimen is retrieved through an abdominal incision. However, as this technique is applied generally for low rectal tumours, the need for proximal colonic length is increased, and these anastomoses are of high risk. No prospective trial has assessed FA in this context; however, it is expected to provide similar benefits to more proximal colonic resections. After restorative proctocolectomy in ulcerative colitis, an ileal pouch is formed to act as a reservoir. The ileal pouch-anal anastomosis (*IPAA*) is a high-risk anastomosis. In this context, FA can be used to assess the pouch and the anastomosis to ensure adequate perfusion [30].

Box 3.1: Application in Theatre: Logistics of Perfusion Assessment with ICG

Clinical application of fluorescence requires a specific camera system with the ability to excite the fluorophore and then record the fluorescence using appropriate filters in the camera. ICG (0.1 mg/kg) is administered intravenously and has a distribution time of approximately 2–3 minutes. Approximately 10 mg (4 ml) is commonly injected per use and is detected within a minute in most cases. There are various modes of image acquisition from visible light, near infrared imaging and an overlay of both. The assessment is qualitative as there is no current standard to quantitate fluorescence intraoperatively. ICG is then excreted by the liver.

Sentinel Nodes and Lymphatic Mapping

The concept of sentinel node has been described by Gould in 1960 [31] and has been applied with success in very diverse settings. Current applications make use of a radiotracer and visual tracer in most cases. Peritumoral injection of ICG can be used to identify the lymphatic drainage of a tumour as the compound is drained through lymphatic channels when injected interstitially. This concept has been used in breast, [32] uterine and cervical [33] cancers. It has been shown to be a safe and feasible technique in small numbers of patients with colorectal cancer [34–36]. A recent review of 12 prospective studies including in total 248 patients [37] has documented a pooled sensitivity and specificity rates of 71% and 84.6%, respectively, for the detection of sentinel lymph nodes with ICG. The papers included in this meta-analysis were highly heterogeneous (I^2 96.5% for sensitivity and 98.7% for specificity). The clinical relevance of sentinel lymph node assessment in this context remains to be defined.

In colorectal cancer, the concept of lymphatic mapping seems attractive as it may be able to change surgical decision making about the lymphadenectomy by identifying drainage patterns specific to the tumour and thus allowing for a more precise and 'oncologically appropriate' mesenteric resection and perhaps reduce morbidity of unnecessary extensive resections. Feasibility of a standardised technique for lymphatic mapping has been published recently [38], noting a change in operative plan in 20% of patients to include fluorescent lymph nodes outside the standard resection field. These nodes were found to be positive on pathological assessment.

The approach to pelvic sidewall (PSW) nodes in rectal cancer is still a matter of some controversy, with notoriously different practices in the East, where systematic lymphadenectomy is performed [39], and the West, where it is done selectively. Concerns have been raised on the benefit of systematic lymphadenectomy given the associated morbidity [40]. ICG may help in selection of patients for pelvic lymphadenectomy [41, 42]. This has been shown to be feasible by Kazanowski and colleagues [42], who identified PSW nodes in all of the five patients undergoing abdominoperineal resection after neoadjuvant chemoradiotherapy where this technique was applied. No patient in this group had lymph node metastasis on pathological examination of the identified nodes. Noura and colleagues [41] injected ICG around low rectal cancers in 25 patients and identified PSW sentinel nodes in 92% of them. Of these, three were positive for metastasis, based on rapid intraoperative haematoxylin-eosin staining, and led to PSW node dissection with one specimen (33%) revealing metastasis. If the PSW sentinel nodes can be identified with greater accuracy intraoperatively, this may improve the ability to select patients for PSW node dissection. Patients with less likelihood of benefit would thus be spared of the morbidity associated with this technique. The use of fluorescence for PSW identification is still an experimental technique and requires further investigation.

Urinary Tract Identification

The left ureter is often seen as a landmark in left colon and rectal surgery; identification and preservation of this important structure is often a prescribed step of the procedure. On occasion the ureter can be difficult to locate, particularly if involved in an inflammatory process where the anatomy can be distorted, leaving it vulnerable to iatrogenic injury. Ureteric damage is associated with significant morbidity [43, 44] and cost to the patient, possibly leading to litigation [45]. Preventative strategies include positive identification of the ureters during dissection and preoperative stenting. The latter is associated with a certain degree of morbidity [46].

Methylene blue can be used for intraoperative identification of the ureters after intravenous administration. This has been shown to be feasible by Yeung and colleagues [47], who identified successfully 10 out of 11 ureters examined. Maximal fluorescence was detected after a mean of 14.4 min (range 9–20) after intravenous injection. A case series has been described where methylene blue was assessed for ureter identification in 40 patients [47]. Sixty-nine ureters were assessed, with ten nonrelevant ureters (six left ureters in right-sided colectomies, four right ureters in left-sided colectomies) and one relevant ureter (right ureter in subtotal colectomy) not assessed. In this study 93% of ureters assessed were visible with methylene blue fluorescence, and approximately 22% of these were not identified under white light. Indocyanine has also been used for ureter identification [48]. No comparison between both fluorophores has been conducted to the current date. The use of the transanal approach to rectal pathology has gained recent popularity [49], and urethral injury is a known procedure-related complication. This has provided the impetus to develop new ways to identify this structure using fluorescence. The use of ICG [50] and IRDye800BK [51] has been described for urethral identification through direct urethral injection in a suspension solution. This was performed in cadaveric specimens and remains to be confirmed in live human studies.

Peritoneal Carcinomatosis

Cytoreductive surgery combined with hyperthermic intraperitoneal chemotherapy (HIPEC) is indicated in patients with limited peritoneal metastatic disease. Completeness of resection is an important prognostic factor. However, preoperative imaging (both morphological and functional) has significant limitations in the assessment of peritoneal metastatic disease, with the detection being mostly done by the surgeon intraoperatively [52]. In a sample with 17 patients, ICG injection has been shown to identify peritoneal metastasis with 89% sensitivity [53]. In this study, surgical decision was changed in 29% of cases by detection of additional metastatic disease not previously identified. ICG deposition in peritoneal metastasis is thought to occur via the 'enhanced permeability and retention' effect [40]. Although further documentation of clinical effectiveness is necessary, this seems a very promising area for fluorescence-guided surgery.

Limitations and Future Directions

Currently there is no method to clinically quantify fluorescence in colorectal surgery. Therefore, there is a non-avoidable element of discretion in this assessment. This limitation should be addressed in future studies.

The high spatial resolution of fluorophores is balanced by low tissue penetration. Therefore, the combination of imaging techniques that provide higher tissue penetration with fluorophores seems promising in achieving good results when compared with each technique in isolation. Some combinations have been proposed [7], but there is still no consensus.

The concept of targeted fluorophores has drawn increasing attention. In the present context, difficulties are posed in two different areas: technical and regulatory. Technically, creating a targeted fluorophore with adequate in vivo performance characteristics still remains a challenging objective [8, 54]. There are several mechanisms that could be employed to achieve the goal of targeting a specific marker, and there is no consensus in the use of one over another. There is also no consensus in approval pathways from regulatory agencies in Europe and the United States [55], which has elicited a response from an expert group [56]. Hopefully, the increasing experience with targeted fluorophores will enable their entry into clinical routine with an adequate body of knowledge to document patient benefit.

Conclusions

Surgical technique evolves from the needs of frontline surgeons in devising new ways to improve their therapeutic intervention. This is the case with fluorescence-guided surgery, where its scope is growing with new indications being explored in very diverse settings. This field holds the promise to improve patient outcomes in surgery, but more evidence is necessary. Therefore, continued work and further refinement of the technique are required.

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History and Future of Robotic Colorectal Surgery

4

Joshua MacDavid and Garrett Friedman

Introduction

Medical innovation has always been a curiosity of our society. Two hundred and eleven years ago, Philipp Bozzini (1773–1809) began the era of modern endoscopy with his invention of the *Lichtleiter*, a 35-cm-tall device that housed a series of mirrors that reflected candlelight for looking into the bladder and rectum [1]. It took seven more decades before Max Nitze (1848–1906), a German urologist, developed a clinically usable cystoscope that was eventually used as the first laparoscope [2]. It took another 80 years until the first laparoscopic appendectomy was performed in 1980 [3]. The first prototype robots were created in the mid-1990s and have not achieved widespread usage until this past decade. Currently we are in the robotic era of minimally invasive surgery, which has gone from concepts resembling those in science fiction novels to reality at seemingly increasing rates. This chapter outlines a brief history of minimally invasive surgery with special emphasis on laparoscopic and robotic innovations, along with the current and up and coming robotic platforms.

Laparoscopy

Around the turn of the twentieth century was when laparoscopy was used to visualize intra-abdominal contents, adopting instruments similar to those in endoscopy. In 1901, George Kelling (1866–1945), a German surgeon, used Nitze's cystoscope to examine the intra-abdominal contents in dogs. He created pneumoperitoneum, or what he termed "Lufttamponade" (air tamponade), to alleviate intra-abdominal bleeding. The Swedish internist, Hans Christian Jacobaeus (1879–1937), was credited with performing the first laparoscopic intervention in humans in 1910 where he created pneumoperitoneum and evacuated ascites [4]. This technology made its way to the United States in 1911, by Bertram Bernheim. Further advances in laparoscopy were made by Heinz Kalk, a German gastroenterologist who developed the first forward viewing scope in 1929 and described several new techniques, including liver biopsy. In 1933, the first laparoscopic lysis of adhesions using electrocautery was performed by gynecologist Karl Fervers [2]. From the mid-1950s until the mid-1970s, laparoscopy was widely rejected by the scientific community and was even banned in Germany from 1956 to 1961 [5]. Concerns were raised from the increased risk of pregnancy with tubal ligation performed laparoscopically and the increased incidence of bowel injuries [2].

In 1980, the first laparoscopic appendectomy was performed by Kurt Semm (1927–2003), a German gynecologist. Dr. Semm is often referred to as the father of modern laparoscopy, given the multiple laparoscopic techniques and devices he was involved with creating including the suction irrigator, auto insufflation, and intracorporeal knot-tying devices [3, 6]. Jacobs et al. reported the first laparoscopic colon resections. In their cohort of 20 patients, 9 patients underwent a right hemicolectomy, 8 underwent a sigmoid colectomy, and the other 3 patients underwent either a low anterior resection, Hartmann's procedure, or an abdominoperineal resection. Though their study was not a controlled trial, it made it apparent that laparoscopic colon surgery was possible and could be achieved in a safe manner [7] (Table 4.1).

Robotic

Though laparoscopic surgery has been proven to result in shorter lengths of stay, earlier return of bowel function, and less postoperative pain, it is not without its limitations [14].

J. MacDavid (✉)
Department of Surgery, UNLV School of Medicine,
Las Vegas, NV, USA
e-mail: joshua.macdavid@unlv.edu

G. Friedman
University of Nevada Las Vegas, Las Vegas, NV, USA

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Table 4.1 Timeline

Year	Technology	Author/Company
1868	Esophagoscopy	Bevan [1]
1877	First usable cystoscope	Nitze [1]
1882	First cholecystectomy	Langenbach [1]
1895	Rectoscope	Kelly [1]
1901	"Celioscopy" in dog, using Nitze's cystoscope	Kelling [2]
1910	First laparoscopy in human	Jacobaeus [4]
1911	First laparoscopic procedure in the United States	Bernheim [8]
1932	Flexible gastroscope	Schindler [1]
1980	First laparoscopic appendectomy	Semm [3]
1983	TEM	Buess et al. [9]
1985	First laparoscopic cholecystectomy	Muhe [10]
1991	First laparoscopic colectomy	Jacobs; Fowler et al. [11]
1994	First prototype robot – ARTEMIS	Research Center Karlsruhe [12]
1995	Intuitive Surgical founded	
1999	da Vinci© 1st generation	Intuitive Surgical
2002	First robotic colectomy	Weber et al. [11]
2009	da Vinci© Si	Intuitive Surgical
2010	TAMIS	Atallah et al. [13]
2014	da Vinci© Xi	Intuitive Surgical
2015	Flex© robotic system	Medrobotics® Corporation
2017	Senhance™ robotic surgical platform	TransEnterix Surgical, Inc.
2018	da Vinci© SP	Intuitive Surgical
2018	DiLumen C2™	Lumendi, Ltd.

The 2D plane, rigidness of instruments, and only four to six degrees of freedom make certain dissections technically very difficult, if not impossible.

Robotic surgery first emerged in the early 1990s to address the challenges that arose with laparoscopy. The very first surgical robot, a master-slave manipulator was first presented by the Research Center at Karlsruhe in 1994; it was named ARTEMIS (Advanced Robotic and TElemanipulator System for Minimally Invasive Surgery). The surgeon performed "tele-surgery," by sitting at a console controlling two laparoscopic instruments. ARTEMIS, however, was developed only as a prototype device and never progressed to clinical use. Shortly thereafter, other robotic-assisted technologies were developed, such as the TISKA™ Endoarm, also produced by the Research Center at Karlsruhe, and the AESOP 3000™ system by Computer Motion, Inc. Despite promising technology many of these devices either never made it past animal experimentation or never received widespread adoption from the surgical community [15].

Current robotic technology offers numerous advantages over traditional laparoscopic. The 3D white light imaging restores depth perception and greatly enhances visualization. The "7 degrees of freedom" and 90-degree articulation mimic human anatomy allowing the surgeon real-life ergonomic control. These innovations allow for a more precise and superior dissection. This is particularly important with the dissection of the rectum and prostate given the proximity to major autonomic centers [16].

The debate is now between whether robotic surgery is superior to traditional laparoscopic.

In their study of 113 patients, Baik et al. provided evidence for the superiority of the robotic low anterior resection over laparoscopic low anterior resection, with robotic resections achieving a significantly better mesorectal grade [17]. Additionally, the overall complication rate was nearly double in the laparoscopic group when compared to the robotic group, 19.3% vs. 10.7%, respectively. Given the technical challenge of laparoscopic rectal dissections, six of the patients in the laparoscopic group required conversion to open secondary to rectal perforation, hemorrhage from lateral pelvic wall, or severely compromised visualization from an anatomically narrow pelvis. Operative times were not significantly different between the two groups. In a similar study, Bedrili et al. showed the quality of TME specimens was superior in patients undergoing robotic resections [14].

Current FDA-Approved Platforms

In the remaining paragraphs, we provide a brief outline of the current FDA-approved platforms. These include the da Vinci® Si, Xi, X, and SP by Intuitive Surgical, Senhance™ by TransEnterix Surgical, Inc., Flex® by Medrobotics® Corporation, and the DiLumen C2™ by Lumendi, Ltd.

da Vinci® by Intuitive Surgical

The first-generation da Vinci® robot featured 3D vision and their patented EndoWrist® technology with "7 degrees of freedom" and 90-degree articulation, mimicking human anatomy. Seven years later Intuitive Surgical released the da Vinci® S, which featured upgraded 720p high-definition camera with added reach and mobility. Several new features became available in 2009, when the da Vinci® Si was released, including a dual console for training purposes, Firefly® fluorescent imaging, and other procedure-specific instrumentations, along with an upgraded 1080i camera [18].

da Vinci® Xi

This is the fourth-generation console produced by Intuitive Surgical and released in 2014. They continued to improve visualization with a 1080 p camera and easier robotic arm to trocar docking. Most importantly the design of the robotic arms allowed access to all abdominal quadrants without the need for redocking. Trocar placement was simplified with overall decreased instrument and arm clashing. The addition of a new operating room table allowed repositioning of the patient, while robotic arms are docked and all movements are coordinated.

da Vinci® X

Released in 2017, this is a smaller version of the Xi made for single quadrant applications. It does not have integrated table motion technology described above.

da Vinci® SP

At the time of this writing, this is the latest console that was released by Intuitive Surgical. This is a single-port system, consisting of a single 2.5 cm cannula with three fully elbowed EndoWrist™ instruments and a fully articulating 3D HD endoscope (Fig. 4.1). Other technology includes both a 360-degree boom with 360-degree instrument rotation [19]. The da Vinci® SP has been approved for urologic procedures; however it has been utilized in transanal cadaveric models by Marks and Mak with success [20].

Fig. 4.1 da Vinci® SP. The safety and effectiveness of this device for use in the performance of general laparoscopic surgery procedures have not been established. This device is only intended to be used for single-port urological procedures with the da Vinci EndoWrist SP Instruments and the da Vinci SP Surgical System (SP1098). (©2018 Intuitive Surgical Inc)

Senhance™ by TransEnterix Surgical, Inc.

The Senhance surgical robotic system by TransEnterix Surgical, Inc., consists of a surgeon console and four patient "carts," each containing a single robotic arm (Fig. 4.2). Unlike Intuitive's EndoWrist™, the robotic arms are controlled in a manner similar to laparoscopy. TransEnterix refers to this as digital laparoscopy, whereby the surgeon resides at a console not attached to the working arms. The robot gives more stability than what would be afforded by traditional laparoscopic equipment. They have integrated haptic feedback and eye-sensing camera control. TransEnterix Surgical, Inc., has recently filed 510 K form submission for 3 mm instruments [21].

Flex® by Medrobotics® Corporation

The Flex robotic system, made commercially available in 2017, was the first system to utilize a flexible robotic camera, allowing a nonlinear course to be taken to the desired operative field. The console is located at the patient's bedside with the surgeon. The robotic scope has two separate mechanisms.

Fig. 4.2 Senhance™ © 2018 TransEnterix, Inc

Fig. 4.3 Flex® robotic system. (Image courtesy of Medrobotics® Corporation)

The outer mechanism is controlled by the surgeon using a joystick, and the inner mechanism follows (Fig. 4.3) shortly after. Initially developed for transoral usage, the FDA-approved indications have expanded to include transanal applications. We have found this system to be particularly useful for lesions in the upper rectum and into the distal sigmoid. The reach of the Flex® robotic system is 17 cm proximal to the anal verge; however depending on the patient and the location of the lesion, it can be up to 23 cm. Given that this is a novel system, randomized controlled trials comparing the Flex® to TAMIS systems have not been performed. Paull et al. has described a transanal excision of a rectal gastrointestinal stromal tumor [22]. Our experience with the Flex® robotic system has allowed us to perform a dually robotic transanal total mesorectal excision, in combination with the da Vinci® Xi. Currently, it is marketed as an endoluminal platform; however applications are expanding rapidly [23].

DiLumen C²™ by Lumendi, Ltd.

Although the Lumendi DiLumen C2™ (Fig. 4.4) is not a stand-alone robotic platform, we believe that it deserves mention here. It is marketed as an endoluminal interventional platform. It is an endoscopic accessory consisting of a dual balloon sheath and two accessory channels that house flexible articulating instruments. These instruments are controlled by the operator in a manner similar to that of traditional laparoscopic; however the articulating elbow allows for enhanced retraction and dissection. Currently available instruments include endoscopic graspers and endoscopic scissors that are capable of applying monopolar energy. The dual balloon technology allows for a "therapeutic zone" to be established, whereby the balloons are inflated in succession, thus straightening out and stabilizing the colonic segment upon which the intervention is being performed on. The instruments can then be deployed to complete an endoscopic submucosal dissection with improved precision and ease. The DiLumen C2™ received FDA clearance in May of 2018 [24].

Fig. 4.4 DiLumen C²™ by Lumendi, Ltd (Reprinted with permission from Lumendi LLC)

Platforms Pending FDA Clearance

Included platforms are the Verb Surgical robot, Versius by CMR Surgical, Ltd. (Fig. 4.5), Virtual Incision surgical robot by Virtual Incision Corporation, SPORT by Titan Medical, Inc., and Dexter by Distalmotion. Table 4.2 provides an overview of some of the features.

Where Are We Headed?

Future Technology

Automatization, tissue recognition, MRI integration, and haptic feedback are some of the multitude of technologies that are currently being investigated. In 2016, Shademan et al. developed the Smart Tissue Autonomous Robot (STAR). Using near-infrared fluorescence with a 3D visual tracking system, this robot performed "automatic" in vivo and ex vivo anastomoses in porcine small bowel. The robotic

Fig. 4.5 Versius by CMR Surgical, Ltd. (Image reproduced with permission by CMR Surgical, Ltd)

performed anastomoses had higher leak pressures and more precise suture placement when compared to the human controls; however it took significantly longer to complete the anastomosis (50 minutes vs. 8 minutes) [25]. In addition to automatization, MRI integration has been tested by Porpiglie et al. during robotic prostatectomy. Virtual 3D models of the prostate were constructed from high-resolution MRI images and then integrated into current da Vinci® software. Though only an observational study with six surgeons, they rated the usefulness of the technology a nine out of ten on the Likert scale. Further studies are needed to determine whether this will turn out to be superior in regard to outcomes [17].

Summary

We have come a long way in the development of minimally invasive surgical techniques, and this technology is outpacing the ability for well-designed randomized controlled trials to validate its effects. Hopefully, this does not defer the surgical community away from seeking superior methods of performing surgery. We should all remember that laparoscopic surgery received widespread criticism and rejection, yet, through the perseverance of some, we have advanced to where we are now – in the midst of a robotic revolution.

Table 4.2 Robotic platforms pending FDA clearance [19, 21, 22]

Developer	Name	Features	Release date
Verb Surgical, Inc. (Johnson & Johnson/ Google)	TBD	No public disclosure	TBD
CMR Surgical, Ltd.	Versius	3D camera	TBD
		Portable	
		5.8 mm fully wristed articulating instruments	
		Sit or stand console	
		Smaller footprint	
		Mimics human arm	
Titan Medical, Inc.	SPORT	3D camera	TBD
		Single-port capabilities	
		Single-arm patient cart	
		Multiquadrant reach	
		Articulating instruments	
Virtual Incision Corporation	Virtual Incision	3D camera	TBD
		Single-port system only	
		Requires large incision	
		Small, weight less than 2 pounds	
		Multiquadrant reach	
		Disposable instrument heads	
		Can re-sterilize 10 times	
Distalmotion	Dexter	Two separate robotic arms	TBD
		Utilizing laparoscopic trocars	
		Utilizing laparoscopic arms	
		Sterile surgeon console	
		5 mm fully wristed articulating instruments	

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5 Teaching Robotic Colorectal Surgery

Amir Bastawrous

Introduction

Robotic surgery utilizes computer-aided instruments and platforms to facilitate minimally invasive surgery. The technology is new and advancing rapidly. Unfortunately, the skills needed to master robotic surgery do not directly transfer from the open or laparoscopic experience. Furthermore, the detachment of the surgeon from the operative field, lack of haptic feedback, limitations on visualization, and bulkiness of the machines require constant vigilance for safe maneuvering of instruments to prevent patient injury. As such, a careful, detailed and precise training program is necessary. A graded approach has shown to efficiently ramp up to mastery.

There is currently one dominant robotics platform in the form of the da Vinci Surgical System (Intuitive Surgical, Sunnyvale, CA). As of June 30, 2018, there were 4666 da Vinci systems installed around the world. And the cumulative growth has led to increasing total robotic experience and the proportion of cases performed on the systems. Between 2008 and 2013, there has been a decline of 39.4% of conventional laparoscopic case volume and a 250.0% increase in robotic-assisted procedures [1]. Robotic-assisted colorectal surgery has the advantage of learning from experience gained from robotic urology and gynecology as it trailed them in acceptance and prevalence. Despite initial skepticism and resistance, there has been an increase in the adoption of robotics into colorectal practice. The number of robotic colorectal operations has been increasing in the United States. In a study of the University HealthSystem Consortium (UHC) Clinical Database, between 2011 and 2015, there was a 158% increase in robotic colorectal surgery and an increase in the number of centers utilizing the technology for colorectal surgery [2].

A. Bastawrous (✉)
Swedish Medical Center, Swedish Colon and Rectal Clinic, Seattle, WA, USA
e-mail: Amir.Bastawrous@swedish.org

Several companies (Transenterix, Medrobotics, Verb, and others) have either recently entered or are nearing entry into the field of robotic surgery and have applications for colorectal surgery. While much of the guidelines for training detailed in this chapter can be applied to other systems, obviously, the details will differ by the platform. We will focus here on training for the da Vinci platform in this chapter, as it is most applicable to the greatest number of trainees and trainers.

While there are not consistent and enforceable regulations to robotic colorectal surgery training, there are guidelines published by the Food and Drug Administration (FDA), the manufacturer [3], and the professional societies [4]. The Association of Program Directors in Colon and Rectal Surgeons (APDCRS) has systematically developed and implemented a training curriculum since 2010 which has evolved to provide inclusive training to all colorectal fellows in the United States and Canada [5] (Fig. 5.1). Feedback from trainees who have completed the curriculum has been universally positive [6]. This is borne out in practice patterns. Young Surgeons Committee of the American Society of Colon and Rectal Surgeons surveyed their members and found that 92% of that group has incorporated robotics into their practice [7]. They also found that there was a preference for robotics for pelvic surgery, especially rectal cancer. A broader survey of contemporary graduates of colon and rectal training programs found that despite significant limitations, robotics was a part of the practice for a large proportion of surgeons, even if they were not formally trained during fellowship [5].

Training Overview

Training should include both technical capabilities of the workings of the robot as well as emergency procedures. The FDA mandates that the robotic manufacturers provide some of this training. A recent court case may highlight the role that inadequate preparation can have on patient outcomes [8,

O. Bardakcioglu (ed.), *Advanced Techniques in Minimally Invasive and Robotic Colorectal Surgery*,
https://doi.org/10.1007/978-3-030-15273-4_5

Fig. 5.1 Training curriculum APDCRS

APDCRS
Association of Program Directors for Colon and Rectal Surgery

APDCRS Robotic Colorectal Surgery Training Pathway

To be completed to qualify for the Advanced Course

1. *da Vinci* Technology Online Modules:
   - ○ Documented completion of the set of interactive online modules covering the basic design and operation of the da Vinci system on the Intuitive Surgical Community Site.
2. *da Vinci* Technology Overview In-Service and Skills Simulation:
   - ○ In-person overview of the system conducted at the hospital by an Intuitive CSR (clinical sales representative) and sign off by them
   - ○ Completion of Skills Simulator modules as defined by the APDCRS with a score of 90% (or completion of console skills drills for those without a simulator) and turn in results
     - ▪ Thread the Rings
     - ▪ Matchboard 1
     - ▪ Camera Targeting 1 and 2
     - ▪ Energy Switching 1
     - ▪ Suture Sponge 1
3. Participation in 3 surgeon-led webinars:
   a. Subjects may include, procedural tips/tricks, troubleshooting, complex cases, advanced technology use, career development
4. Enter all robotic cases into the case log system provided by the APDCRS.
5. Participation in 5 da Vinci Cases as console surgeon – entered into the APDCRS case log-by the Advanced Course Application deadline.
6. Participation in the Advanced Course
7. Participants completing the above requirements, 20 Console Cases and 10 Bedside cases may be eligible to earn a Training Certificate issued by Intuitive Surgical after a verifying letter by their program director. Case participation is defined as having completed over 50% of a case as a console surgeon or bedside assist as defined by the APDCRS Program Directors.

9]. It is in the best interests of the patient, the hospital, the surgeon, and the manufacturer to facilitate learning of the technology.

The three main components of robotic colorectal surgery training include learning:

- The operation
- The use of the equipment
- The techniques for optimization of the equipment for specific clinical situations or scenarios

The skills required for each of these facets are very different. Learning how to perform a right colectomy, rectopexy, abdominoperineal resection, or any colorectal procedure requires knowledge of anatomy, physiology, and oncologic principles. Whether the procedure is open, laparoscopic, or robotic, the tissue planes, necessary operative steps, and adherence to these principles are the same. The challenge comes when trying to teach (or learn) the operation while simultaneously teaching a new technology. As such, the general operative experience of the trainee greatly impacts the skill acquisition timeline. We will not further discuss the general operative training of surgeons but will focus on skills specific to robotics.

While the technical skills involved in laparoscopy are different from those required in robotic surgery, previous experience and training in laparoscopy helps in learning robotic surgery. There are steps in robotic surgery that require facility with laparoscopic techniques. These include abdominal entry, insufflation, recognizing tissue tension with instruments, unique dissection techniques not used in open surgery and port site closure. The prerequisite for laparoscopic skills attainment prior to robotic training is controversial. Some studies have shown that laparoscopic experience and training can improve performance in robotic surgery. Training on a fundamentals of laparoscopic surgery (FLS™) standard box trainer was shown to improve the learning of robotic skills in trainees with no prior robotic exposure and limited laparoscopic experience [10]. Some studies have found that prior experience in laparoscopic surgery was not essential to learning robotic surgery through a formal training program [11, 12]; however this study only compared two surgeons.

In the current generation of general surgery residency training in North America, laparoscopy is central to the training curriculum. It is rare for new trainees in robotic surgery to be without any laparoscopic experience. Basic laparoscopic skills such as learning spatial awareness in a three-dimensional field and distant tissue-handling are essential in laparoscopy. While robotic surgery eliminates the challenge of operating with a two-dimensional image, there is still a lack of haptic feedback, and therefore laparoscopic experience and visual feedback becomes important in overcoming this challenge [13].

Basic technical instruction in the use of the da Vinci platform can be done in the inanimate or nonhuman setting. But learning to optimize the robotic surgical technique requires a collection of modules that by necessity utilize cadaveric or live patient access.

Achieving these training goals requires a tailored curriculum or pathway for the different type of trainee. At each step a structured evaluation process to confirm attainment of competence is necessary before advancing to the next stage of training. We emphasize that the progression should be competency-based and not time-based [14]. Phase 1 (learning the equipment) of training is generally similar for any level of student. We will break down our description of Phase 2 (becoming proficient with the robotic platform for specific cases) of the training into resident, fellow, and postgraduate surgeon since there are substantial differences necessary to successfully complete this stage.

Most published curricula are similar. While the details and sequence may slightly vary, each involves successive advancement through dry lab exercises, video review, simulator exercises, bedside assisting, wet lab sessions with animal or cadaver models, and console training [14–19] (Fig. 5.2).

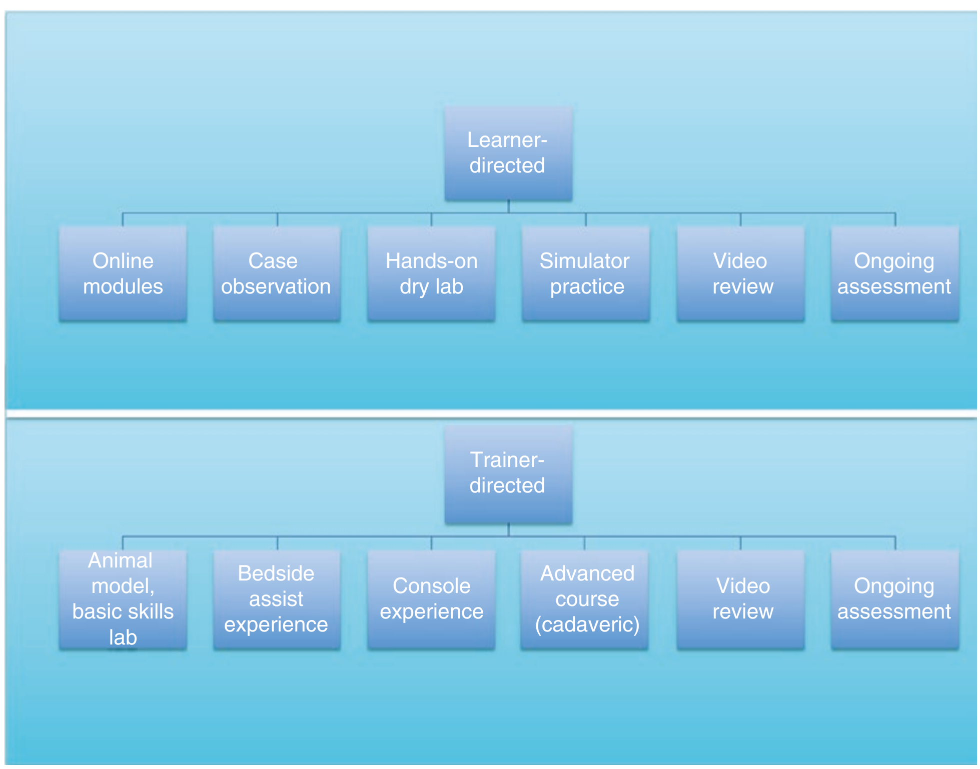


Fig. 5.2 Training components (after Winder 17)

Phase 1: Learning the Equipment and System Components

Step 1: Online Modules

The first step to learning the robotic platform is completion of the set of interactive online modules covering the basic design and operation of the da Vinci system on the Intuitive Surgical Community Site https://us.davincisurgerycommunity.com [3] (Fig. 5.3). The modules consist of a set of videos and assessment tools that cover an overview of the system, the console, the patient cart, the vision cart, and the electrosurgery. Each of these is further customized to the specific model and software version of the da Vinci system accessible to the trainee. Successful completion of the module and adequate scoring on the assessment tools are required. At conclusion, a certificate is generated. These modules are available for review or refresher as needed at any point in training or practice. Often times returning to these modules prior to accessing the system and again when using it on an animate or human subject reinforces the skills taught. The modules are most effective if the trainee uses them without preconceived expectations or hubris. While they may appear (and truly are) very basic, if used properly with an open mind, they will fill in gaps in the user knowledge base.

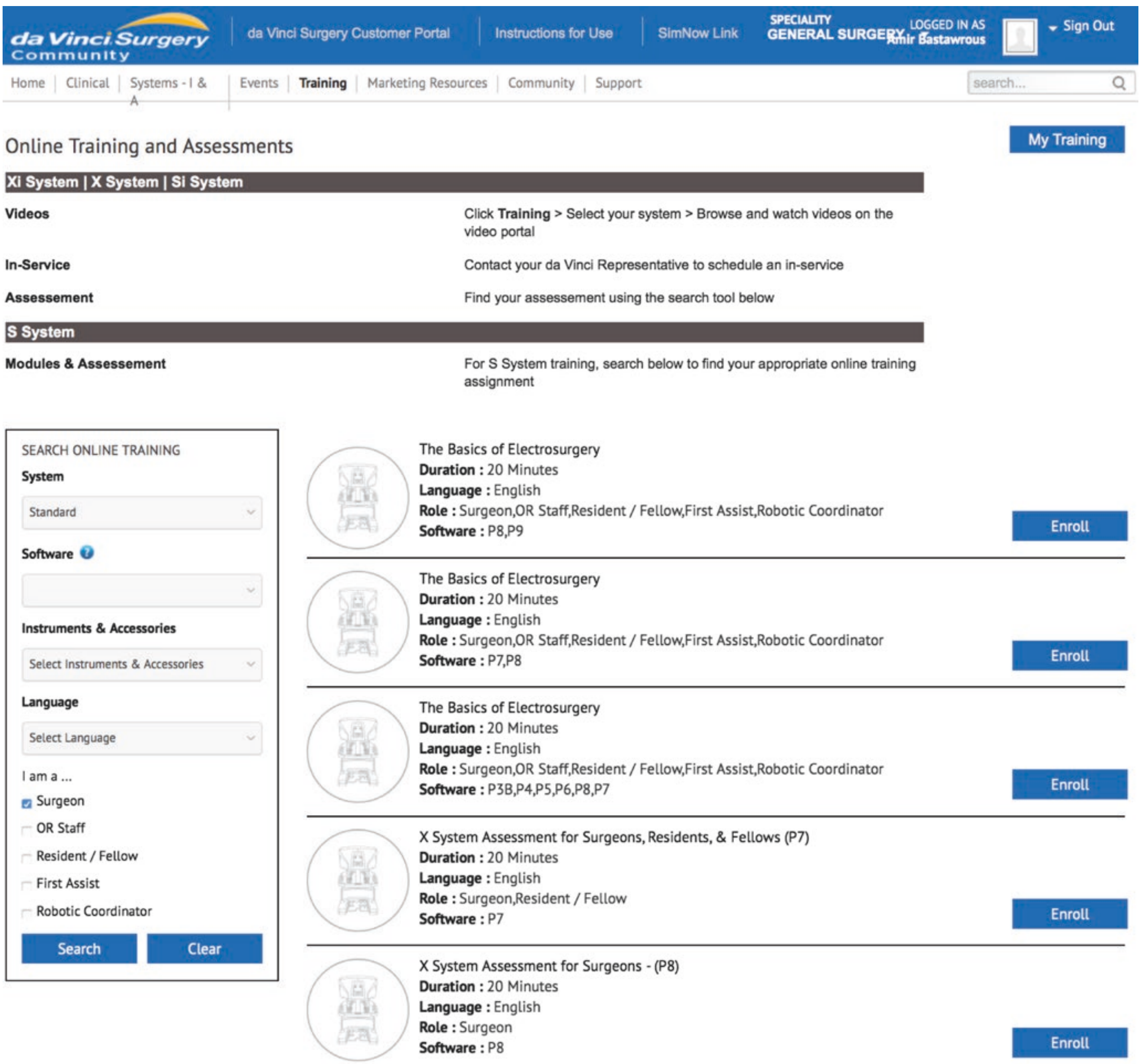


Fig. 5.3 Online training modules [3]

Step 2: In-person Overview of the System

This step is usually performed in a hospital operating room or simulation lab setting one on one between the trainee and the clinical sales representative (CSR) of Intuitive Surgical. The CSRs are the frontline people who guide the surgeon day to day on the operation of the equipment, troubleshoot problems, and provide technical assistance when needed.

These facilitators will review with the trainee much of what was taught in the online modules but now in a live setting with a functioning robot (Fig. 5.4 [3]). This training covers use of the system components, accessories, instruments, and interface with the patient. The CSR will also help prepare the surgeon for a real case by going through docking and port placement, troubleshooting, and case planning. This is particularly important for surgeons who are not in a residency or fellowship training setting. For graduated surgeons, the robotic training curriculum is condensed into a very short time frame, and the ultimate and personal responsibility of patient safety and an efficient, successful operation are weighty.

The CSR will cover key features and operation of the vision cart, the patient cart, and the surgeon console. They can provide guidance on selection of and optimal use of the camera and robotic instruments for specific cases. They may utilize a dry lab style model to help teach port placement, targeting, and instrument wristing. Importantly, the trainer will provide information on emergency response procedures and safety features of the equipment. At the successful completion of this phase, the CSR will sign off on the trainee having achieved this milestone.

Step 3: Simulator

The use of a robotic simulator is somewhat unique in surgical training in that it provides an opportunity to repeatedly practice specific skills with high fidelity. The most widely used simulator is the da Vinci Surgical Skills Simulator. It consists of an add on device that attaches to the robot console

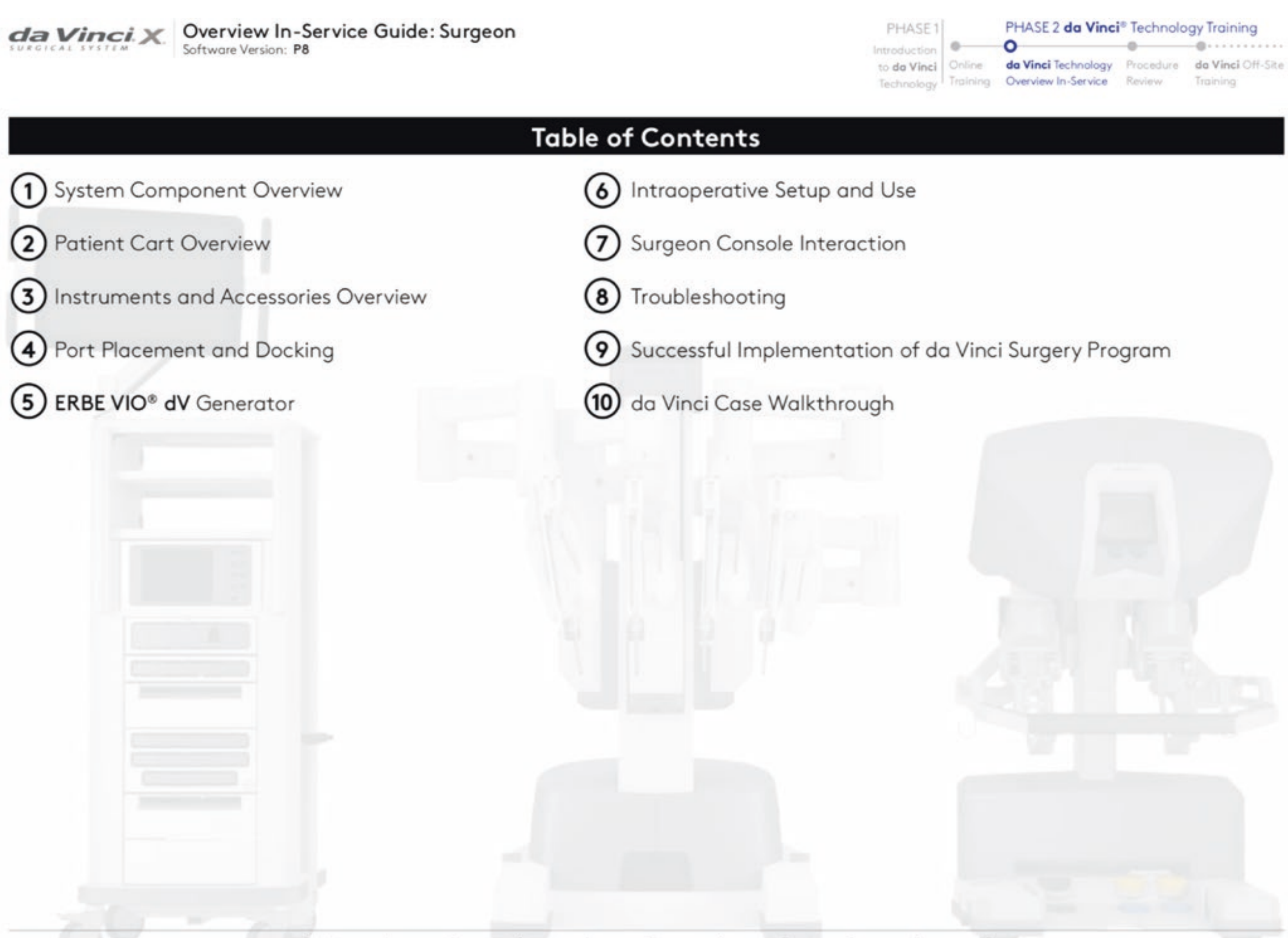


Fig. 5.4 Dry lab in service with CSR [3]

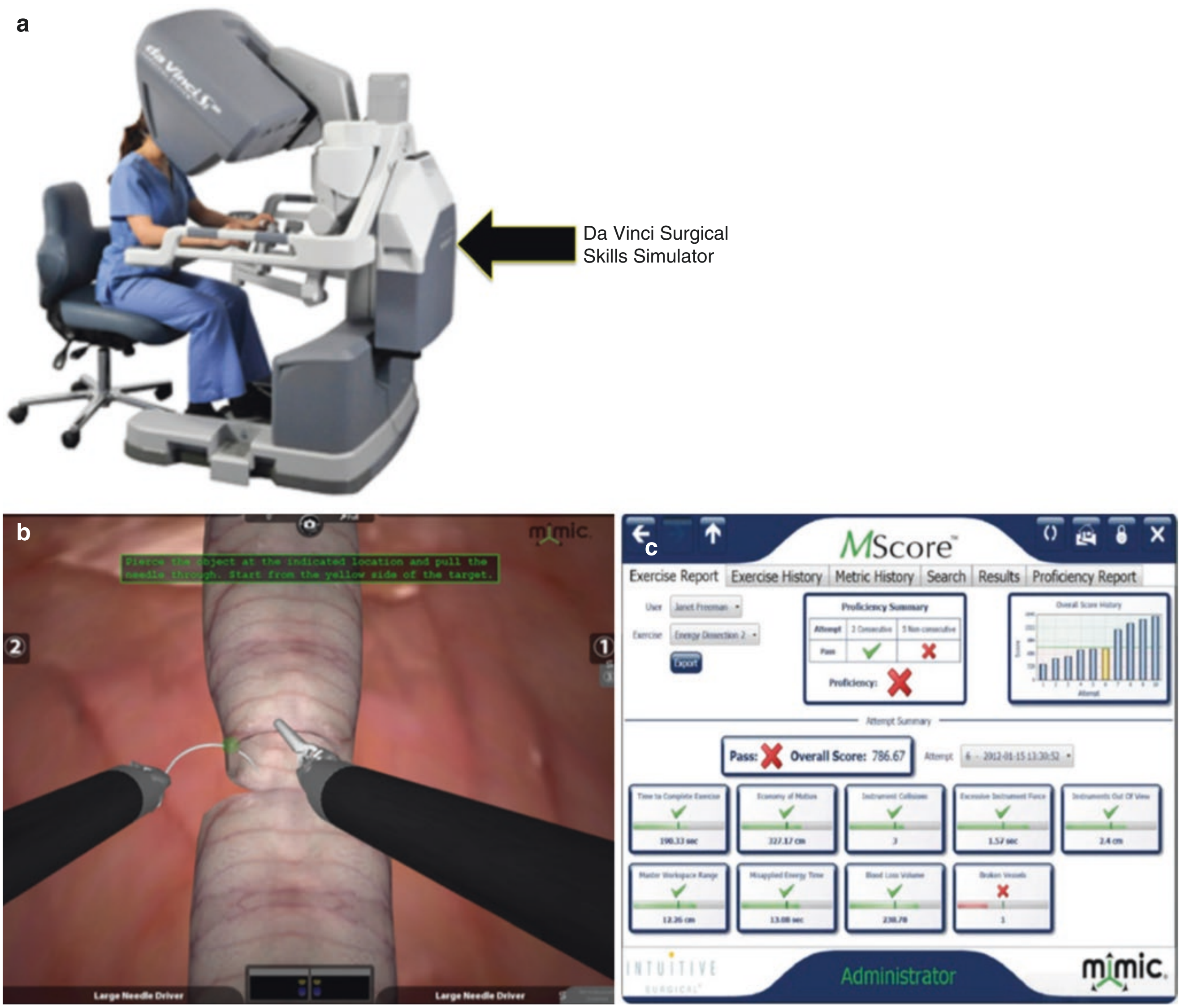


Fig. 5.5 Simulator image [23]

(Fig. 5.5). It integrates a virtual visual experience with the console system. There are now several da Vinci Simulator systems on the market.

While not every surgeon will have easy access to a robotic simulator at their institution, one can often be borrowed, or the surgeon can travel to another site to practice. Regardless, the current robotic simulator utilizes advanced imaging and a step-by-step skill acquisition. It will help the novice to learn the system and the experienced surgeon to hone their skills to a specific procedure [20]. Procedure-specific simulation with augmented reality is being developed and will be detailed later in the chapter. Several studies have shown that the da Vinci Surgical Skills Simulator training improves performance in dry laboratory exercises and real-life cases [21–23]. A 2016 systematic review looked at articles that studied any commercially available virtual reality simulator for the da Vinci Surgical System [24, 25].

If a simulator is not available, a dry lab can be set up with physical models, peg boards, models, or other real devices to practice the same skills. These can be a bit more cumbersome and less standardized and lack the tracking utility of the formal simulator but still provide a useful and safe practice environment. The CSRs are equipped to facilitate these labs.

For colorectal surgery fellow training, the following simulator exercises have been found to be most useful and are used in the Association of Program Directors in Colon and Rectal Surgeons Fellow Training Curriculum for Robotic Surgery (Fig. 5.1). The trainees are required to achieve a score of 90% or greater.

There are other simulator skills that are helpful, and practice shouldn't be limited to these few. The thoracic robotic surgery specialty has developed an even more granular definition of the exercise and suggestions for practice. The lessons are of course not limited to thoracic surgery (Fig. 5.6).

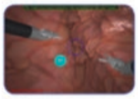
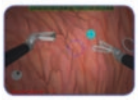
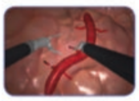
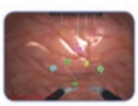
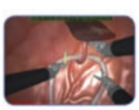
Exercise	Category	Suggestions for Practice
Camera Targeting 1 	• Camera and Clutching	Try to keep instruments in view and close to the center of your screen in between movements of the camera. Understanding this technique can be useful while moving your instruments around the target anatomy during surgery.
Camera Targeting 2 	• Camera and Clutching	Watch the camera icon during this exercise to make sure that you are managing your horizon properly. This is good practice for staying aware of the rotation of your camera.
Energy Switching 1 and 2 	• Energy and Dissection	Be mindful of the use of bipolar and monopolar energy as directed. You may notice similarities between these exercises and how you might deal with small bleeders during your procedural dissections.
Energy Dissection 1 	• Energy and Dissection	The goal of this exercise is to cauterize six smaller vessels along a larger central vessel. Before dissecting all the smaller vessels, though, see if you can mobilize the large vessel enough to burrow your bipolar forceps from one side of the vessel to the other to open up space behind it. Do this without letting your instrument shaft turn red.
Energy Dissection 2 	• Energy and Dissection	This exercise is similar to "Energy Dissection 1," but some smaller vessels will spontaneously re-bleed throughout the exercise. Plan your approach and view of the anatomy accordingly.
Matchboard 3 	• *EndoWrist*® Manipulation 2	With two doors to open at a time, you will need to use your fourth arm to complete this exercise. Watch out that your instruments do not turn red due to excessive force. If they do turn red, try rearranging your instruments so that they are holding different doors.
Needle Targeting 	• Needle Control	Passing a needle through the various targets in this exercise takes precision and a keen awareness of your hands. While the backhanded techniques may not reflect something that you would do in surgery, remember that this exercise is an opportunity to build well-rounded comfort with the console.
Ring Walk 2 	• Camera and Clutching	Sometimes, you can do an exercise over and over to see if you can improve a certain metric. Challenge yourself to improve your "Master Workspace Range" metric score on this one. This is good practice of the clutch.
Ring Walk 3 	• Camera and Clutching	Practice engaging the fourth arm and attempt some challenging movements while still safely managing all three instruments.

Fig. 5.6 da Vinci surgical simulator exercises [3]

Phase 2: Learning to Optimize the System for Specific Clinical Scenarios

Step 1: Case Observation

The case observation step allows the trainee to see what they have learned online or in a dry lab in action. For a resident or fellow trainee, this may be as simple as moving to an adjacent operating room where the system is being used. But for a postgraduate surgeon in practice, this may require travel to an epicenter where the trainee can watch an experienced surgeon operate utilizing the robotic platform. There are significant resources available on the

Intuitive Online Community and other sources to watch videos of relevant robotic operations.

It is at this point that the training paths diverge to a great degree for practicing surgeons, fellows, and residents.

Step 1a: Practicing Surgeon Case Observation

A surgeon new to the robotic system may have varying degree of laparoscopic and open experience. A new tool does not replace surgical judgment, so the indications for and timing of surgery will likely not be any different between open, laparoscopic, or robotic cases. The graduated surgeon will have to invest time and money to complete the training path and become proficient in robotic surgery. It is also often difficult to return to a learner mentality the longer one has been out in practice. This mindset can often be a hindrance to safe and efficient acquisition of robotic skills.

The time course from Phase 1 through Phase 2 is usually very short compared to fellows and residents, and there is pressure to get through training quickly to minimize lost skills. The case observation is an opportunity to plan a specific case, and it is most useful to try to watch a case comparable to the planned first case the surgeon trainee will perform. It makes sense to make the most of this visit. Ask questions of the expert surgeon whenever possible. Arrive early to discuss port placement philosophy, tips and tricks, and the plan for the operation at hand. Establish a relationship with the master surgeon who can be a sounding board or guide during the later stages of the learning curve. If the opportunity arises to watch multiple cases, take it.

Step 1b, c: Fellow and Resident Trainee Case Observation

The colorectal fellow may have had some experience during general surgery residency and have had case observations in that setting. The first cases for the trainee will likely be at the bedside as the assistant. In fact for an equivalency certificate (Fig. 5.7), ten documented cases of bedside assist are required. These allow the trainee to become acquainted with the system in a low-pressure setting (not being the responsible surgeon for the patient on the table). It also provides an opportunity to watch the arm responses to the console surgeon's movements, perform instrument exchanges, troubleshoot collisions, and learn what is needed of the bedside assist. This is a skill set not afforded to practicing surgeons who rarely if ever spend time during training at bedside. The advantage here is that when the resident or fellow becomes independent, they can better train their staff at bedside.

Completion of da Vinci System Online Training, for Surgeons, Residents, & Fellows (recommended)	
Video-based training, which includes topics such as system component overview, instruction in the use of system components, EndoWrist® instruments and accessories, and advanced technologies.	• Use www.davincisurgerycommunity.com to access training videos pertaining to use of the various **da Vinci** system models (e.g., **da Vinci** X® system, **da Vinci** Xi® system, or **da Vinci** Si® system)
Completion of da Vinci System Overview In-Service Training	
Hands-on training, which includes such as system component overview, docking, port placement, EndoWrist instrument overview, Surgeon Console overview, emergency procedures, and powering off the system.	• **da Vinci** X® system, **da Vinci** Xi® system, or **da Vinci** Si® system Overview In-service Guide
Completion da Vinci System Online Assessment	
The above training activities are prerequisites for the **da Vinci** System Online Assessment. A training certificate can be printed upon completion of the assessment.	• **Note:** For instructions on how to print a certificate showing completion of the **da Vinci** System Online Assessment, please refer to "How to Print a Certificate" Quick Reference Guide (Intuitive Surgical PN 1015165)
Performance of da Vinci Procedures in Primary Role of Console Surgeon (Minimum of 20) and Primary Role of Bedside Assistant (Minimum of 10)	
Solicit Letter of Verification of da Vinci System Training and Procedures Completed from Chief of Surgery or Program Director	
Submit Copy of Online Training Certificate, Case Log, and Letter of Verification to Intuitive Surgical Representative	

Fig. 5.7 Equivalency certificate requirements [3]

Step 2a: Basic Training Course for Practicing Surgeons

The Intuitive Surgical training courses are either 1- or 2-day events. The trainee travels to a training center at which they will practice on live animal and cadaveric specimens. The trainee is required to complete the training and pass the assessment to receive the basic certificate. Sometimes these courses are offered during national meetings.

Step 2b, c: Basic Training Course for Residents and Fellows

This is often enfolded into the on-site curriculum or skipped altogether for residents and fellows. The equivalency certificate takes into account the experience as bedside assist for multiple cases to qualify. Tracking these cases is required to receive the certificate.

Step 3: First Operative Cases, Practicing surgeon

For the practicing surgeon, getting a proctored case booked that is of appropriate indication, ease, and timing that fits with her block time can be a challenge. Planning ahead to ensure that one or two cases can be scheduled for the week of or the week after basic training allows for the least loss of learning and muscle memory. Individual hospital credentialing (which varies dramatically from hospital to hospital and even within a hospital by specialty) will dictate how many cases must be proctored. There are also rules for the qualifications of a proctor. The hospital credentialing committee may require the proctor to be of the same specialty as the surgeon being proctored, to have a minimum case experience, or even to acquire hospital privileges. Coordinating an appropriate proctor, an appropriate case, available robot block time, and a patient willing to be a surgeon's first case can prove challenging but is critical for success.

The proctor should be able to assist the trainee surgeon in case planning, port placement philosophy, docking efficiency, case sequencing, and instrument selection. They should also advise on technical tips and tricks as the surgeon progresses. Having different proctors over the training course provides different viewpoints that can help with tips but may generate conflicting advice that can confuse the novice robotic surgeon. It all depends on the surgeon and the proctors.

Step 3b, c: First Operative Cases, Residents and Fellows

For residents and fellows, the first operative cases will likely be after some time spent at bedside. It is helpful for residents to express an interest and enthusiasm for robotics to get an opportunity on console. Similar to open or laparoscopic surgery, the trainee experience will vary depending on where on the learning curve their trainer is located. For an attending that has only completed 10–30 cases themselves, it may be difficult to allow a trainee on console, and the training they can provide may be limited. The experience with a master robotic surgeon will be very different. The attending may choose to be at bedside and utilize telestration on the vision cart monitor to guide the trainee with precise directions. If dedicated bedside assistance from another surgeon, physician assistant, or first assist is available, a dual console system (Fig. 5.8) allows the attending to assist the resident or fellow directly either by utilizing one of the arms moving the camera or using arrows to guide movements. They can also quickly switch operators back and forth (without having to

Fig. 5.8 Dual console

scrub out/scrub in) to set up or demonstrate a task. This allows a very efficient mechanism for teaching.

Typically, over the course of training, the attending can provide progressive responsibility commensurate to the trainee's abilities at the time. For instance, early in training, the resident may be allowed to do a low-risk step like mobilize the lateral colon attachments to demonstrate their skill level. Later on, they may be allowed to perform the medial to lateral mobilization. Still later, they may perform the intracorporeal anastomosis. How quickly the resident or fellow progresses through this step depends on the experience and comfort level of the attending, the skill level of the trainee, and the availability of cases. Here the advantage is to the general surgery resident in that they have 5 years of general surgery residency to get through the experience and will have multiple specialties to draw on. The colorectal fellow will need to pick up the skill set in 1 year while also learning colonoscopy, laparoscopic surgery, anorectal surgery, etc. The one advantage the fellow has over the resident is the focus on a limited number of case types to perfect technique.

Step 4a, b: Advanced Course, Practicing Surgeon and Fellow

After gaining experience, the trainee will then benefit from attending an advanced course. This is a 1- or 2-day course taught by an experienced robotic surgeon and utilizing a cadaver to typically teach a low anterior resection and a right colectomy with intracorporeal anastomosis. This course allows the trainee to return to the low-pressure setting to now build on their experience. For the practicing surgeon, they will have experienced some inefficiencies or problems that they can now address. For the fellow, this is an opportunity to "fly solo" for the first time without their attending.

In rare situations, a general surgery resident will attend an advanced course. However both sets of resident or fellow trainees can get an equivalency certificate if they meet the training criteria (Fig. 5.7).

Along the way, continuing to watch expert videos will facilitate learning of the case steps and optimizing arm movements. Practicing on the simulator to maintain skills between days that they get on console will help anyone at this stage.

Technical Evaluation of Trainee

There are several validated tools to assess trainee proficiency. The one that seems to have the greatest acceptance is the Global Evaluative Assessment of Robotic Skills (GEARS) [26, 27] (Fig. 5.9). The immediate use of feedback helps the trainee learn from errors and provides a framework for skill improvement. The GEARS tool allows for an objective mechanism by which that feedback can be given.

The Future of Robotics Training

Intuitive Surgical, Inc. has partnered with 3D Systems (Rock Hill, SC) to create procedure-specific simulation modules with true to life graphics. Here surgeons can practice key steps in operations such as hysterectomy, prostatectomy, and inguinal hernia repair. Modules in colorectal surgery, such as right hemicolectomy with intracorporeal anastomosis, are planned for the future and can then be integrated into training curricula. These more advanced modules have an improved fidelity and improved graphics [28].

For the experienced surgeon, Intuitive Surgical is working with other venders (InTouch) to facilitate remote mentoring. The idea is to allow international experts to coach surgeons around the world from their home campus without the need to travel to the learner. Utilizing cameras that provide a view of the operating room setup and robotic camera images, the expert can provide telestration and verbal guidance similar to the experience she would provide in person.

Finally, more advanced simulators are coming online as noted above that promise to better recreate the operative experience in an augmented reality and virtual reality (VR) setting. Further down the line, current development simulation work being conducted will take individual patient preoperative imaging (CT or MRI) and recreate a high-fidelity three-dimensional VR graphic environment to allow for unlimited practice robotic surgery runs prior to the actual surgery. The potential for standardized objective assessment of technical skills on uniform patients is enticing for fairer assessment and may even be used in high-stakes exams, like board certification tests.

Learning Curve, Credentialing, and Maintenance of Skills

Credentialing in robotic surgery is not standardized from one institution to another. The requirements for robotics privileging and maintenance of privileges vary widely by institution and surgical specialties. Some hospitals will accept training

Date: ____________________ Evaluator Code: ____________________

Operator Code: ____________________ Attending Code: ____________________

Global Evaluative Assessment of Robotic Skills

Depth perception

1	2	3	4	5
Constantly overshoots target, wide swings, slow to correct		Some overshooting or missing of target, but quick to correct		Accurately directs instruments in the correct plane to target

Bimanual dexterity

1	2	3	4	5
Uses only one hand, ignores nondominant hand, poor coordination		Uses both hands, but does not optimize interaction between hands		Expertly uses both hands in a complementary way to provide best exposure

Efficiency

1	2	3	4	5
Inefficient efforts; many uncertain movements; constantly changing focus or persisting without progress		Slow, but planned movements are reasonably organized		Confident, efficient and safe conduct, maintains focus on task, fluid progression

Force sensitivity

1	2	3	4	5
Rough moves, tears tissue, injures nearby structures, poor control, frequent suture breakage		Handles tissues reasonably well, minor trauma to adjacent tissue, rare suture breakage		Applies appropriate tension, negligible injury to adjacent structures, no suture breakage

Autonomy

1	2	3	4	5
Unable to complete entire task, even with verbal guidance		Able to complete task safely with moderate guidance		Able to complete task independently without prompting

Robotic control

1	2	3	4	5
Consistently does not optimize view, hand position, or repeated collisions even with guidance		View is sometimes not optimal. Occasionally needs to relocate arms. Occasional collisions and obstruction of assistant.		Controls camera and hand position optimally and independently. Minimal collisions or obstruction of assistant

Case Difficulty

1	2	3	4	5
Ideal anatomy		Moderate difficulty		Very challenging, unusual anatomy

Total score: ________

Fig. 5.9 GEARS [26, 27]

credentialing alone. Others require 1–4 case observations by a member of the medical staff skilled in robotic surgery to confirm robotic skills for any surgeon new to the staff. Still others insist on case log documentation or proctored cases. As robotic surgery is initiated earlier in general surgery training and becomes more comprehensive and reproducible (as is laparoscopic surgery), these hurdles should become less necessary.

Recredentialing is another area of variability. Some institutions require at least 20 robotic cases per year to maintain robotic privileges, while others in the same area may require as few as 10 cases. There are data that demonstrate that those surgeons who perform <20 cases per year robotically have worse outcomes, with increased blood loss and longer operative times, than those higher volume surgeon [29]. Though there are no hard and fast rules for low-volume surgeons, guidelines suggest that surgeons should perform at least 1–2 robotic cases per month to keep up their skill set [30].

Specifically, in regard to colorectal surgery, one study showed that the first 9–11 cases consisted of learning technique, the next 12 cases represent consolidation and increased competence, and the final 20 cases represent the "mastery" phase of learning the robot [31]. A second study by Bokhari confirmed these results [32]. Interestingly, Kim et al. suggest that even one surgeon who was a laparoscopic novice having only completed 13 cases was able to gain proficiency in robotic total mesorectal excision within 20 cases without an increase in complications [33]. Another study suggests that the use of the robot may decrease the steep learning curve associated with laparoscopic TME [34].

Objective Evaluation of Robotic Skills Through Crowdsourcing

Throughout the training process and into the clinical skill development, there remains a need for continued assessment of the practitioner. This can be done by analyzing outcomes, but this method is delayed by months or years and may not detect technical weakness. Furthermore, it doesn't facilitate any quality improvement.

To fill that gap, standardized assessment of surgical skill is being highlighted at the initial training, credentialing/recredentialing, and ongoing professional development phases of a surgeon's career. One company has leveraged online crowdsourcing and expert feedback by outside reviewers to evaluate surgeon technical performance (C-SATS, Seattle, WA). C-SATS breaks down the operation into key steps and utilizes the GEARS [26, 27] tool with multiple distributed evaluators (both non-expert and expert) to provide rapid feedback on uploaded robotic videos. Validated studies have shown that crowdsourced feedback is comparable to expert feedback [35–38]. Both trainees and experienced robotic surgeons can receive objective coaching and technical skill evaluation along with tips and tricks.

Social Media and Online Resources

Several social media outlets have become platforms for training, discussion, and dissemination of ideas among colorectal surgeons. The "Robotic Colorectal Surgery Interest Group" is a closed-membership Facebook group (facebook.com) with over 1000 members. The content in the posts vary from asking for or giving clinical or technical advice, sharing interesting cases or a recent accomplishments, to posting a robotic case video. Twitter (twitter.com) has also become a popular forum among surgeons to share, discuss, and sometimes debate the use of robotic surgery. Posts and discussion on robotic colorectal surgery can be found under the "hashtag" #roboticCRS. YouTube (youtube.com) has long been a repository for robotic videos. Several experts and the APDCRS are using this platform with dedicated channels to supplement the education of their trainees. The Advances in Surgery Channel (aischannel.com) is a unique online platform that streams worldwide live surgeries performed by expert surgeons.

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6 Robotic Right Hemicolectomy with Intracorporeal Anastomosis

Robert K. Cleary and Craig S. Johnson

Background

There are potential outcome advantages associated with the intracorporeal anastomosis when compared to the extracorporeal approach for minimally invasive right colectomy for benign and malignant disease [1–4]. It is not only the anastomosis that distinguishes intracorporeal and extracorporeal approaches as there are distinct differences in the degree of colonic and mesenteric mobilization and differences in specimen extraction. Intra- and extracorporeal *anastomoses* may be more accurately described as intra- and extracorporeal *approaches* or *techniques* that include the anastomosis. The extracorporeal technique for minimally invasive right colectomy is characterized by an extraction site incision that is typically in the midline where the anastomosis is constructed by standard open techniques and where the hernia rate is 8–12% [5–7]. In some patients, the transverse colon may not easily reach the midline extraction incision, and this may cause stretching and bleeding of the mesentery with the possible need to extend the extraction site incision. This may potentially cause delay in gastrointestinal recovery time.

In contrast, the intracorporeal technique does not require an anastomosis through a small incision with poor visualization. The anastomosis is performed within the abdominal cavity after the specimen is completely freed from surrounding structures. There is less mobilization of the transverse colon because it does not have to be stretched to an extraction site incision. The extraction site incision may be anywhere off-midline where hernia rates are <2%, typically in the Pfannenstiel location [1, 2, 8–11]. The intracorporeal off-midline extraction site incision size is limited only by the size of the pathology.

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R. K. Cleary (✉)
Department of Surgery, St Joseph Mercy Hospital, Ann Arbor, MI, USA
e-mail: Robert.Cleary@stjoeshealth.org

C. S. Johnson
Department of Surgery, Oklahoma Surgical Hospital, Tulsa, OK, USA

Preoperative Planning

The patient interview includes a family history focused on identifying hereditary nonpolyposis colon cancer or other inherited cancers that may warrant a total abdominal colectomy or restorative proctocolectomy rather than a right hemicolectomy. Colonoscopy addresses the possibility of synchronous neoplasms, and computed tomography imaging of the chest, abdomen, and pelvis is done to rule out metastatic disease that may warrant neoadjuvant chemotherapy. Comorbidities, performance status, nutrition, and preoperative education that includes expectations and recovery milestones are optimized ideally within a structured standardized enhanced recovery pathway [12]. Mechanical bowel preparation with oral antibiotics and carbohydrate loading are implemented prior to surgery. Multimodal pain management begins either the night prior to surgery or in the preoperative suite with oral acetaminophen, oral gabapentin, and a transversus abdominis plane block.

The operating team should be aware of the risks of pneumoperitoneum and signs of hypercarbia, air embolism, bradycardia, and subcutaneous emphysema [13].

Room Setup and Positioning (Fig. 6.1)

The robotic surgical team should be well versed in robotic draping and positioning of the operating table, patient cart, vision cart, surgeon console, and instruments. The anesthesia team should be prepared for potential airway issues related to robotic and patient draping and patient positioning. Anesthesia should be included in the planning process and may also assist with integrated table motion and immunofluorescence to assess bowel viability. The vision cart should be visible to

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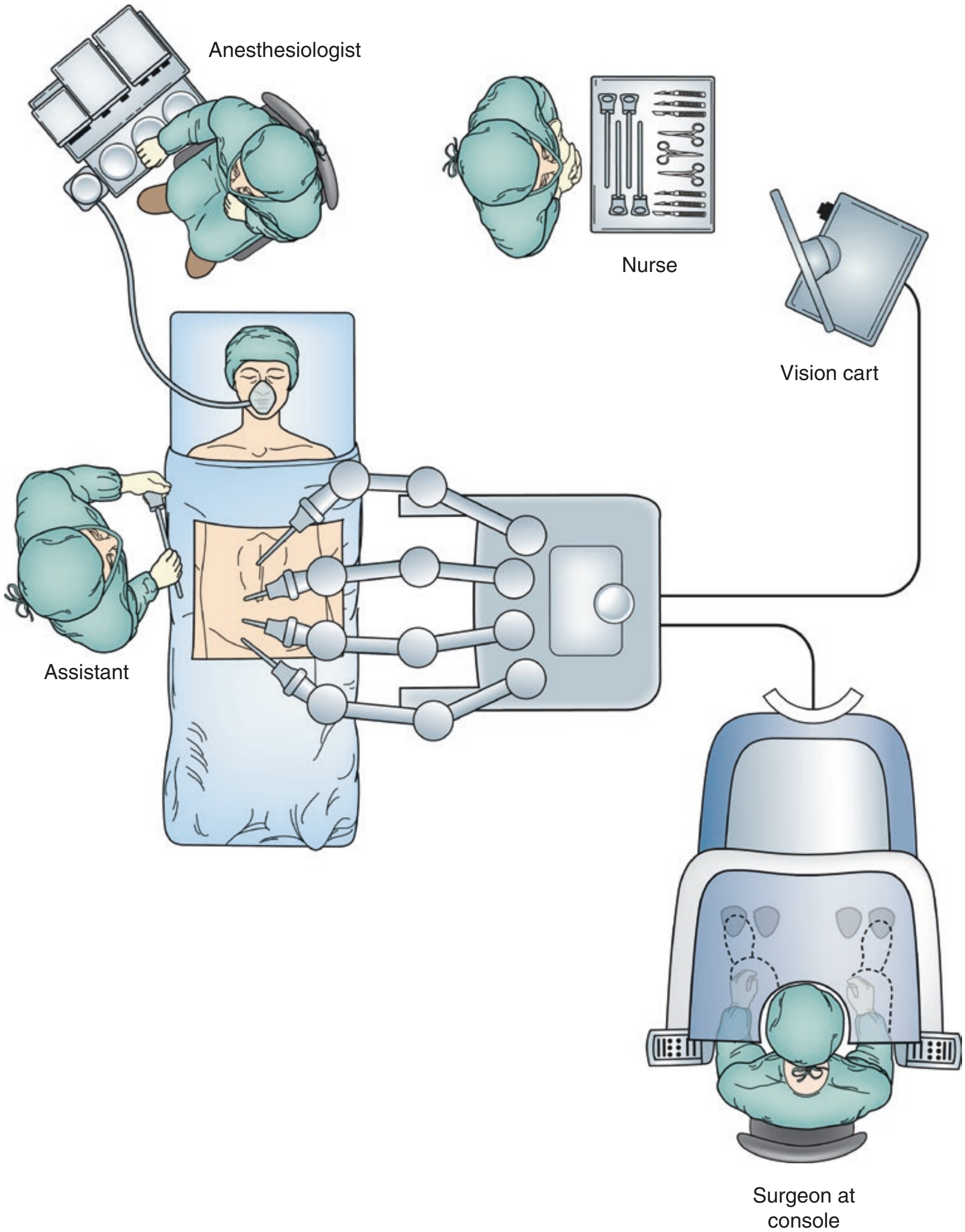

Fig. 6.1 Room setup and positioning

operating staff but outside of the sterile field, usually outside of and lateral to the right foot of the patient. The surgeon console should be positioned in a way that allows visualization of the operating table, patient, and personnel and effective communication between surgeon and staff.

The memory foam "Pigazzi pink pad" may be placed on the table prior to transferring the patient from the gurney to limit patient movement with table rotation. The patient is placed on the operating table in the supine position, and the right arm or both arms are tucked after pressure points are padded, especially the olecranon to prevent ulnar nerve injury and with the hand in neutral position to prevent hyperextension and radial nerve injury [14]. Foam straps are placed across the waist and chest. Urinary catheters are used per surgeon discretion based on patient comorbidities, and fluid administration is goal-directed. The robotic patient cart is docked on the right side.

Port Setups and Extraction Sites

Xi arms are more trim than the Si counterparts and have an extra joint that provides more robotic arm flexibility and decreases the risk for external collisions. Port placement

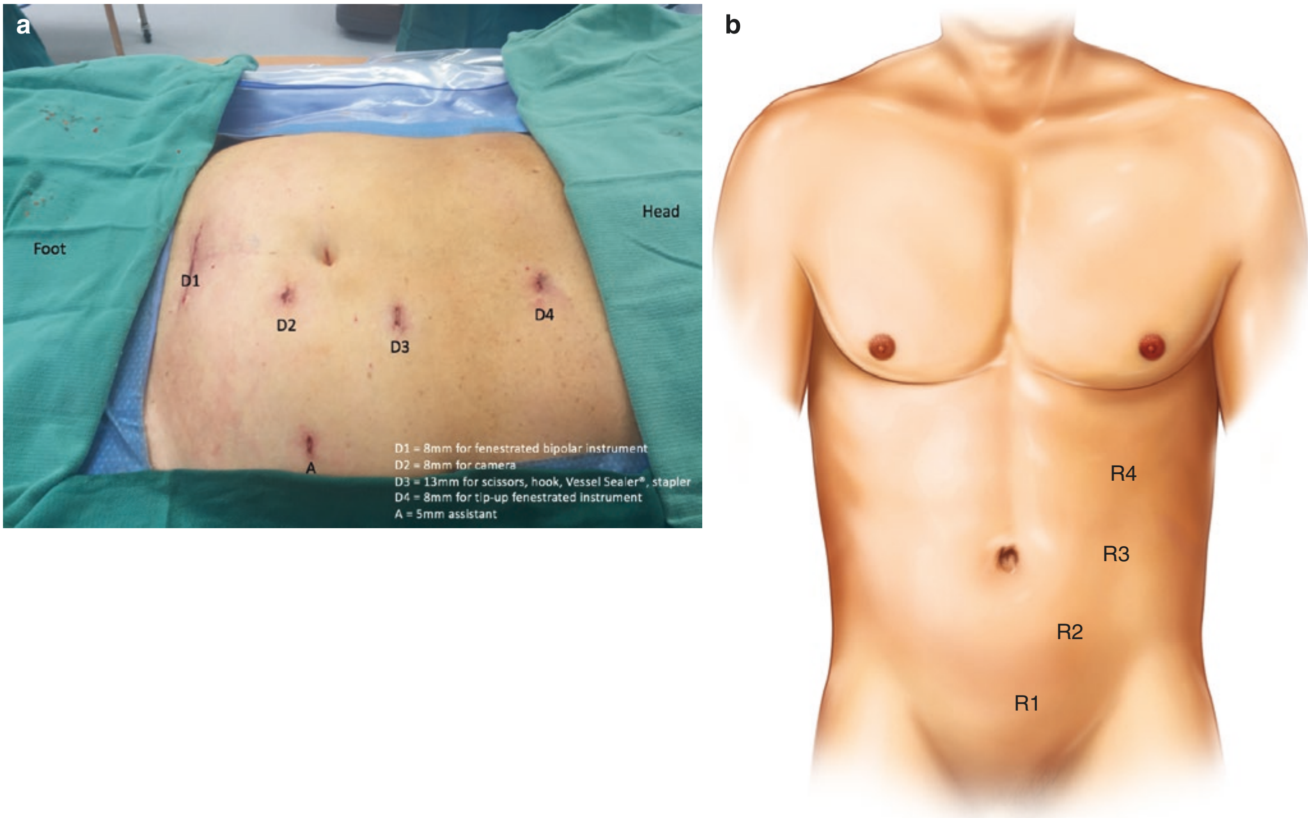

Fig. 6.2 Diagonal port arrangement

strategy is therefore different for the Xi with the focus on robotic arm movements in the same direction rather than angled from different directions as with the Si arrangement. Pneumoperitoneum may be established with either a Veress® needle or Optiview® trocar, often in the subcostal region just to the left of the midline.

Diagonal Port Arrangement (Fig. 6.2a and b)

After pneumoperitoneum is established, four robotic trocars are placed under direct "laparoscopic" vision in a diagonal or nearly diagonal (semicircular) arrangement. The camera is placed in the subcostal Optiview® trocar to allow the placement of three more trocars 7–8 cm apart (R1–3), with the last in the suprapubic midline. If the subcostal Optiview® trocar is 5 mm, the camera is then repositioned into one of the three robotic trocars to enable replacing the 5 mm subcostal Optiview® trocar with an 8 mm robotic trocar (R4). Depending on surgeon preference, the retroperitoneal attachments, and what position provides best visualization of the ileocolic vessels, the patient is placed in either slight Trendelenburg or slight reverse Trendelenburg position with right side up rotation. The robot is docked over the right side, and the camera arm is attached to the 8 mm trocar R2. The remaining robotic arms are attached to the respective trocars after targeting is complete. Instruments are then passed under direct vision. The R1 suprapubic trocar is 8 mm and typically accommodates either the fenestrated bipolar or cadiere instruments. R2 is an 8 mm trocar for the camera and should be left off the midline so that the camera tip is not too close to the ileocolic vessels. The R3 trocar is 13 mm and used for the scissors, hook, Vessel Sealer®, and stapler. The R4 trocar is another 8 mm robotic trocar used for the 3rd arm for fixed retraction, often the tip-up fenestrated instrument. A 5 mm or 8 mm assistant trocar is placed in the left lower quadrant.

Suprapubic Port Arrangement (Fig. 6.3a, b, and c)

Some surgeons prefer other port setup options. The suprapubic port location is well below the umbilicus and is particularly suited for patients receiving transversus abdominis plane neural blockade and for cosmesis. An 8 mm R2 trocar is placed in the midline at what will ultimately be the

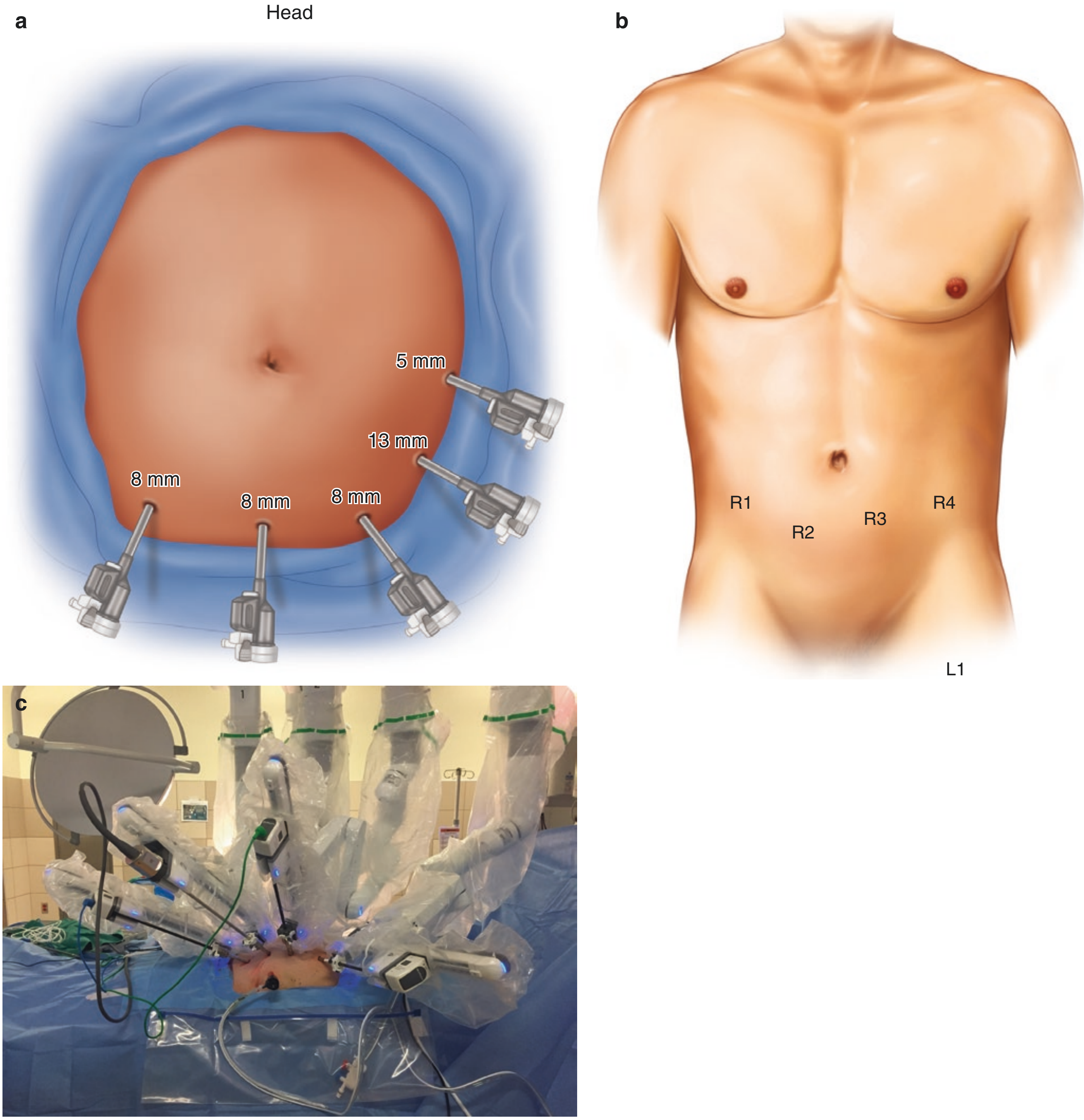

Fig. 6.3 Suprapubic port arrangement

Pfannenstiel incision specimen extraction site. An 8 mm R1 trocar is placed 7 cm to the patient right of R2, and an 8 mm R3 trocar is placed 7 cm to the left of R2. A 13 mm R4 trocar is placed 7 cm to the left of R3, and an assistant port L1 is placed 5–7 cm to the left of R4. The patient is placed in 5° of reverse Trendelenburg with 5° of right to left rotation. After camera insertion into R3, targeting is done with the hepatic flexure as the target point. Under direct vision, a small grasping instrument is passed into R1 and a fenestrated bipolar instrument into R2. R4 is for the scissors, hook, Vessel Sealer®, and robotic stapler. This port setup option is versatile and allows standard right colon resection, extended right colon resection, transverse colon resection, and subtotal colectomy.

The extraction site for both port arrangement options is off-midline and often the Pfannenstiel position where a trocar incision is already present and where hernia rates are low.

Operative Steps

Operative steps	Degree of difficulty (scale 1–5)
Exploratory laparoscopy	1
Identification of ileocolic vessels and duodenum	2
Medial to lateral mesenteric mobilization	3
Ligation of ileocolic vessels	2
Lateral mobilization of terminal ileum and hepatic flexure	3
Division of ileal and colonic mesentery	3
Transection of ileum and transverse colon	3
Ileocolic anastomosis	4
Specimen extraction	2

Exploratory Laparoscopy

Prior to docking the robot, exploratory laparoscopy is done in standard fashion to identify the primary lesion, identify a colonic tattoo if present, rule out metastatic disease, and identify concomitant unexpected pathology. The ileocolic vessels are identified in anticipation of upward 3rd arm retraction of these vessels being the first maneuver after the surgeon sits at the console. The ileal mesentery is splayed in the natural position with the proximal ileum on the left side of the abdomen thereby allowing easy identification of the ileocolic vessels.

Identification of Ileocolic Vessels and Duodenum

After the robot is docked and the instruments passed under direct vision, the console surgeon first identifies the ileocolic vessels and gently lifts them with the 3rd arm for fixed retraction – often the tip-up fenestrated instrument in R4. The mesentery is scored at the base of the ileocolic vessels in preparation for developing a medial to lateral plane between the mesentery and retroperitoneum. The duodenum may also be identified during this maneuver in patients who are not obese, and this serves as a useful landmark (Fig. 6.4, Video 6.1).

After identifying the plane between the mesentery and retroperitoneum, the ileocolic mesentery is dissected away from the retroperitoneum in a medial to lateral direction toward the terminal ileum, cecum, ascending colon, and hepatic flexure. This dissection is facilitated by using a closed instrument to lift the mesentery while gently dissecting the retroperitoneum down. The duodenum serves as a useful landmark of the correct plane; lifting the mesentery over the duodenum with the closed instrument while dissecting the duodenum down keeps the surgeon in the correct plane all the way to the hepatic flexure. It is also important to stay in the correct plane above Gerota's fascia laterally (Fig. 6.5, Video 6.2).

The lateral attachments serve as another "arm" facilitating medial to lateral dissection and keeping the mesentery and vessels from obstructing the operative view as can occur during lateral to medial dissection. However, some patients do not have easy medial to lateral dissection planes. Bleeding suggests that the operating plane between the mesentery and retroperitoneum is not exactly correct and the surgeon should not hesitate to switch to lateral to medial dissection if medial to lateral proves challenging. It is best to dissect planes that are anatomically clear than pursue a plane that is not obvious. The ureter should be thought of and identified when necessary to ensure that it is not injured during this dissection.

Ligation of Ileocolic Vessels

Medial to lateral dissection allows easy identification of the course of the ileocolic artery and vein. The ileocolic vessels are ligated with either clips or the Vessel Sealer®. Division of the ileocolic vessels typically allows clear visualization for further medial to lateral dissection that is facilitated by placing an open tip-up fenestrated 3rd arm under the mesen-

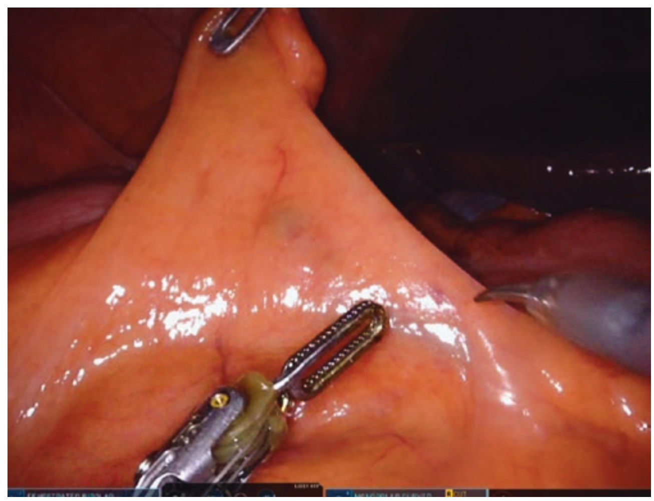

Fig. 6.4 Cephalad retraction of ileocolic vessels

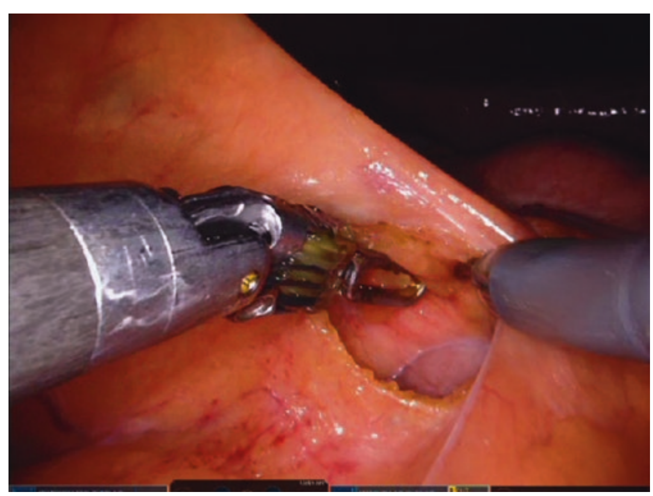

Fig. 6.5 Medial to lateral dissection of mesentery from retroperitoneum before ligation of vessels

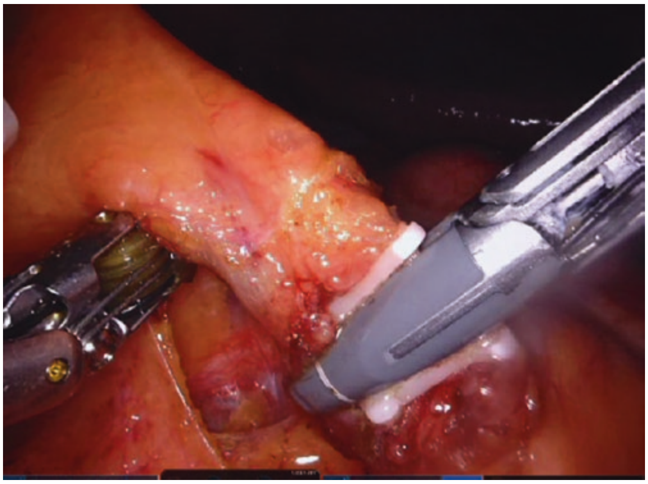

Fig. 6.6 Ligation of ileocolic vessels

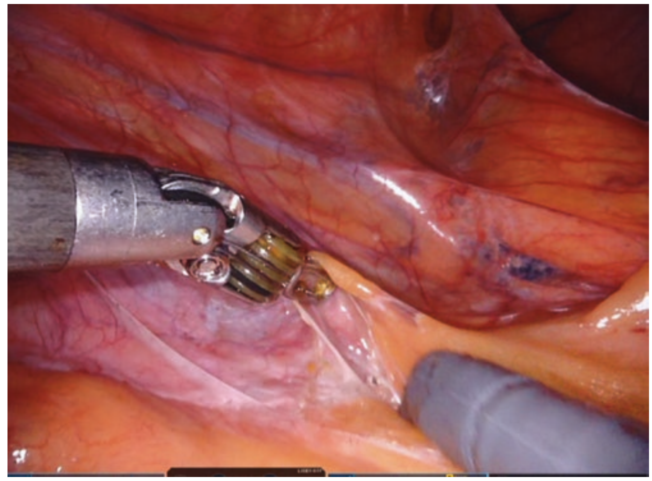

Fig. 6.8 Lateral to medial dissection

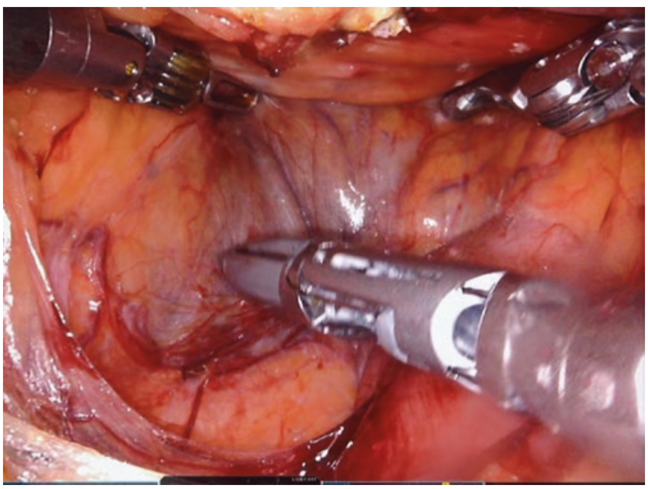

Fig. 6.7 Medial to lateral dissection after ligation ileocolic vessels

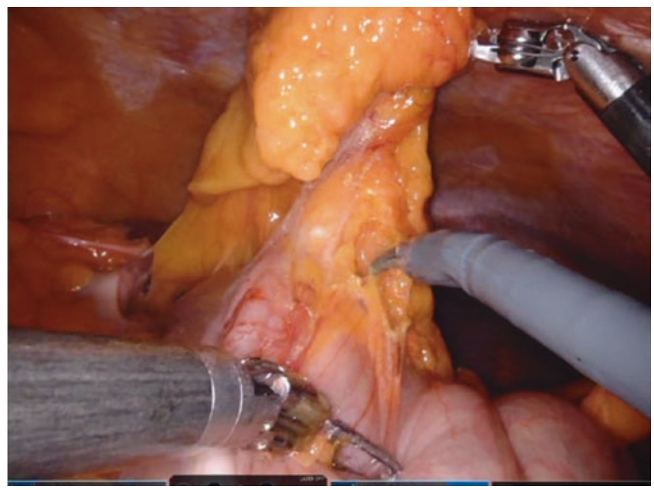

Fig. 6.9 Dissection of omentum from transverse colon

tery providing excellent exposure. The intracorporeal approach requires full mobilization of all mesentery off the retroperitoneum for ultimate specimen retrieval, so these medial to lateral maneuvers constitute time well spent (Figs. 6.6 and 6.7, Videos 6.3).

Lateral Mobilization of Terminal Ileum and Hepatic Flexure

After division of the ileocolic vessels and after exhausting medial to lateral dissection, remaining mesenteric attachments and lateral colonic attachments are divided by lateral to medial dissection. If there are ileal retroperitoneal attachments, division of these and any remaining right colon attachments may be facilitated by 3rd arm retraction of the cecum toward the right upper quadrant. The omentum may require dissection away from the hepatic flexure and proximal transverse colon, and this is typically done with the hot scissors and/or Vessel Sealer®. Any remaining hepatic flexure dissection of mesentery away from retroperitoneum is done at this time usually with the divided ileocolic vessels and duodenum clearly visualized (Figs. 6.8 and 6.9, Videos 6.4 and 6.5).

Division of Ileum and Colonic Mesentery

After full mobilization of the terminal ileum, cecum, ascending colon, and hepatic flexure with division of the ileocolic vessels, the mesentery to the terminal ileum and the mesentery to the transverse colon are then divided to the proposed point of bowel transection using total mesocolic principles with ligation and division of the right colic and right branch of the middle colic vessels at their origin with either clips or the Vessel Sealer®. After all relevant mesentery has been divided, 3 cc of indocyanine green may be injected intravenously by the anesthesia team to confirm viability of the proposed points of transection using Firefly® (Figs. 6.10, 6.11, and 6.12, Videos 6.6, 6.7, and 6.8).

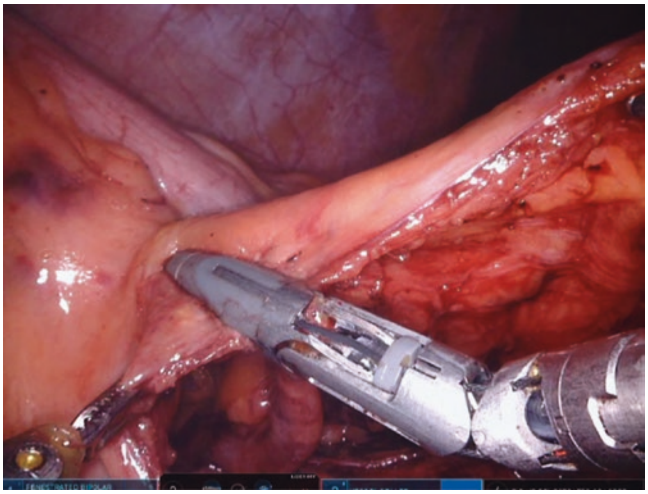

Fig. 6.10 Division of ileal mesentery

Division of Ileum and Transverse Colon

The terminal ileum and transverse colon are then divided with the robotic stapler or a laparoscopic stapler through the 13 mm trocar (R3 in the diagonal arrangement and R4 in the suprapubic port setup). The specimen is then placed in the right upper quadrant using the “roll” technique to confirm that all retroperitoneal attachments to the specimen have been divided (Figs. 6.13 and 6.14, Video 6.9).

Ileocolic Anastomosis

Taking care to ensure proper orientation to avoid mesenteric twisting, the divided terminal ileum is brought to the divided transverse colon in either an isoperistaltic or anti-

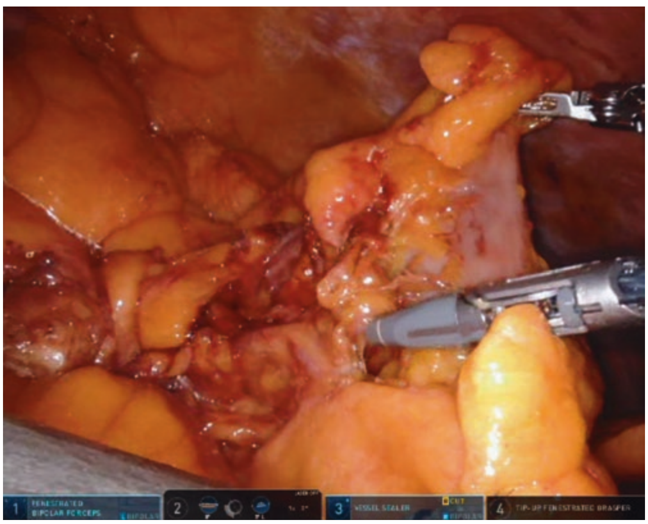

Fig. 6.11 Division of transverse colon mesentery

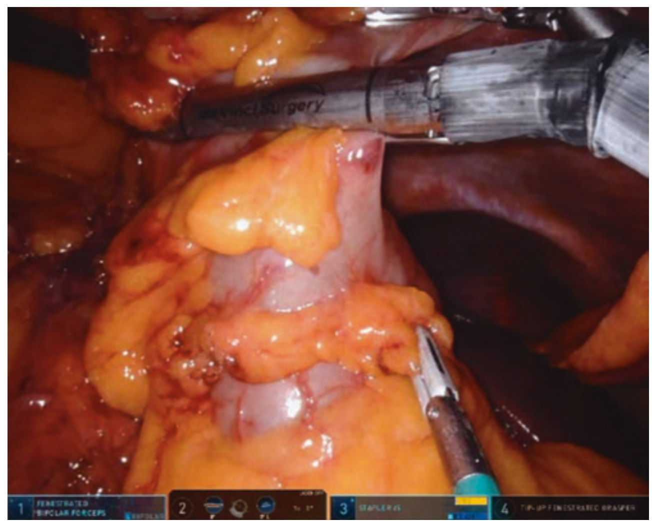

Fig. 6.13 Division of transverse colon

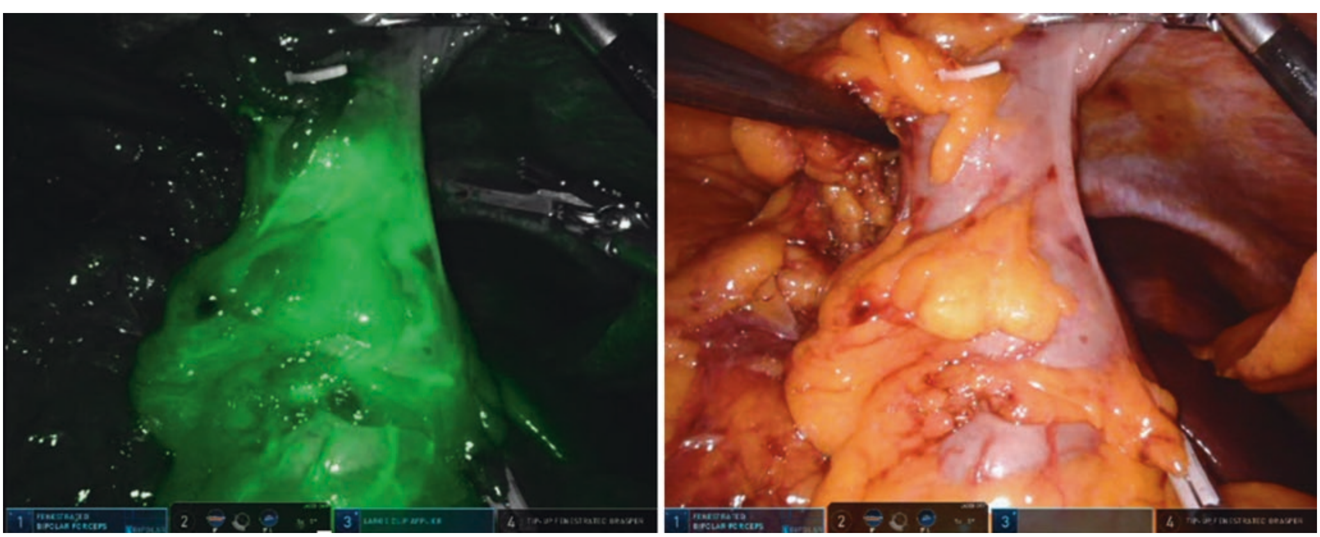

Fig. 6.12 Immunofluorescence demonstrating viable transverse colon

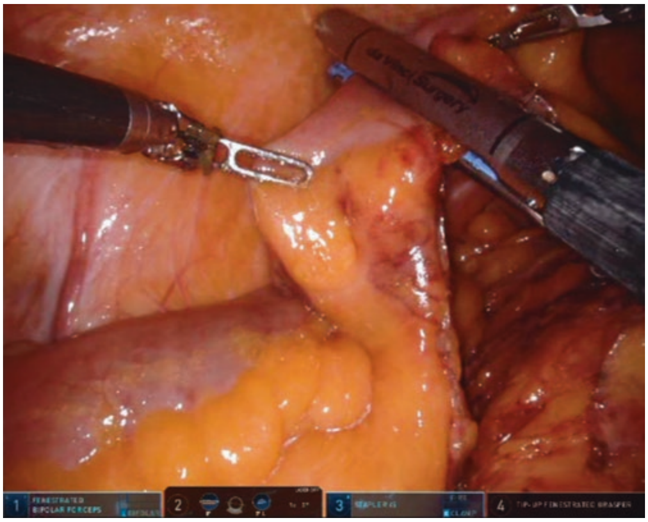

Fig. 6.14 Division of ileum and roll technique

peristaltic configuration. Seromuscular sutures are placed to align the bowel for the anastomosis, and one of the ends of the suture is cut long, so an instrument in R4 (diagonal port arrangement) or R1 (suprapubic port arrangement) can be used to retract the proposed site for the anastomosis toward the right side of the abdomen for easy visualization. An enterotomy and colotomy are made with scissors to form a common enterotomy passageway, and one limb of the robotic stapler is passed into the colotomy and then the other limb into the enterotomy. The anastomosis is constructed with either one or two applications of the robotic 45 mm stapler. The common enterotomy is then closed with either suture or another application of the stapler. For those who prefer to sew the common enterotomy, a 3-0 barbed suture is a common choice.

Tip: Perform the ileal enterotomy 2 cm away from the ileal transection/staple line if an isoperistaltic anastomosis is done, so that the staple line does not interfere with the suture closure of the common enterotomy.

Tip: Pay special attention to the inferior crotch when closing the common enterotomy by suture as this is the most common site of a leak (Figs. 6.15, 6.16, and 6.17, Video 6.10).

Specimen Extraction

After the anastomosis, the robotic part of the operation is complete. The robotic instruments are removed under direct vision. The robotic arms are detached from the trocars and the robotic cart directed away from the operating table. The 13 mm trocar site fascia is closed typically with suture under laparoscopic guidance using the Carter-Thomasson® device. The trocars are removed under direct vision looking for

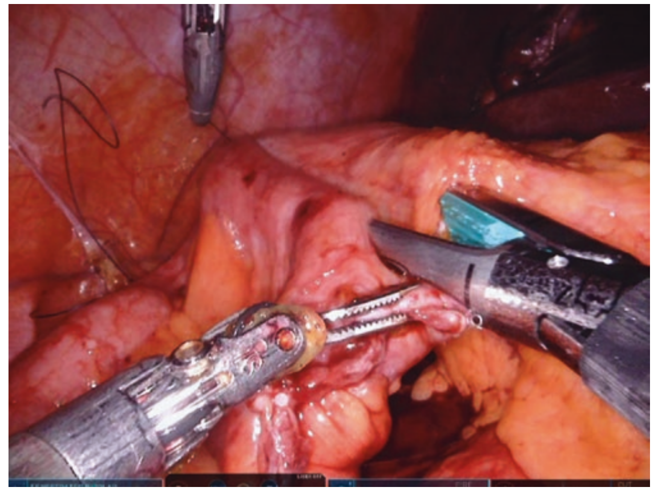

Fig. 6.15 Stapled anastomosis

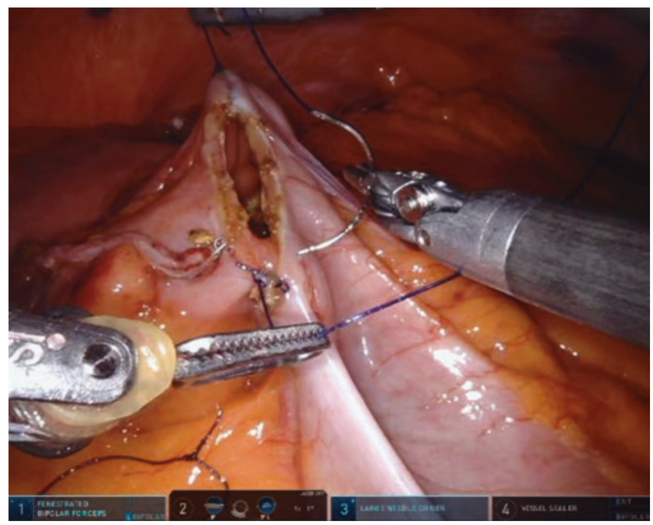

Fig. 6.16 Sewing common enterotomy

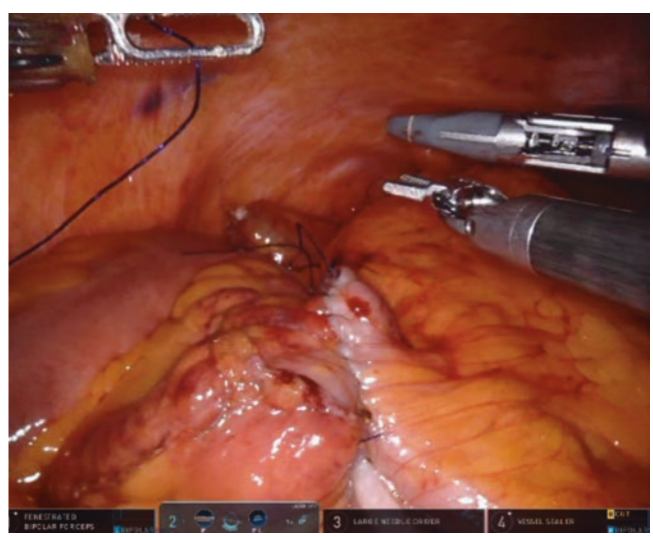

Fig. 6.17 Completed intracorporeal anastomosis

Fig. 6.18 Specimen retrieval

bleeding. The suprapubic port site incision is then extended to include the subcutaneous tissue and fascia over the rectus muscles. The peritoneum is entered and a wound protector placed. The specimen is then retrieved through this wound. Wound closure is done in standard fashion after changing gloves and with a separate wound closure instrument tray (Fig. 6.18, Video 6.11).

Summary

The robotic right colectomy for benign and malignant disease is particularly well suited for the intracorporeal technique with the Xi® robotic surgical system and with outcomes that include shorter time to gastrointestinal recovery and fewer incisional hernias when compared to the extracorporeal approach. The National Robotics Colon and Rectal Surgery Fellowship Training Course, sponsored by the Association for Program Directors in Colon and Rectal Surgery, has implemented these intracorporeal principles for young surgeons in training. Continued advances in robotic technology warrant consideration of further development of intracorporeal alternatives.

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7 Robotic Left Colectomy with Natural Orifice IntraCorporeal Anastomosis with Extraction: The NICE Procedure

Eric Haas

Introduction

Minimally invasive colorectal surgery continues to evolve with new technologies enabling platforms. In particular, advances in robotic surgery have led to renewed interest in natural orifice-assisted surgery with intracorporeal anastomosis (ICA) and transrectal extraction of specimen [1].

This chapter presents a stepwise approach to robotic left-sided resection with transrectal extraction of the specimen as well as a complete ICA. This approach can be successfully completed for numerous types of disease presentations including diverticulitis, colitis, rectal prolapse, and neoplasm. This approach is performed with no incision other than those required for the ports.

Background

Over 20 years ago, laparoscopic left-sided colonic resection with transanal specimen delivery and intracorporeal colorectal anastomosis was first reported by Franklin ME. Since that time, several authors have reported meaningful benefits including earlier return of bowel function, decreased postoperative pain and opioid use, and decreased length of hospital stay [2, 3]. Additionally, decreased postoperative complications and better cosmetic results without compromising oncologic outcomes have been reported [4, 5]. Early adopters of robotic technology were also reported on colectomy with ICA with transrectal extraction in 2009 and again in 2013 with similar benefits [6].

Despite these merits, the technical challenges of laparoscopic and first-generation robotic approaches have limited widespread adaptation and routine use. However, recent advances in robotic technologies and techniques have resulted in a surge of renewed interest [7].

This chapter presents a stepwise approach to the completion of a left-sided colorectal resection with ICA with retrieval of the specimen via the rectum. We refer to this approach as the NICE procedure, Natural orifice IntraCorporeal anastomosis with Extraction.

For the purposes of this chapter, left-sided colectomy refers to disease involving the left colon, sigmoid, and upper rectum. The stepwise approach is presented for benign disease including diverticulitis, rectal prolapse, and colitis. We will not address the entirety of the various types of procedures as these are addressed throughout the book. Rather, we will describe the specific steps unique to natural orifice-assisted ICA and rectal extraction. We will also describe the procedure with the da Vinci Xi platform although the procedure can be accomplished with the Si model.

Room Setup and Positioning

The setup for this procedure is identical to the setup for left-sided colectomies. The patient is placed in a modified lithotomy position using adjustable stirrups and tilted into Trendelenburg position with the left side elevated. The robotic is docked on the patient's left side. The assistant is positioned on the patient's right side (Fig. 7.1).

Port Placement

A total of five ports are used for the NICE procedure: a 5 mm RUQ port for the assistant, an 8 mm port in the RLQ, an 8 mm port hidden in the umbilicus, an 8 mm port in the left quadrant, and another 8 mm port in the left upper quadrant (Fig. 7.2).

Electronic Supplementary Material The online version of this chapter (https://doi.org/10.1007/978-3-030-15273-4_7) contains supplementary material, which is available to authorized users.

E. Haas (✉)
Division of Colon and Rectal Surgery, Houston Methodist Hospital, Houston, TX, USA
e-mail: ehaasmd@houstoncolon.com

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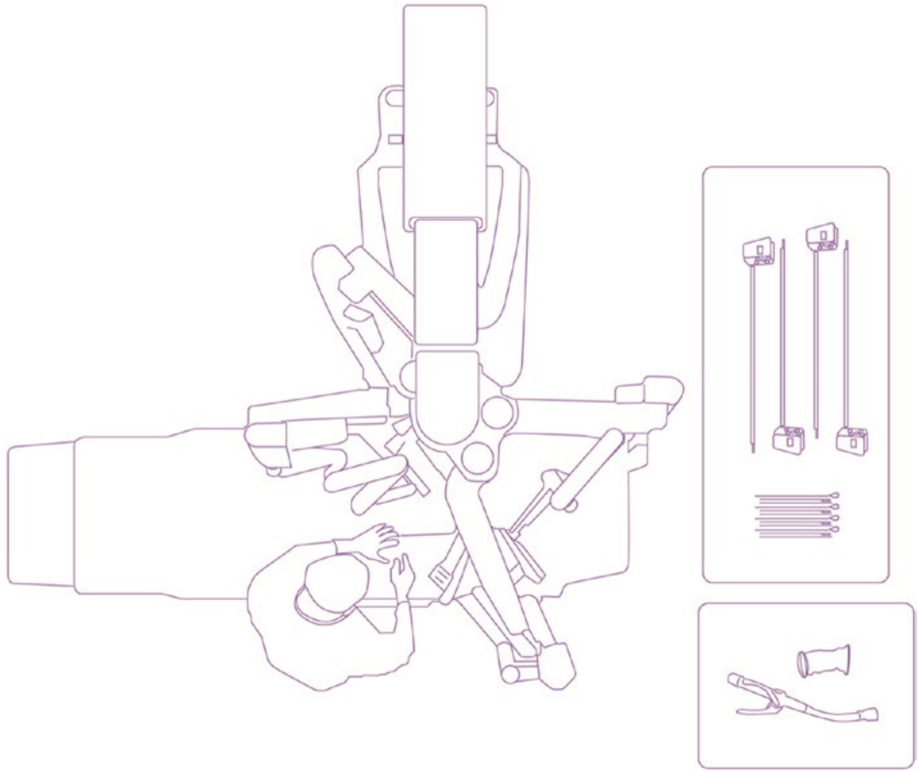

Fig. 7.1 OR room setup with the robot docked on the patient's left side, the assistant positioned on the patient's right side and the back table

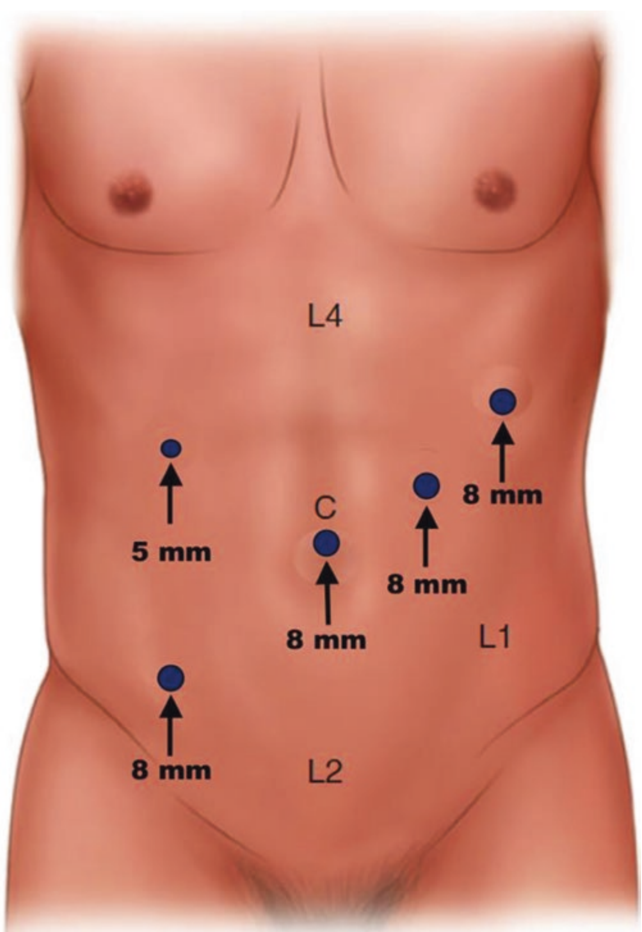

Fig. 7.2 Port placement for NICE procedure. RUQ 5 mm assistant port and four 8 mm robotic ports – one in the RLQ, one hidden in the umbilicus, and two on the left side

We initiate the procedure via direct optical entry using a 5 mm Optiview trocar placed in the right upper quadrant. This port is initially used to visualize placement of the robotic 8 mm ports and thereafter used as the assist port.

Operative Steps

Operative steps	Degree of technical difficulty (scale 1–10)
1. Lateral dissection with release of lateral peritoneal attachments	2
2. Identification and isolation of the proximal level of resection	4
3. Division of the mesentery	3
4. Identification and isolation of the distal level of resection	4
5. Division of the proximal margin	2
6. Division of the distal margin	2
7. Transrectal insertion of the alexis retractor	3
8. Transrectal extraction of the specimen	6
9. Transrectal delivery of the anvil into the abdomen	4
10. Securing the anvil to proximal bowel	5
11. Closing the distal bowel around circular stapler	5
12. Formation and oversewing of end-to-end anastomosis	4

Some of the salient features of the NICE procedure for benign disease include dissection close to the bowel wall through the mesentery above the superior rectal artery. Unlike dissection planes for malignant disease, avoidance of

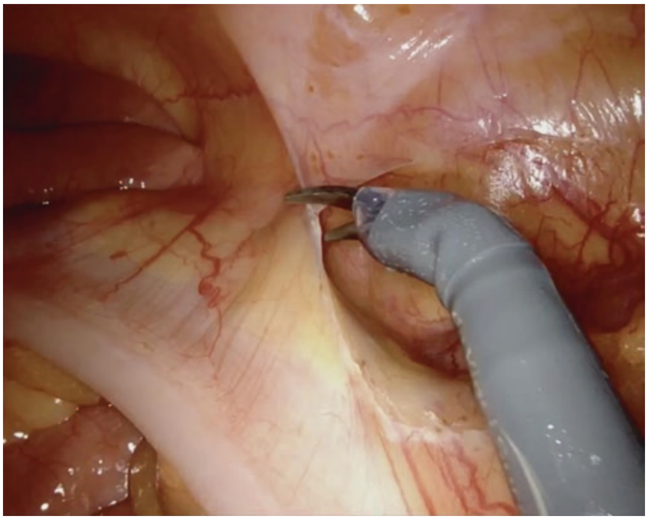

Fig. 7.3 Initial steps with release of lateral peritoneal attachments utilizing monopolar robotic scissors

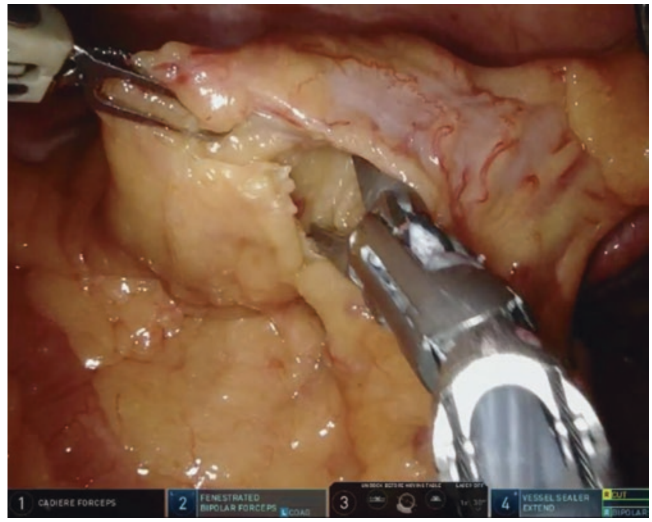

Fig. 7.4 Creation of window through mesentery at proximal level of resection

dissection into the avascular retroperitoneal plane is preferred with dissection close to the bowel wall. This serves to diminish the size of the specimen by leaving behind some of the mesentery important during the rectal extraction process to limit rectal trauma that may result if the specimen is too bulky in nature. It also keeps the dissection planes well above the location of the presacral and hypogastric nerves thereby avoiding inadvertent injury. As a further advantage, the superior rectal artery is preserved which may play in role in the vascularization of the anastomosis. Lastly, the distal margin of the bowel is closed around the spike of the circular stapler using a purse-string suture instead of a linear stapler. Therefore, the circular stapler does not cross linear staple lines. For benign disease, splenic flexure takedown is not routinely performed unless required for a tension-free anastomosis.

Lateral Dissection with Release of Lateral Peritoneal Attachments (Video 7.1)

The left and sigmoid colon is released from the lateral peritoneal attachments. Dissection is initiated in a lateral to medial fashion with release of the white line of Toldt along the left colon to the level of the splenic flexure. The intersigmoid fold is then released exposing the left gonadal vein and left ureter. The dissection can be achieved with the use of the monopolar robotic scissors or the vessel sealer (Fig. 7.3).

The goal of this step is to mobilize the left and sigmoid colon from the lateral attachments to allow access to the mesenteric dissection along the axis of the bowel. Once a window is developed through the mesentery in step 2, division of the mesentery can proceed without concern of injury to the ureter or others critical structures of the pelvis.

Fig. 7.5 Division of mesentery utilizing vessel seal device from the level of the proximal resection margin to the level of the distal resection margin

Identification and Isolation of the Proximal Level of Resection (Video 7.2)

The proximal level of resection is identified. The mesentery is dissected from the bowel wall, and a window is made through the mesentery (Fig. 7.4). This step is best accomplished with the vessel sealer which provides hemostasis while avoiding thermal injury to the bowel wall.

Division of the Mesentery (Video 7.3)

The mesentery is divided using the vessel sealer from the level of the proximal resection margin to the level of the distal resection margin. Care is taken to remain above the superior rectal artery (Fig. 7.5). In cases in which the mesentery is severely thickened, inflamed, or involved with a phlegmon, this step may be difficult and cumbersome. In these cases, it may be best to enter into the retroperitoneal plane deep to the superior rectal artery toward the distal level of resection.

Identification and Isolation the Distal Level of Resection (Video 7.4)

The distal level of the resection margin is identified, and the mesentery along the surface of the bowel is cleared at this level.

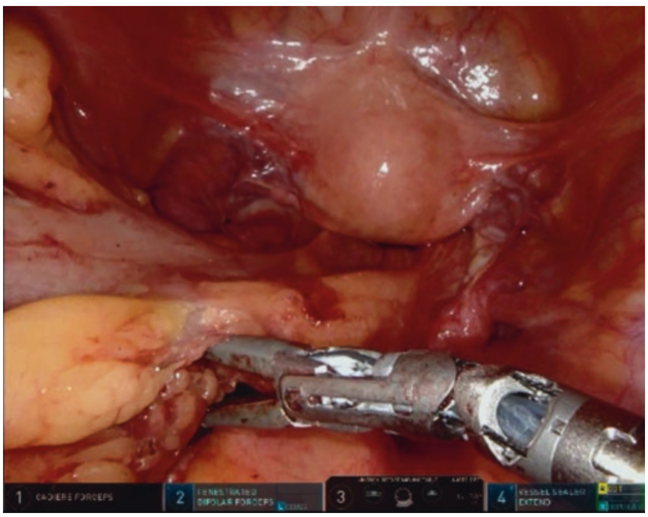

Fig. 7.6 Division of mesentery at distal level of resection utilizing vessel seal device

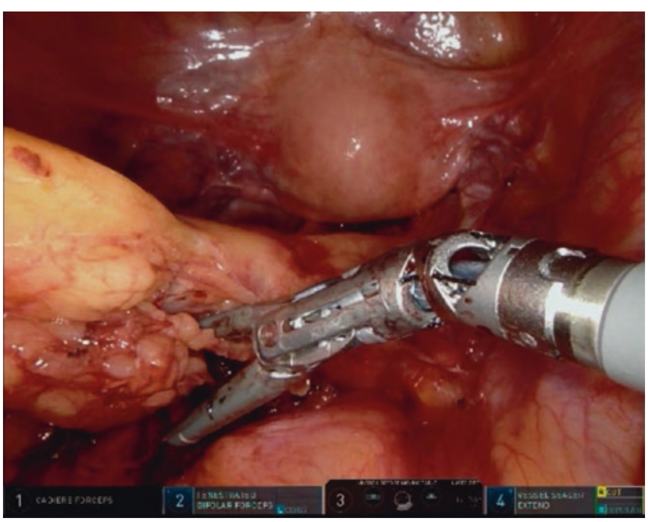

Fig. 7.7 Division of mesentery at distal level of resection utilizing vessel seal device

The vessel sealer is preferred to avoid thermal injury to the bowel wall (Figs. 7.6 and 7.7). It is often preferable to score and release the peritoneum laterally along the mid- and distal rectum as well as the anterior peritoneal reflection. This allows the rectum to be released and straightened which will serve as an anatomical advantage during many of the ensuing steps.

Division of the Proximal Margin (Video 7.5)

The bowel is divided at the proximal margin which has been cleared of the mesentery (Figs. 7.8, 7.9, and 7.10). The ves-

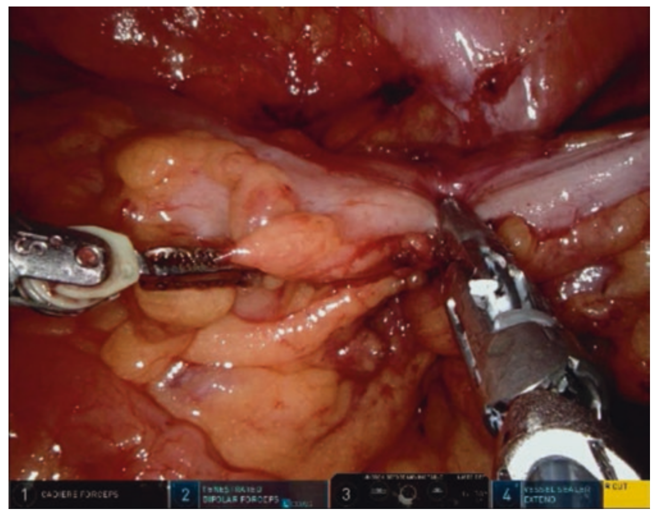

Fig. 7.8 Division of bowel at the proximal margin which has been cleared of the mesentery

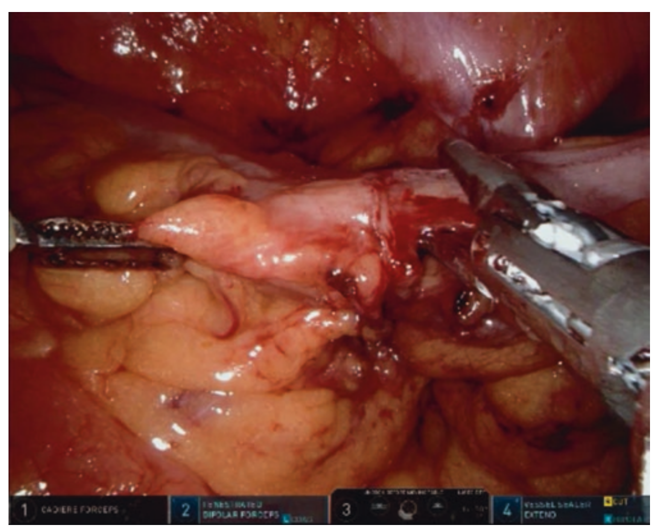

Fig. 7.9 Division of bowel at the proximal margin which has been cleared of the mesentery

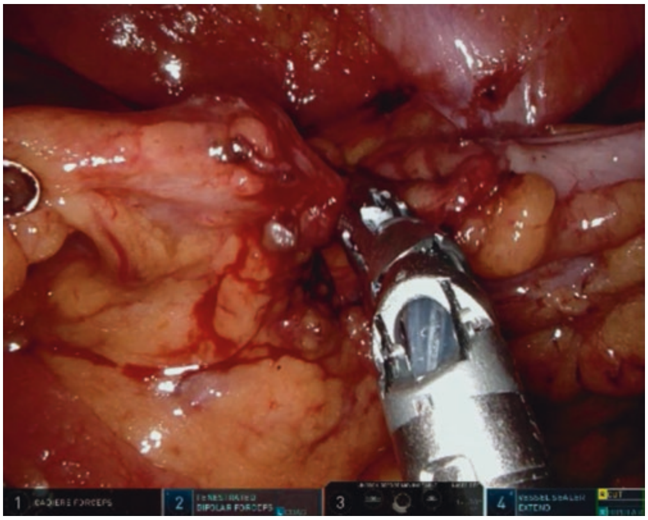

Fig. 7.10 Division of bowel at the proximal margin which has been cleared of the mesentery

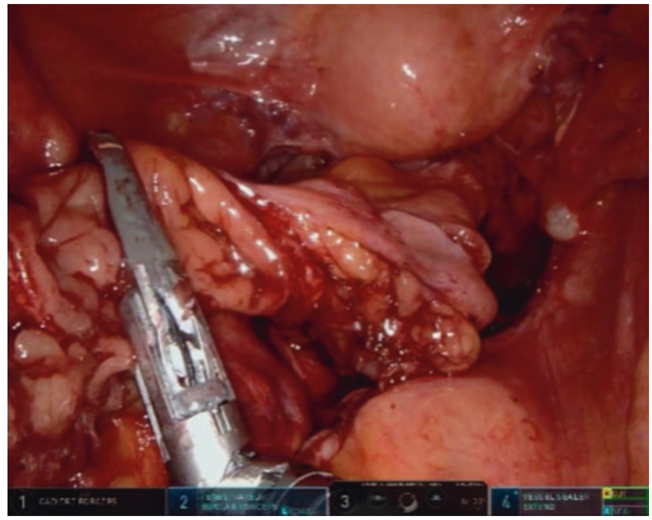

Fig. 7.11 Division of bowel at the distal margin which has been cleared of the mesentery

sel sealer is used to cut the bowel without the use of energy. This device provides consistent division. As an alternative, the robotic scissors can be used; however, this typically results in tendency for uneven edges.

Division of the Distal Margin (Video 7.6)

The bowel is divided at the distal margin which has been cleared of the mesentery (Figs. 7.11 and 7.12). When the proximal and distal bowel is divided, the assistant should be prepared to aspirate any residual intraluminal content to prevent inadvertent fecal soiling.

Transrectal Insertion of the Alexis Retractor (Video 7.7)

The Alexis retractor is placed through the rectum in preparation for extraction of the specimen. We utilize the small Alexis retractor for this purpose. The white rim is compressed with a large Kocher clap and gently introduced through the anus in a retrograde fashion. It is then delivered across the edge of the distal margin (Figs. 7.13, 7.14, 7.15, and 7.16). Placing a retractor through the rectum prior to specimen extraction is optional; however it is typically recommended to help reduce tearing and trauma to the rectal wall during the extraction process. As an alternative, an endobag can be delivered through the rectum; however, this tends to be more cumbersome and traumatic.

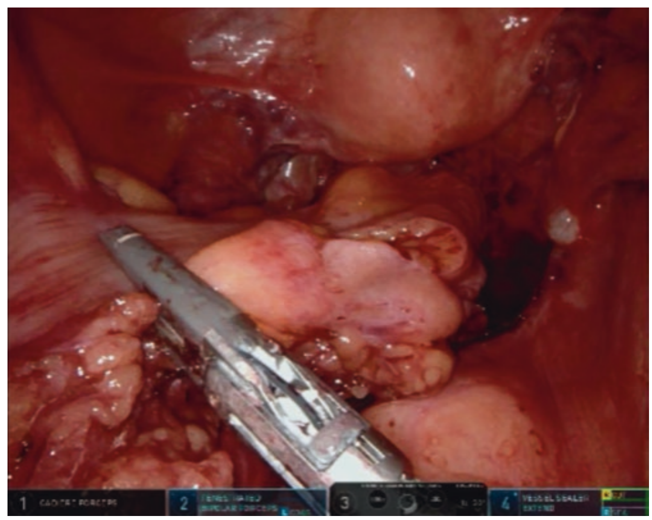

Fig. 7.12 Division of bowel at the distal margin which has been cleared of the mesentery

Transrectal Extraction of the Specimen (Video 7.8)

A bowel clamp is introduced through the anus in a retrograde fashion through the open cuff of the distal bowel. The clamp is opened, and the specimen is delivered into the jaws of the clamp. The clamp is closed about the specimen and extracts the specimen through the retractor and lumen of the rectum to complete the transrectal extraction process. The rim of Alexis retractor is then inverted, and the retrac-

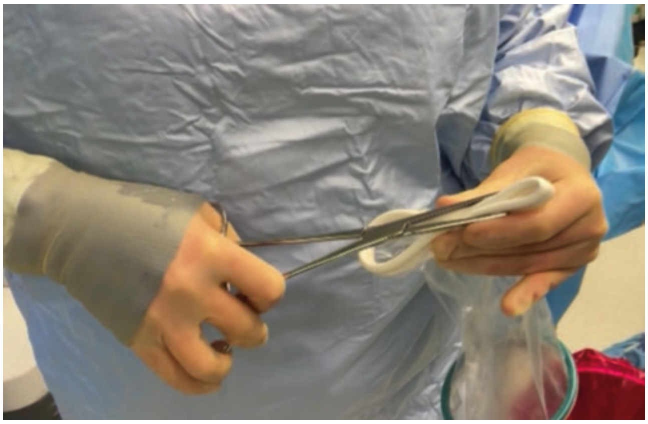

Fig. 7.13 Compression of the small Alexis retractor's white rim with a large Kocher clamp

Fig. 7.14 Introduction of Alexis retractor through the anus in a retrograde fashion

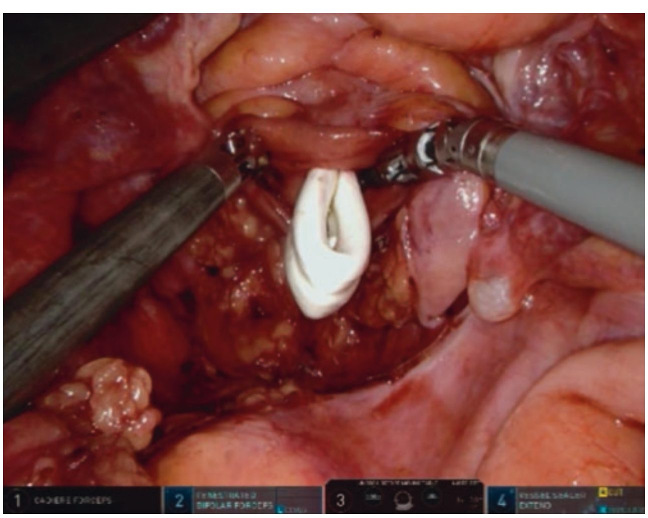

Fig. 7.15 Delivery of retractor across the edge of the distal margin

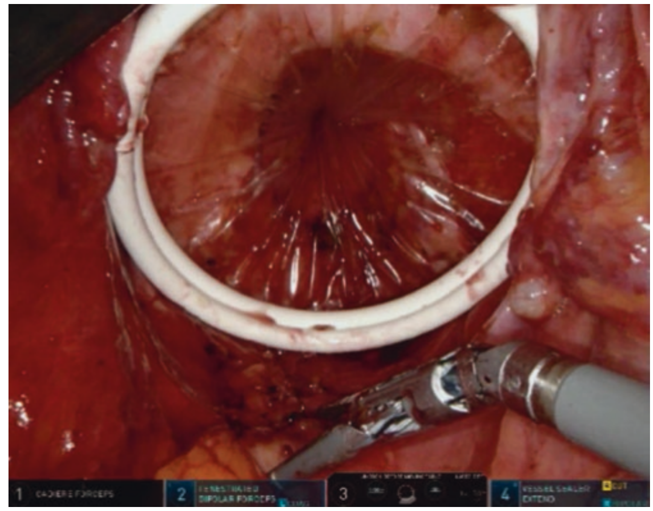

Fig. 7.16 Full expansion of retractor through the rectum

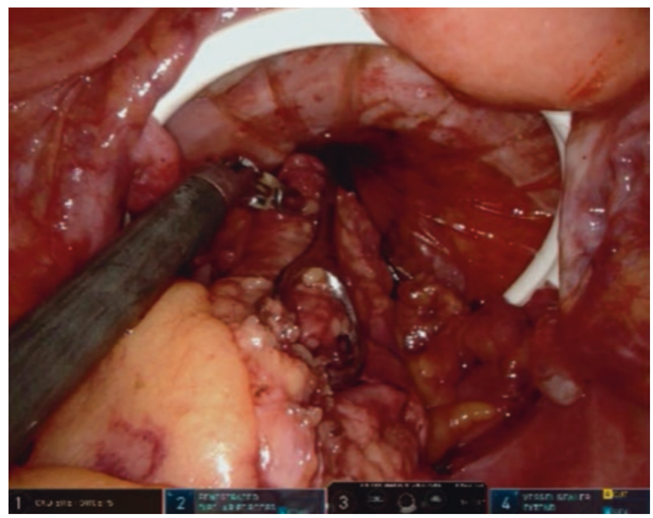

Fig. 7.17 A bowel clamp is introduced in a retrograde fashion through the anus beyond the open cuff of the distal bowel in order to grasp the specimen

tor is removed (Figs. 7.17, 7.18, 7.19, and 7.20). This step can be the most challenging and injury-prone step of the procedure. Measures to avoid trauma and facilitate delivery are addressed below.

Transrectal Delivery of the Anvil into Abdomen (Video 7.9)

The circular stapling device is inserted through the anus with the anvil attached and advanced through the open distal bowel lumen. The anvil is then detached and delivered into the abdominal cavity. Alternatively, the anvil can be detached from the stapler prior to insertion and delivered with a clamp

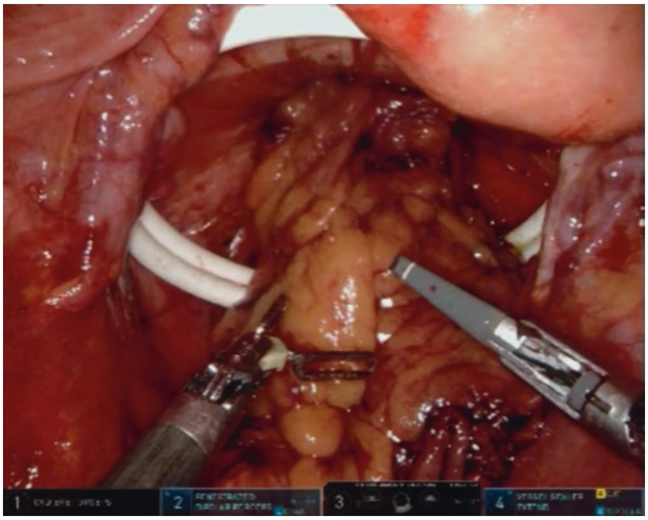

Fig. 7.18 The clamp is closed about the specimen, and extraction through the retractor and lumen of the rectum is accomplished

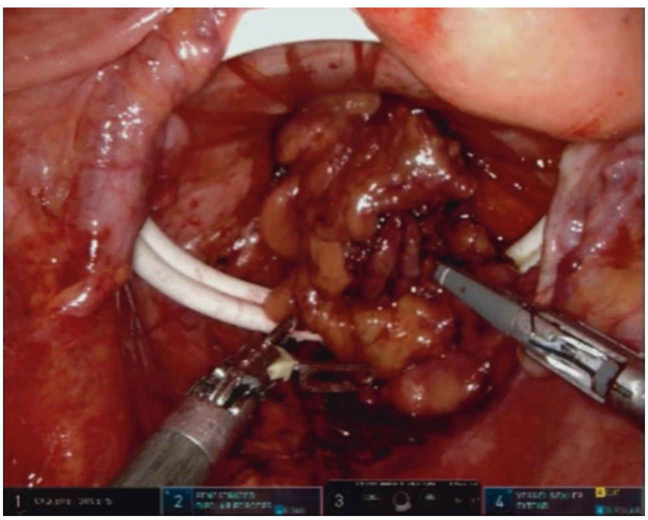

Fig. 7.19 The clamp is closed about the specimen, and extraction through the retractor and lumen of the rectum is accomplished

through the rectum (Figs. 7.21, 7.22, and 7.23). Introducing the stapler through the rectum with the anvil attached facilitates ease of passage. This serves a distant benefit in cases in which the flat edge of the stapler head results is tearing or difficulty passing through the rectum.

Securing the Anvil to Proximal Bowel (Video 7.10)

A purse-string suture is placed around the edge of the proximal bowel lumen using a 3–0 V-lock suture. The anvil is then placed into the bowel lumen and secured in place by

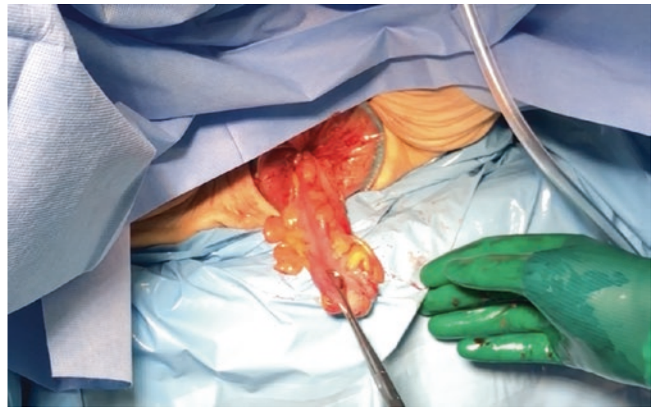

Fig. 7.20 The specimen is extracted through the rectum

Fig. 7.21 The circular stapling device is inserted through the anus with the anvil attached and advanced through the open distal bowel lumen

tightening the suture. Typically, additional suturing is required to ensure the tissue is adequately drawn into the anvil (Figs. 7.24, 7.25, and 7.26). An Endoloop can be used to reinforce the closure once the purse-string is place. In some cases, the Endoloop alone may suffice to secure the anvil.

Closing the Distal Bowel Around Circular Stapler (Video 7.11)

A second purse string is placed around the edge of the distal bowel lumen. The spike of the circular stapler is advanced, and the purse string is tightened drawing the tissue around the spike. Additional sutures may be required to ensure complete closure of the tissue about the spike of the stapler (Figs. 7.27 and 7.28).

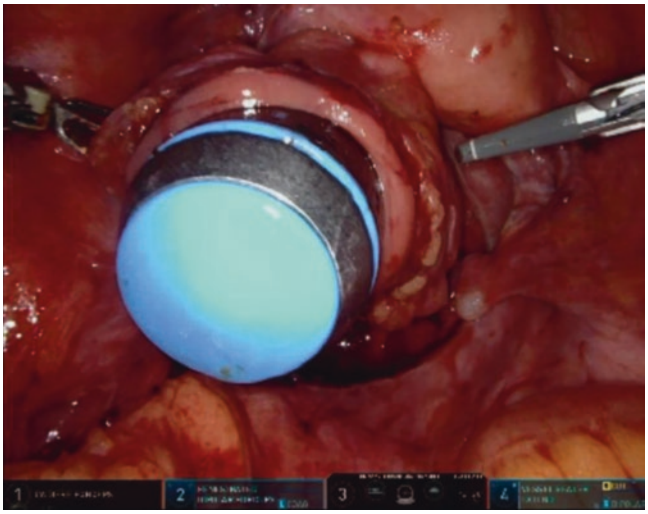

Fig. 7.22 The anvil is detached from the head of the circular stapler and delivered into the abdominal cavity

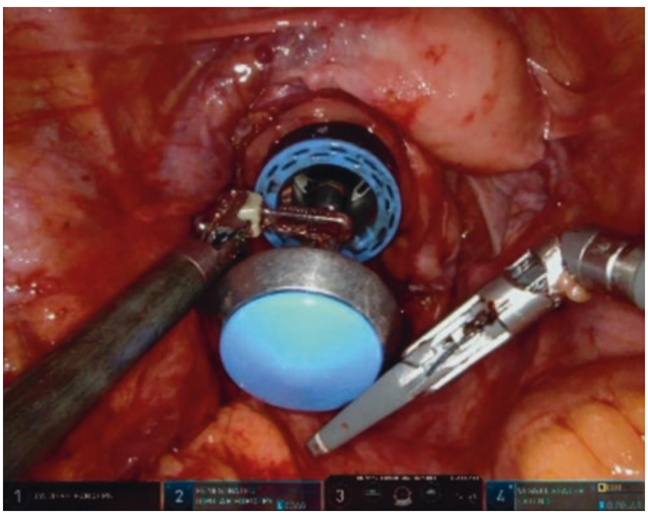

Fig. 7.23 The anvil is detached from the head of the circular stapler and delivered into the abdominal cavity

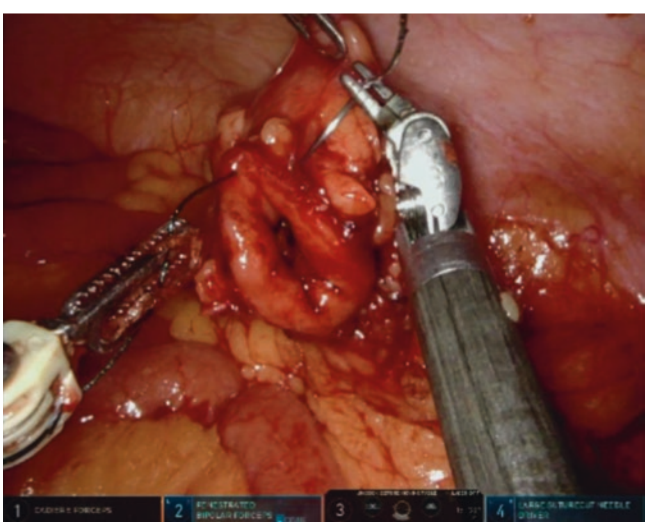

Fig. 7.24 A purse-string suture is placed around the edge of the proximal bowel lumen

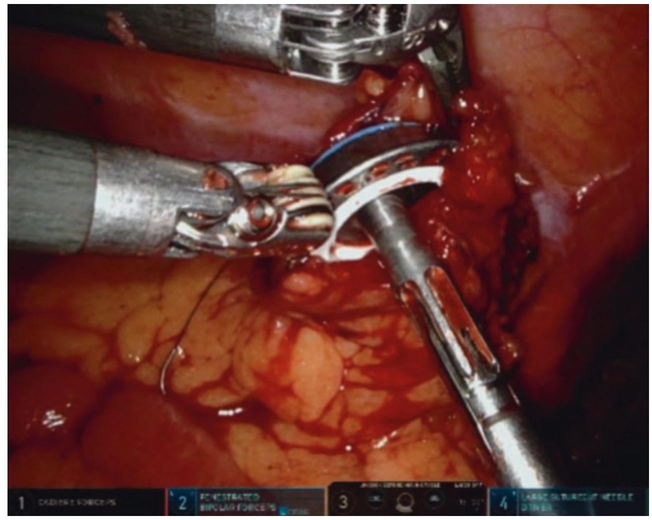

Fig. 7.25 The anvil is placed into the bowel lumen

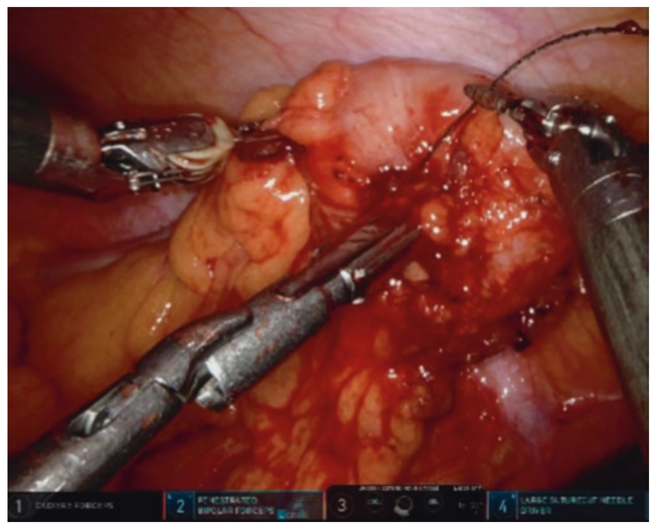

Fig. 7.26 The anvil is secured in place by tightening the suture

Formation and Oversewing of End to End Anastomosis (Video 7.12)

The anvil is seated to the spike of the circular stapler, and an anastomosis is formed by activating the stapling device (Figs. 7.29, 7.30, and 7.31). The anastomosis is evaluated by several measures. Direct luminal visualization is achieved via rigid or flexible proctosigmoidoscopy. External visualization is performed before and during air insufflation testing. The proximal and distal donuts are removed and inspected for completeness and thickness. If any measures indicate, the anastomosis is oversewn preferentially with interrupted 3.0 absorbable suture (Figs. 7.32 and 7.33).

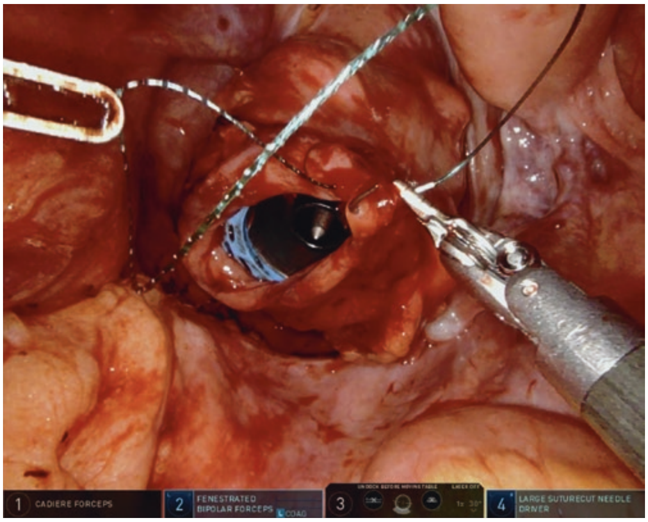

Fig. 7.27 A second purse string is placed around the edge of the distal bowel lumen

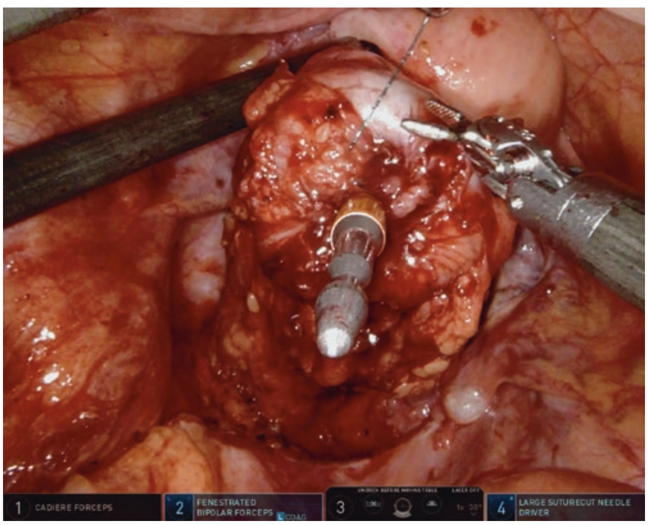

Fig. 7.28 The spike of the circular stapler is advanced, and the purse string is tightened drawing the tissue around the spike

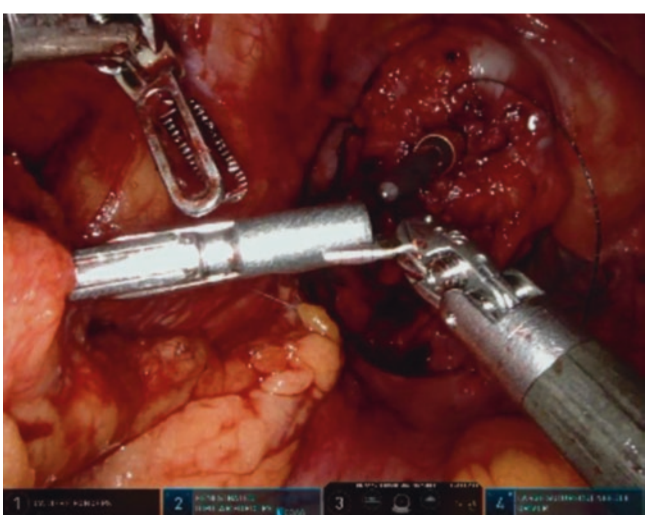

Fig. 7.29 The anvil is seated to the spike of the circular stapler

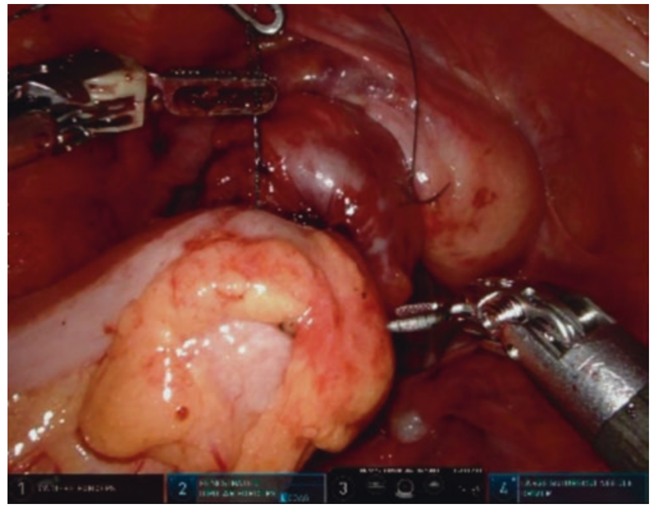

Fig. 7.30 The anastomosis is formed by activating the stapling device

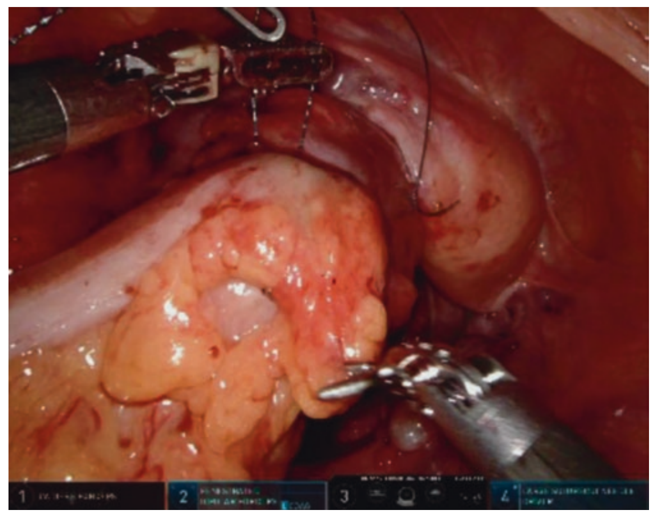

Fig. 7.31 The anastomosis is formed by activating the stapling device

Technical Considerations

Bowel prep: A mechanical bowel preparation is recommended for these cases to help avoid contamination following division of the bowel. When dividing the bowel, prepare for inadvertent contamination by having the beside assistant hold a suction adjacent to the tissue. If soilage occurs, evacuation can typically be accomplished with suction and gentle irrigation alone. If this is not sufficient, insertion of a small surgical sponge through one of the 8 mm ports can help to aspirate and clear the contents. The soiled surgical sponge can then be delivered transrectally along with specimen through the Alexis retractor.

Continuous pressure pneumoperitoneum: To facilitate continuous pneumoperitoneum, we prefer to use the air-seal device although others can be used. Continuous pressure pneumoperitoneum is most important during the transrectal

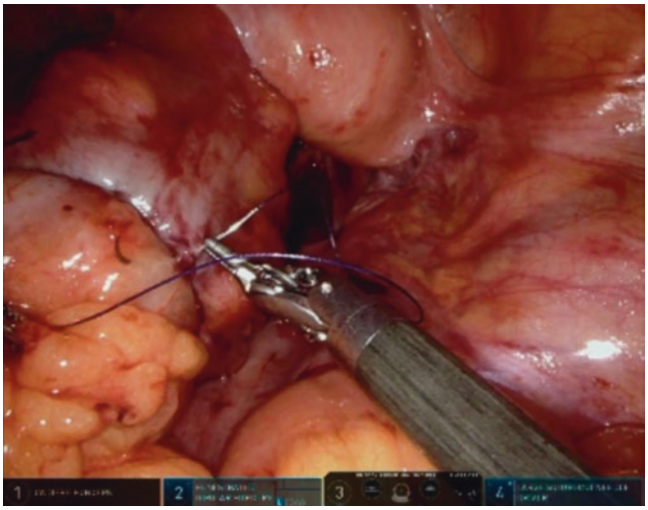

Fig. 7.32 Oversew of the anastomosis with interrupted 3.0 absorbable suture

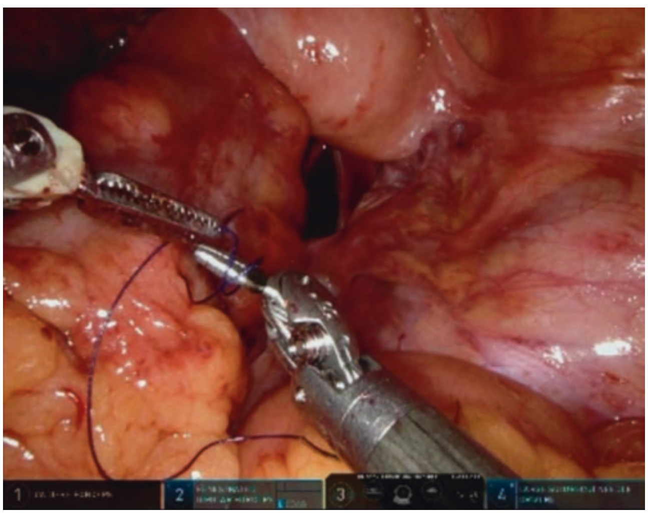

Fig. 7.33 Oversew of the anastomosis with interrupted 3.0 absorbable suture

extraction process where loss of pneumoperitoneum can occur when placing the Alexis and extracting the specimen.

Securing the anvil: Intracorporeal placement of the anvil in preparation for the anastomosis can be one of the more technically challenging and important steps of the procedure. Suboptimal placement can lead to an insecure anastomosis. We prefer placement of a purse-string suture; however, in some scenarios, an Endoloop alone can be used to secure the anvil. In other scenarios, we use a purse-string suture followed by an Endoloop to reinforce the closure. Once the anvil is secured, it may be necessary to trim excess tissue to achieve a smooth surface in preparation for a successful anastomosis. Allow for additional time to successfully complete this step in the early phases of your learning curve.

Closing the rectal cuff: Closing the bowel wall around the spike of the circular stapler can also be technically challenging especially during the early phases of the learning curve for this technique. Using an Endoloop is typically not feasible. In cases in which the distal level of the bowel margin is closer to the mid- or low rectum, the rectal wall tends to be wider, and it may be more feasible to staple across the rectum as opposed to placing a purse-string suture.

Extracting the specimen: There can be several situations in which it is difficult to extract the specimen transrectally. This most commonly occurs in complex diverticular disease with an abscess or phlegmon. In these cases, it becomes evident during the extraction process that the bulky nature of the specimen will not readily pass through the rectum. It is important not to force too much pressure during the extraction process as this can lead to significant injury and tearing of the rectal wall. In such cases, we divide the mesentery along the border of the specimen using the vessel seal device or robotic scissors. This serves to effectively splice the specimen in half and allow retrieval of the bowel and then retrieval of the detached mesentery in a second extraction. This process allows safe extraction while avoiding inadvertent injury. Although this can be a laborious task, we find these patients may benefit the most by avoiding a larger abdominal wall incision required to extract the bulky specimen.

Injury to the bowel during extraction: Trauma during the extraction process may result in tearing of the bowel wall. Most cases involve minor injury along the edge of the bowel lumen that can be primarily repaired. Some tears may not be readily apparent and may occur in the mid or lower rectum if too much force is used to extract a bulky specimen. Unassuming injury may also occur while placing the extracting instrument into the rectum to grasp the specimen. Regardless of the mechanism, the key is to identify the full extent of the injury and repair it. The repair can be a single layer with running or interrupted suture oriented to avoid narrowing of the rectal lumen. It is prudent to perform a thorough evaluation of the anastomosis as well as the integrity of the distal bowel in every case to ensure any injury is identified and attended to. Diverting loop ileostomy is not required or recommended as long as the full extent of the injury is identified and properly repaired.

Summary

The NICE procedure is an advanced robotic technique that facilitates left-sided resection and primary anastomosis without an extraction incision. All of the steps of the anastomosis are performed intracorporeally with enabling robotic technology. The procedure affords the patient many advantages including elimination of pain associated with the extraction incision as well as elimination of surgical site infection risk and hernia risk.

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Robotic Total Mesocolic Excision

8

Deniz Atasoy, Bilgi Baca, Ismail Hamzaoglu, and Tayfun Karahasanoglu

Introduction

In this chapter, we aim to describe the robotic total mesocolic excision (TMCE) technique for colon cancer. We will discuss the basics of TMCE and specifically the robotic approach. Robotic technology offers better dexterity, increased triangulation, and ergonomic superiority. The disadvantages like increased cost and operative time may be counterbalanced by achievement of better specimen quality and improved oncologic outcomes, which needs further investigation. We will describe the procedural steps in each approach in detail with special emphasis on the key points in every step.

Background

The hypothesis of total mesocolic excision (TMCE) is based on the concept of total mesorectal excision described by Heald et al. in 1982 [1]. TMCE includes removal of the mesocolon and supplying vessels en bloc with the tumor [2]. The length of healthy colon to be removed proximal and distal to the tumor differs between European and Japanese schools [3]. Vessels should be highly ligated, and the mesocolon should have an intact peritoneal envelope [2, 4]. TMCE involves high ligation of the supplying vessels both in right-sided and left-sided colon tumors [4].

The aim is to remove the colon tumor with all its draining lymphatics and blood supply within an intact envelope. In a retrospective population-based study, it was reported that TMCE was associated with better disease-free survival in stage I–III colon adenocarcinoma compared to conventional colon cancer surgery [5].

Although the TMCE concept was first described in 2003, its popularity is increasing lately.

The mesocolic fascia envelops all the colon from rectum to cecum [2]. The TMCE procedure is meticulously advanced in the embryologic plane between the mesocolic and retroperitoneal fascia [2]. The dissection is advanced within the embryological plane of Toldt's fascia (mesofascial-retrofascial planes). Injuries to the visceral peritoneum should be avoided. It is reported that excision with an intact mesocolon is associated with a 15% greater 5-year survival [6].

The idea of en bloc removal of a colon tumor was not new before 2003. Turnbull R.B., Jr. [7], described a so-called no-touch isolation technique in 1953, in which the tumor-bearing colonic segment was handled only after ligation of the lymphovascular pedicles and transection of the proximal and distal ends of the colon in order to prevent tumor dissemination. He reported that with this technique, 5-year survival of colon tumor patients increased. However, in his technique, he didn't mention about the mesocolic visceral peritoneal envelope and high ligation of the vessels.

Although debated some studies reported that increased lymph node harvest with high-ligation technique was associated with better survival [8–10].

The robotic platform overcomes some of the laparoscopic limitations. Until recently the only available robotic platform is the da Vinci system (Intuitive Surgical Inc., Sunnyvale, CA, USA). Hence, the procedure in this chapter is discussed based on this platform.

The robotic skill set is built upon the experiences gained from the laparoscopic approach. However, differences between two approaches exist. In this chapter we will describe the robotic approach for TMCE in detail especially

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D. Atasoy · I. Hamzaoglu · T. Karahasanoglu
Department of General Surgery, Acibadem Mehmet Ali Aydinlar University, School of Medicine, Istanbul, Turkey

B. Baca (✉)
Department of General Surgery, Acibadem Mehmet Ali Aydinlar University, School of Medicine, Istanbul, Turkey

Atakent Acibadem Hastanesi, Kucukcekmece/Istanbul, Turkey

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the medial to lateral approach. Some modifications and variations to this approach including a modified top-down approach will also be discussed.

In theory, robotic technology bears all the advantages of laparoscopic surgery [11, 12]. Theoretical advantages of the robotic platform which include stable vision, increased articulation, better dexterity, and ergonomic superiority are still to be addressed.

To this date, the only randomized study available comparing the robotic and laparoscopic approaches was the ROLARR study, conducted in rectal cancer [13].

Previously, a right hemicolectomy was considered a "learning procedure" for beginners in laparoscopic colorectal surgery, compared to a left hemicolectomy [14]. However, with the introduction of the TMCE concept, a right hemicolectomy is considered more technically challenging than the left hemicolectomy.

Room Setup and Positioning

Common/General Rules

The da Vinci system has currently two main platforms in use: the da Vinci Si and Xi platforms. The port placement varies according to the platform utilized. Generally, for the Si platform, ports are placed in a "crescent" fashion. However, ports for the Xi platform, which we currently use, are placed in a linear fashion.

Legs are separated apart with Allen stirrups. Allen stirrups are preferred, due to allowing for lithotomy repositioning in case an endoscopy is required and due to less collision with the robotic arms. The bedside assistant stands on the left side of the patient.

The patient is placed in supine position with both arms tucked on the sides. The position is preferably supported with padded straps and shoulder supports (Fig. 8.1). This prevents arm injury or nerve injuries due to longer operating times or Trendelenburg positioning. In contrast to the Si platform, the Xi platform could be docked from both sides of the patient. However, in order not to obstruct the working space of the bedside surgeon, the robotic cart is placed from the patient's right for right colon approaches and from the patient's left for left colon approaches. The monitor should be in direct view of the bedside surgeon. The distance between ports should be kept at least 8 cm in both platforms.

Fig. 8.1 Patient position

The pneumoperitoneum could be created in several ways. We generally prefer the closed technique with a Veress needle. Two commonly used places for insertion of the Veress needle are the umbilicus and Palmer's point at the intersection of left subcostal and midclavicular lines. Open Hasson technique could be used, especially with previous abdominal surgeries. Optical trocar entry could also be utilized especially in obese patients.

To enable passage of an endoscopic or robotic stapler, one of the robotic or bedside assistant's trocars should be changed for a 12 mm laparoscopic or robotic trocar for laparoscopic or robotic stapler use accordingly.

For specimen extraction, median, para-median, lower quadrant transverse or suprapubic incisions are described. In our practice, we use the suprapubic incision due to its cosmetic superiority and decreased incisional hernia risk [15].

Robotic Right and Extended Right Colectomy with TMCE

For cecal tumors we perform a right TMCE with high ligation of the right branch of the middle colic vessels. For ascending colon, hepatic flexure, and proximal transverse colon tumors, an extended right TMCE with the ligation of the middle colic vessels at their roots is performed.

Port Placement

Port placement for robotic right and extended right TMCE is different according to the tumor location. For cecal tumors, ports and instruments are placed as follows: double fenestrated tip-up grasper at R1 (8 mm), double fenestrated bipolar forceps at R2 (8 mm), camera at R3 (8 mm), and monopolar curved scissors at trocar R4 (8 mm) (Fig. 8.2a, b). For hepatic flexure or transverse colon tumors, ports and instruments are placed as follows: double fenestrated bipolar forceps at R1 (8 mm), camera at trocar R2 (8 mm), monopolar curved scissors at R3 (8 mm), and double fenestrated tip-up grasper at

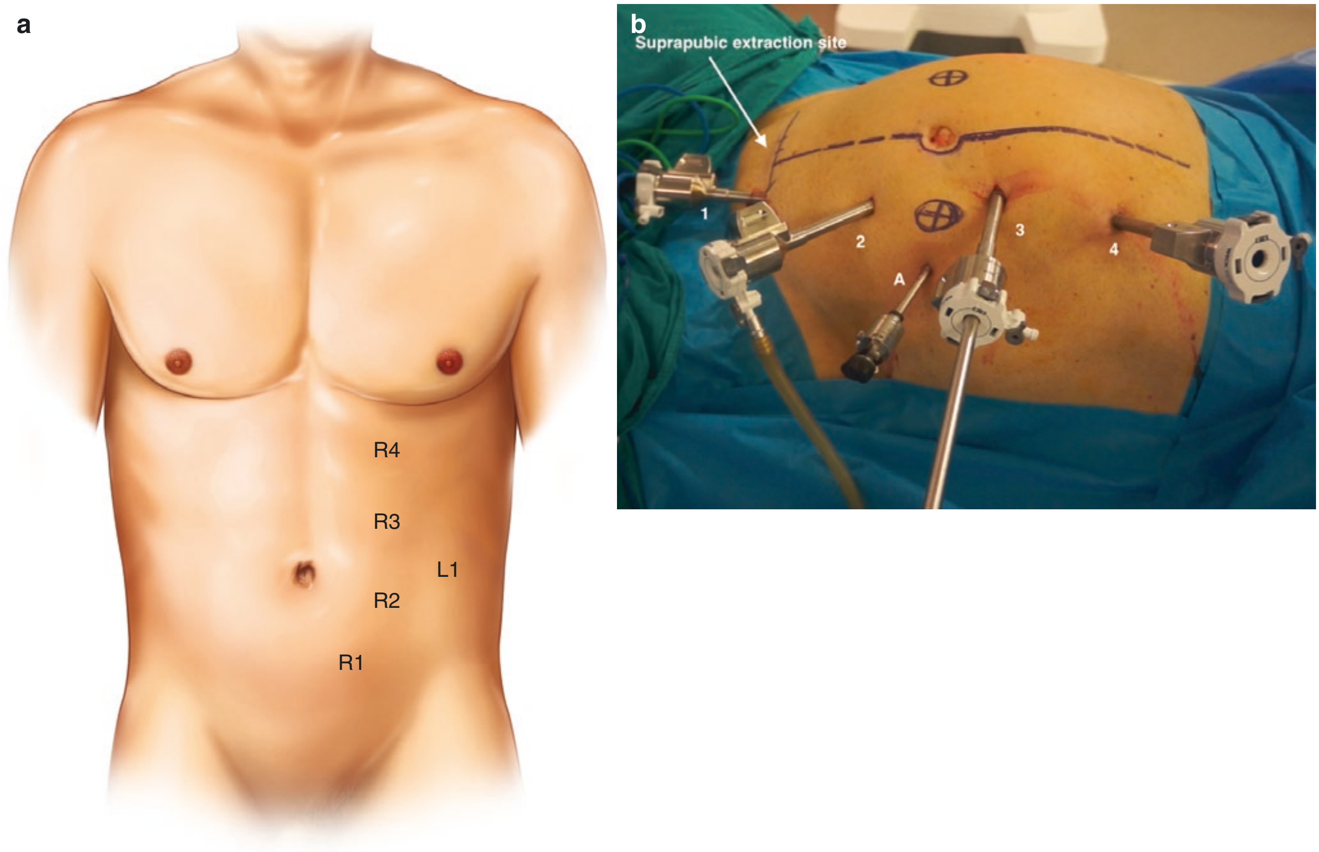

Fig. 8.2 (**a**, **b**) Port configuration for cecum tumor

trocar R4 (8 mm). Later in the operation, R4 is changed to a 12 mm trocar in order to introduce the endoscopic stapler for bowel transection and intracorporeal anastomosis. An assistant 5 mm port is placed on the left lower quadrant (Fig. 8.3a, b).

Operative Steps

Operative steps	Degree of technical difficulty (scale 1–10)
1. Exploratory laparoscopy	1
2. Identification of the SMV to ileocolic pedicle junction	5
3. Dissection and division of the ileocolic vessels	6
4. Identification, dissection and division of Henle's trunk	8
5. Dissection and division of middle colic vessels	7
6. Mobilization of the right colon and transection of the distal ileum	3
7. Mobilization of the hepatic flexure and transection of the transverse colon	3
8. Specimen extraction and intracorporeal anastomosis	4

Exploratory Laparoscopy

The abdominal cavity and the liver are examined for any metastatic disease. After verification of limited disease to the colon, the operation proceeds with positioning of the patient. The table is tilted leftward 30° and 15–30° in a Trendelenburg position. The small bowel is displaced toward the left half of the abdomen. Omentum is placed over the transverse colon, and the colon is retracted cranially as much as possible. After docking the robot for a cecal tumor, the robot is targeted toward the right colon; for hepatic flexure or proximal transverse colon tumor, the robot is targeted toward the hepatic flexure of the colon.

Identification of the SMV to Ileocolic Pedicle Junction

The anticipated ileocolic pedicle is grasped near the cecum and retracted anterolateral toward the abdominal wall (Fig. 8.4). Elevation of the right mesocolon enables to see the superior mesenteric vein (SMV) edge or reflection as well as the duodenal fossa under the visceral mesocolon (Fig. 8.5). The peritoneum is incised with monopolar robotic scissors or a hook over

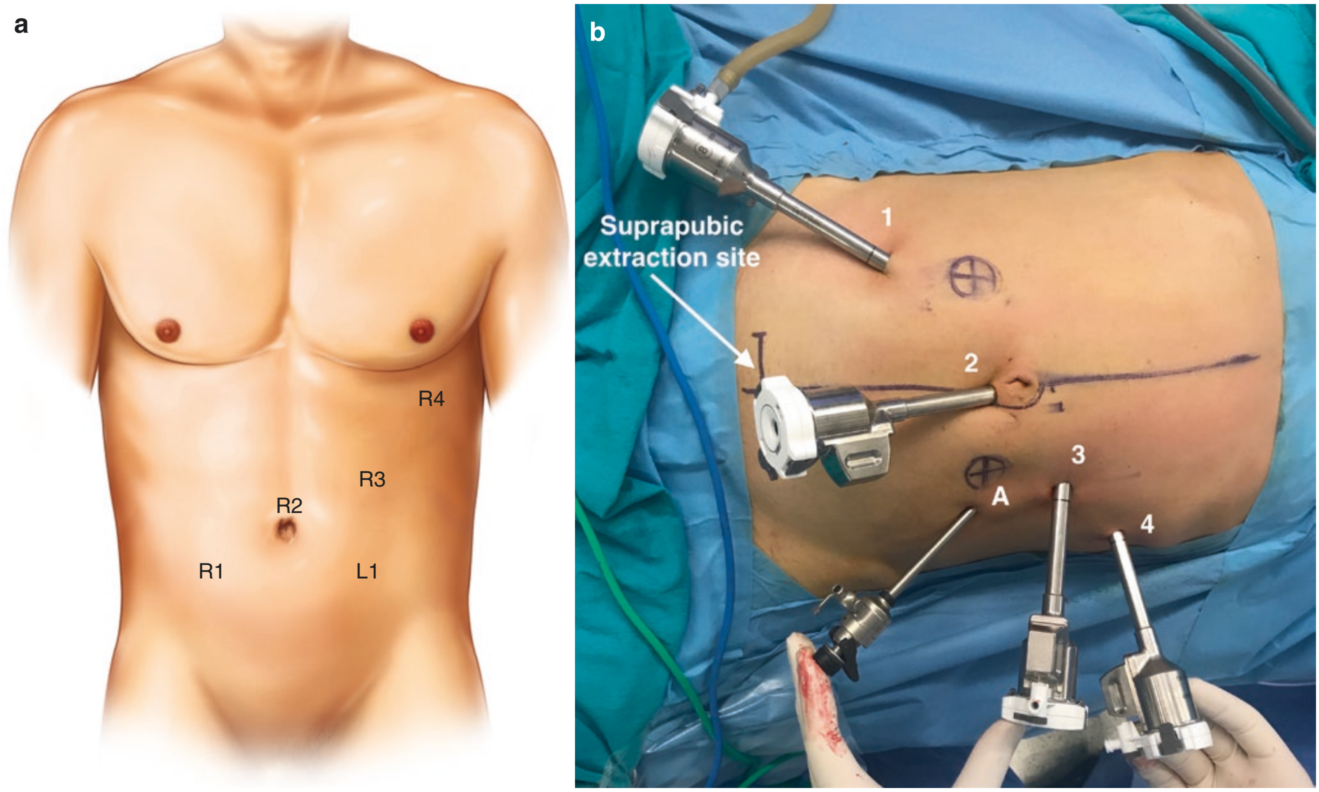

Fig. 8.3 (**a**, **b**) Port configuration for right flexure or transverse colon tumor

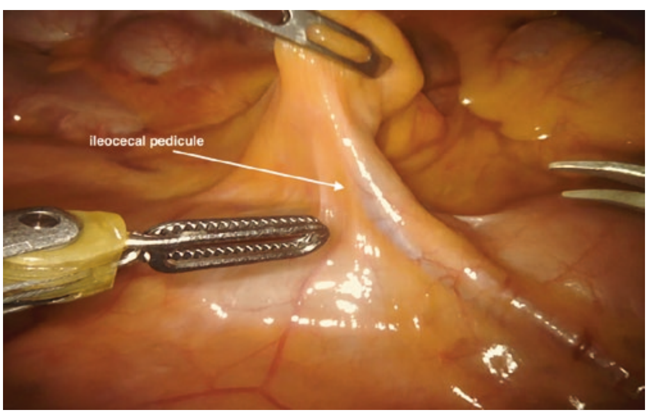

Fig. 8.4 Identification of the ileocolic pedicle

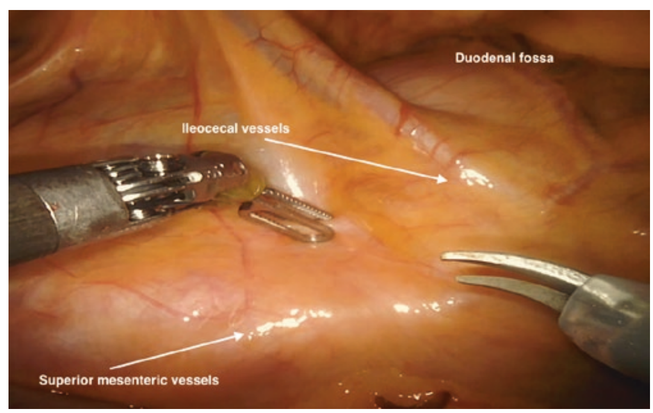

Fig. 8.5 Superior mesenteric vein reflection and duodenal fossa are seen

the SMV. Dissection first proceeds caudally toward the ileal mesentery and then returns cranially toward the mesentery of the right colon. Because there is no tactile feedback in robotic surgery, all-important structures should be visualized before dissecting, clipping, or cutting. Otherwise significant injuries and severe bleeding can occur during the procedure.

The terminal ileal mesentery is dissected toward the ileum 10 cm from the ileocecal valve (Fig. 8.6). In this stage bipolar forceps or a vessel sealer can be used for vascular control of the ileal tributaries. The ileum is not transected in this stage in order to prevent twisting of the bowel during TMCE.

Sharp dissection is preferred, since blunt dissection may cause inadvertent injuries to the small tributaries leading to difficulty visualizing detailed structures in the surgical field.

Dissection and Division of the Ileocolic Vessels

Dissection advanced proximally along the SMV is continued to the ileocolic vessels cranially. Dissection of the lymph nodes around the SMV as well as the SMA posteriorly is com-

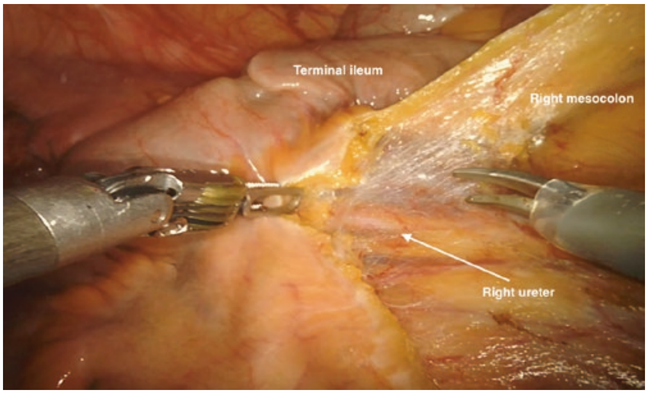

Fig. 8.6 Dissection of terminal ileum mesentery

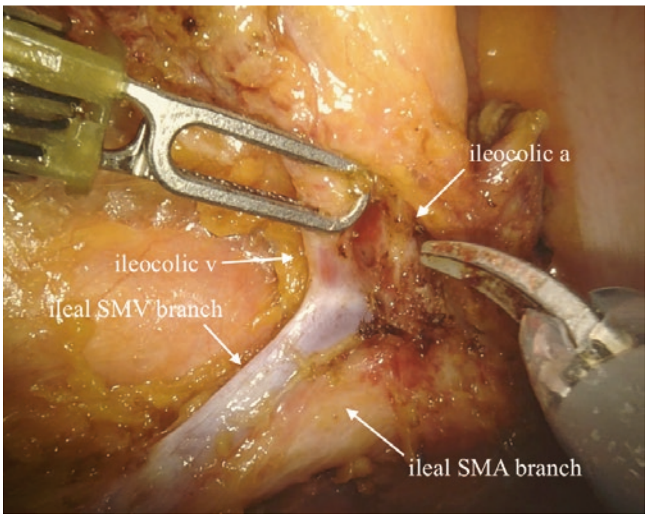

Fig. 8.7 Central isolation of the ileocolic vein

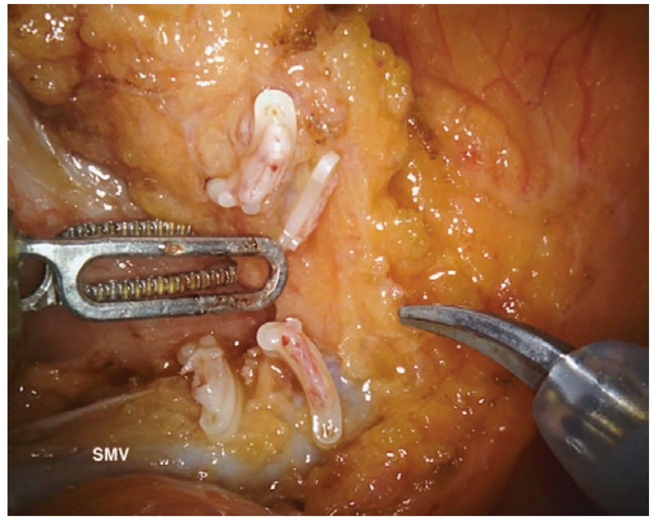

Fig. 8.8 İleocolic vessels are clipped and cut

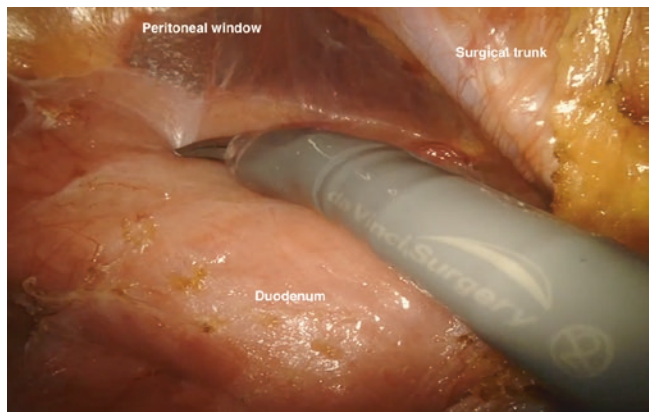

Fig. 8.9 Intact peritoneal window and surgical trunk are seen

pleted. The ileocolic vein and ileocolic artery are seen, respectively (Fig. 8.7). After identification of the ileocolic artery and vein, they are dissected and cut between clips (Fig. 8.8, Video 8.1). For this transection a vessel-sealing device or intracorporeal ligation could also be used. Vessels are generally dissected from the lymph nodes and nerves for safe ligation. In this stage, care should be taken to prevent duodenal injury.

Identification, Dissection, and Division of Henle's Trunk

Following ligation of the ileocolic vessels, dissection is advanced along the SMV cranially. At this phase, the "peritoneal window" and "surgical trunk" of the ascending colon mesentery next to the duodenum are kept intact (Fig. 8.9).

During the dissection it should be kept in mind that the SMV is usually anterolateral to the SMA and the dissection plane proceeds close to the SMV. Attention should be paid to the variations of the vessels. Right colic vessels, if present, should be ligated at their roots. Proximally, a gastropancreatocolic vein (*Henle's* trunk) is encountered (Fig. 8.10, Video 8.2). A meticulous surgical dissection should be performed in order to avoid unintentional injuries to the *Henle's* trunk. This is the most probable bleeding point during this operation. Traction and counter traction should be very gentle to avoid venous injuries. This vein is formed by three vessels: right gastroepiploic, superior right colic, and anterior-superior pancreatic veins.

Dissection and Ligation of Middle Colic Vessels

Following ligation of the gastropancreatocolic vein, the middle colic artery is encountered cranially. Branches going to the right colon should be ligated and transected. For right TMCE, ligation of right branches of the middle colic vessels is sufficient (Figs. 8.11 and 8.12). For extended right TMCE, the middle colic vessels should be ligated at their roots.

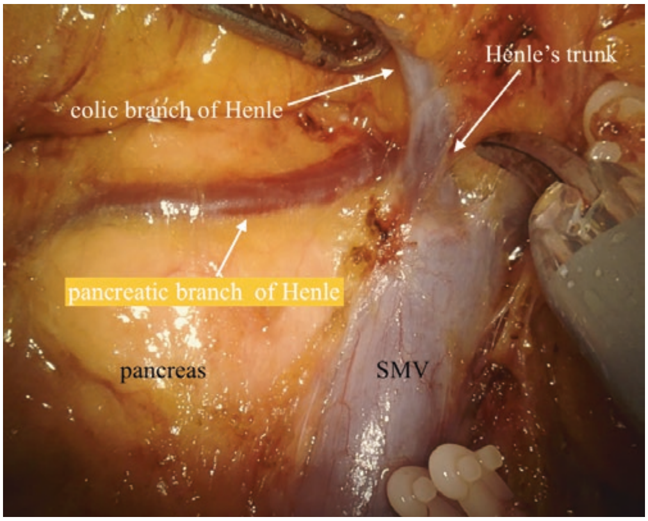

Fig. 8.10 Vascular anatomy of the gastrocolic trunkus (*Henle's* trunk) is seen

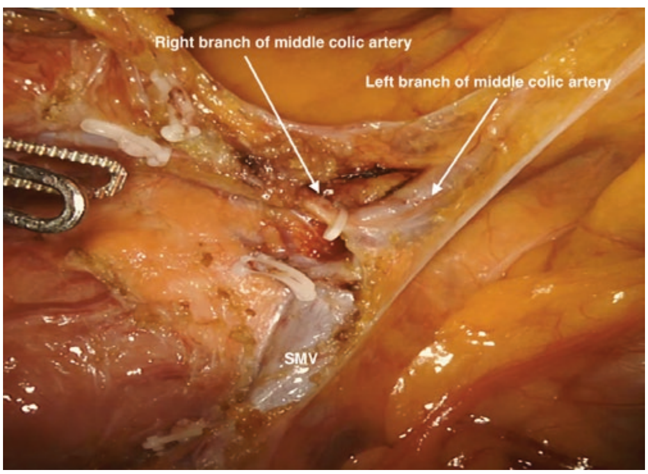

Fig. 8.11 Bifurcation of the middle colic artery

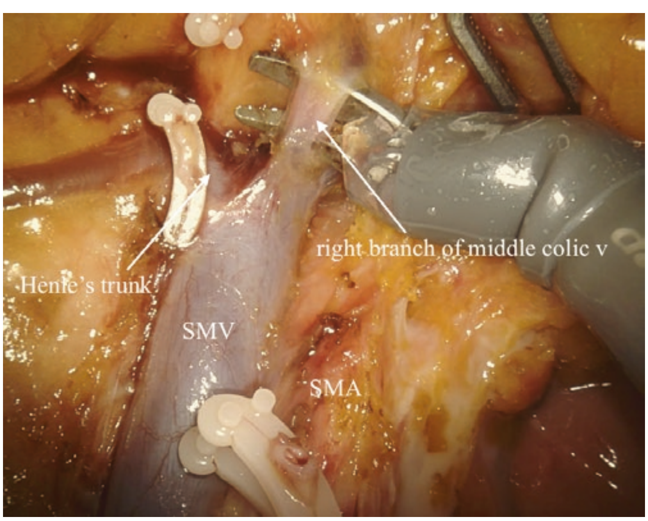

Fig. 8.12 Identification of the middle colic vein

Mobilization of the Right Colon and Transection of the Distal Ileum

After completion of vessel ligation, dissection is proceeded in the avascular embryologic plane between the retroperitoneal fascia and posterior peritoneal leaf of the right mesocolon (Figs. 8.13 and 8.14, Video 8.4). If the dissection is kept in the embryologic plane, the right ureter, right gonadal vessels, and autonomic nerves are safe. Division of the lateral attachments frees the right colon.

The distal ileum is prepared for transection. Care is taken to preserve the vascular arcade to the terminal ileum. The ileum could be transected by either laparoscopic or robotic linear staplers (Video 8.5). At this point, a 12 mm laparoscopic or robotic port replaces one of the 8 mm port sites to accommodate a stapler.

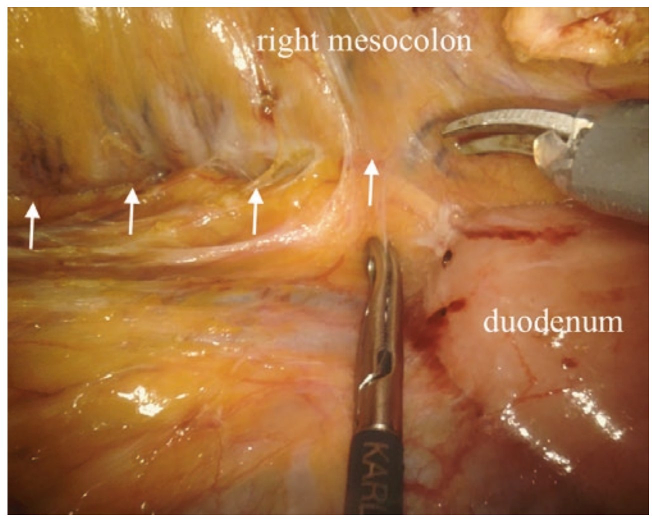

Fig. 8.13 Medial to lateral dissection is completed

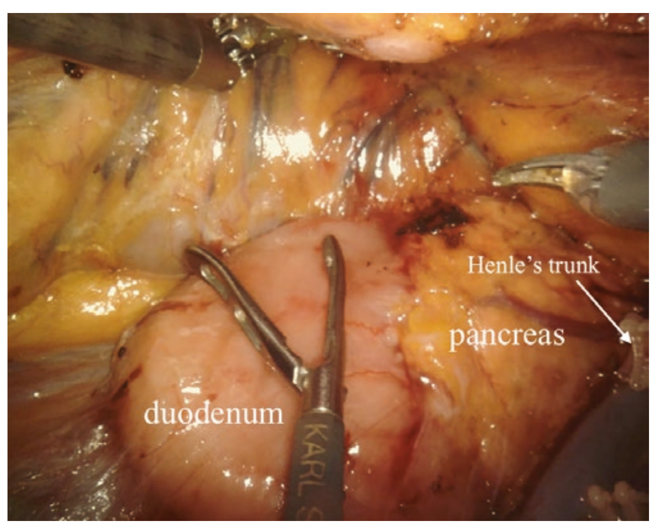

Fig. 8.14 Duodenum and head of the pancreas are fully separated from the right mesocolon

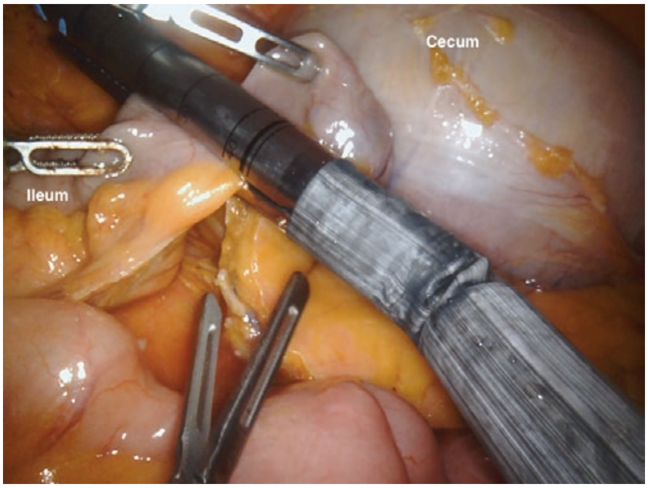

Fig. 8.15 Terminal ileum is transected with robotic stapler

Generally, "blue" cartridges are preferred. Depending on the diameter of the ileum, one or two firings are needed (Fig. 8.15). The position of the patient generally is not changed until the end of resection because every change in the position requires undocking and redocking of the robotic system.

Mobilization of the Hepatic Flexure and Transection of Transverse Colon

The hepatic flexure is freed in both right and extended right TMCE procedures.

It could be taken down by a lateral to medial approach or vice versa. In our practice, we prefer the medial to lateral method. The dissection plane is advanced between the head of the pancreas and the transverse mesocolon.

In the lateral to medial approach, the lesser sac is entered first, through the gastrocolic ligament (greater omentum), and then the dissection continues to the hepatocolic ligament (Fig. 8.16).

The right-sided omentum and subpyloric lymph nodes are taken out en bloc with the transverse colon for tumors located at the hepatic flexure and in the proximal transverse colon. The right gastroepiploic artery and vein are ligated. However, omentum is not harvested in patients who have cecal tumors.

After completion of the hepatic flexure takedown, the proximal transverse colon is prepared for transection. Firefly technology can be used to check perfusion of the bowel ends with the help of intravenous indocyanine green (Fig. 8.17).

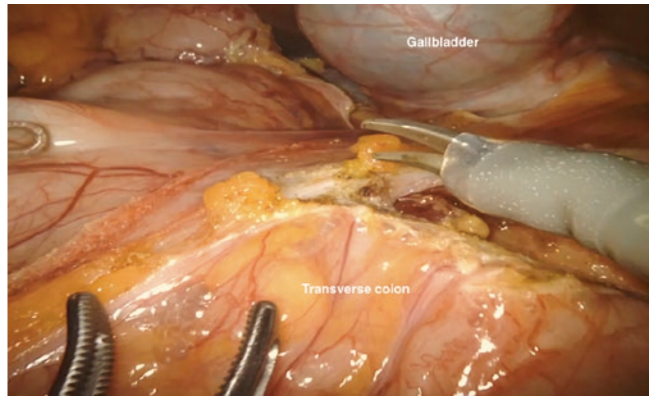

Fig. 8.16 Gastrocolic dissection

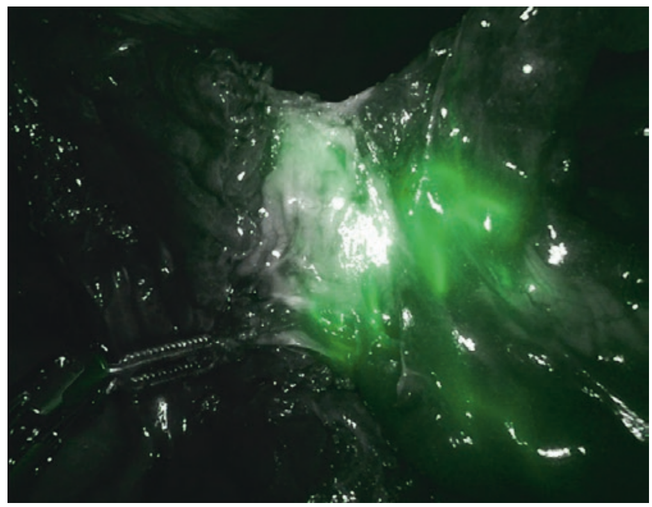

Fig. 8.17 Specimen is retrieved from the suprapubic incision

Fig. 8.18 Transection line can be easily seen after indocyanine green perfusion

Specimen Extraction and Intracorporeal Anastomosis

Following transection of the proximal transverse colon, we prefer to create a suprapubic Pfannenstiel incision for specimen extraction (Fig. 8.18, Video 8.6). Generally, a 6–8 cm incision is adequate. Other incisions could also be utilized including a median supraumbilical and transverse extension of the port site in the left upper or lower quadrants. Midline incisions allow for extracorporeal anastomosis. A suprapubic Pfannenstiel incision has an advantage of being more cosmetic and having less risk of an incisional hernia [15]. A wound protector or specimen bag must be used to protect the wound edges from tumor cell contamination. After removal of the specimen, the suprapubic incision is closed, and pneumoperitoneum is established again.

The two edges of the terminal ileum and transverse colon are brought together and fixed with 3-0 silk suture. The stitch is secured to the abdominal wall at the most suitable point for a stapled anastomosis. Small enterotomies are created through the antimesenteric wall of the bowel edges, and robotic stapler jaws are placed into the small and large bowel lumen for a side-to-side anastomosis (Fig. 8.19). After completion of the stapler firing, the common enterotomy is closed in a two-layer fashion (Fig. 8.20). In our practice, for the first layer, we prefer a 3-0 barbed suture. For the second layer, interrupted Lembert 3-0 silk sutures are used (Video 8.7). A drain is placed as per surgeon's discretion.

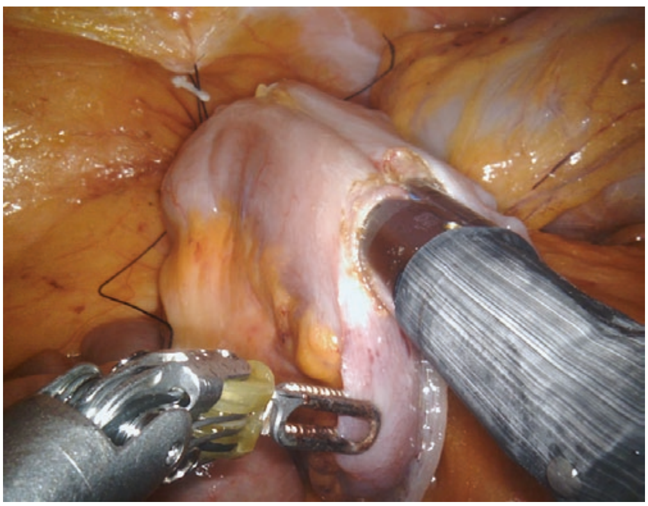

Fig. 8.19 Side-to-side ileocolic anastomosis

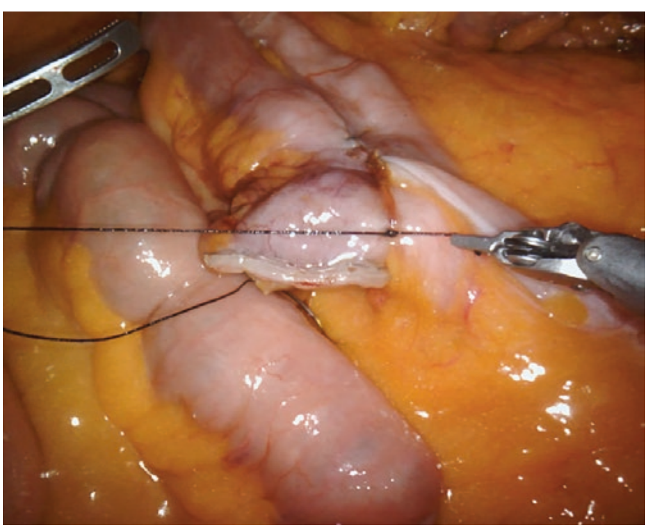

Fig. 8.20 Anastomosis is completed in a two-layer fashion

Alternative Methods

Cranio-Caudal Approach

This technique was described by Matsuda et al. in 2015 for removal of transverse colon cancers with a laparoscopic approach [16]. The aim was early dissection of the middle colic vessels. Inadvertent injuries to *Henle's* trunk and superior right colic vein could be prevented due to reduced traction with this technique.

It uses the same steps as in the caudo-cranial approach. In our practice, we prefer this technique for tumors located at the hepatic flexure or proximal transverse colon.

The operative steps for port placement, intra-abdominal exploration, robot docking, arm configuration, and specimen extraction are the same as the caudo-cranial approach. Modifications are explained below.

The patient is first placed in a 15–30° reverse Trendelenburg position with a left tilt.

The procedure starts with opening of the gastrocolic ligament close to the stomach. Following identification of the right gastroepiploic vessels, the dissection is advanced along them. The subpyloric lymph nodes are included within the resection. The omentum adherent to the proximal colon is also removed.

The right gastroepiploic vein is used as a landmark to reach the *Henle's* trunk. Trunk tributaries coming from the colon are clipped and ligated (Fig. 8.21). Next, the middle colic vessels are identified, and for a right TMCE, only the right branches of middle colic vessels are transected. After completion of transection of the gastroepiploic vessels, *Henle's* tributaries, and middle colic vessels or their branches, the robotic platform is undocked.

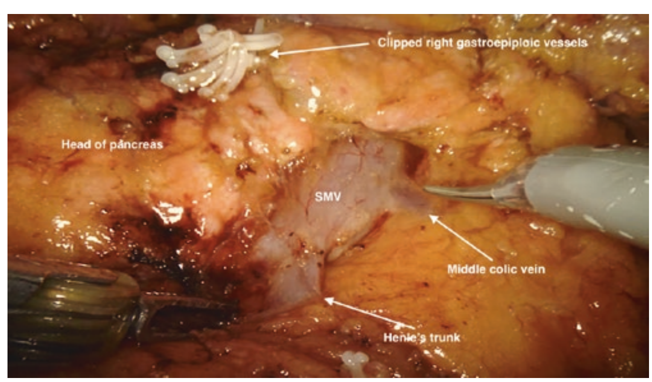

Fig. 8.21 Cranio-caudal view of SMV and gastrocolic veins

The patient is placed in a 15–30° Trendelenburg position. Small bowel and omentum are retracted toward the left part of the abdomen. Similarly, the transverse colon is retracted cranially.

The dissection of the ileocolic vessels is accomplished like in the caudo-cranial approach. Similarly, the dissection plane is advanced over the SMV and merged with the plane previously advanced cranio-caudally. The mobilization of the hepatic flexure and right colon is accomplished as described previously. Following transection of the terminal ileum and transverse colon with robotic linear staplers, a side-to-side ileocolic anastomosis is created. Removal of the specimen is similar to the abovementioned approach.

Robotic Sigmoid Resection and Left Colectomy with TMCE

Like in the right and extended right TMCE, the patient is positioned in the lithotomy position in Allen stirrups. The bedside assistant stands on the right side of the patient. The robotic cart is placed from the patients' left.

Port Placement

Pneumoperitoneum is achieved with either of the abovementioned methods. Port placement for robotic anterior and left colectomy depends on tumor location. For sigmoid or descending colon tumors and left flexure or distal transverse colon tumors, port placements are shown in Figs. 8.22a, b and 8.23a, b, respectively. Ports and instrument selection are as follows: double fenestrated at R2 (8 mm) and a double fenestrated tip-up grasper at R1 (8 mm). Later in the operation, R3 and R4 are exchanged to a 12 mm trocar in order to introduce the endoscopic stapler for bowel transection and intracorporeal anastomosis. An assistant 5 mm port L1 is placed on the right upper quadrant and generally utilized for traction and suction-aspiration.

In our practice, we do apply the sterile cover of the robotic arms only after laparoscopic exploration of the abdominal cavity for metastatic disease. After completion of the diagnostic laparoscopy, the table is tilted 30° to the right and 15–30° in Trendelenburg position. After retraction of the omentum and transverse colon cranially, small bowel loops

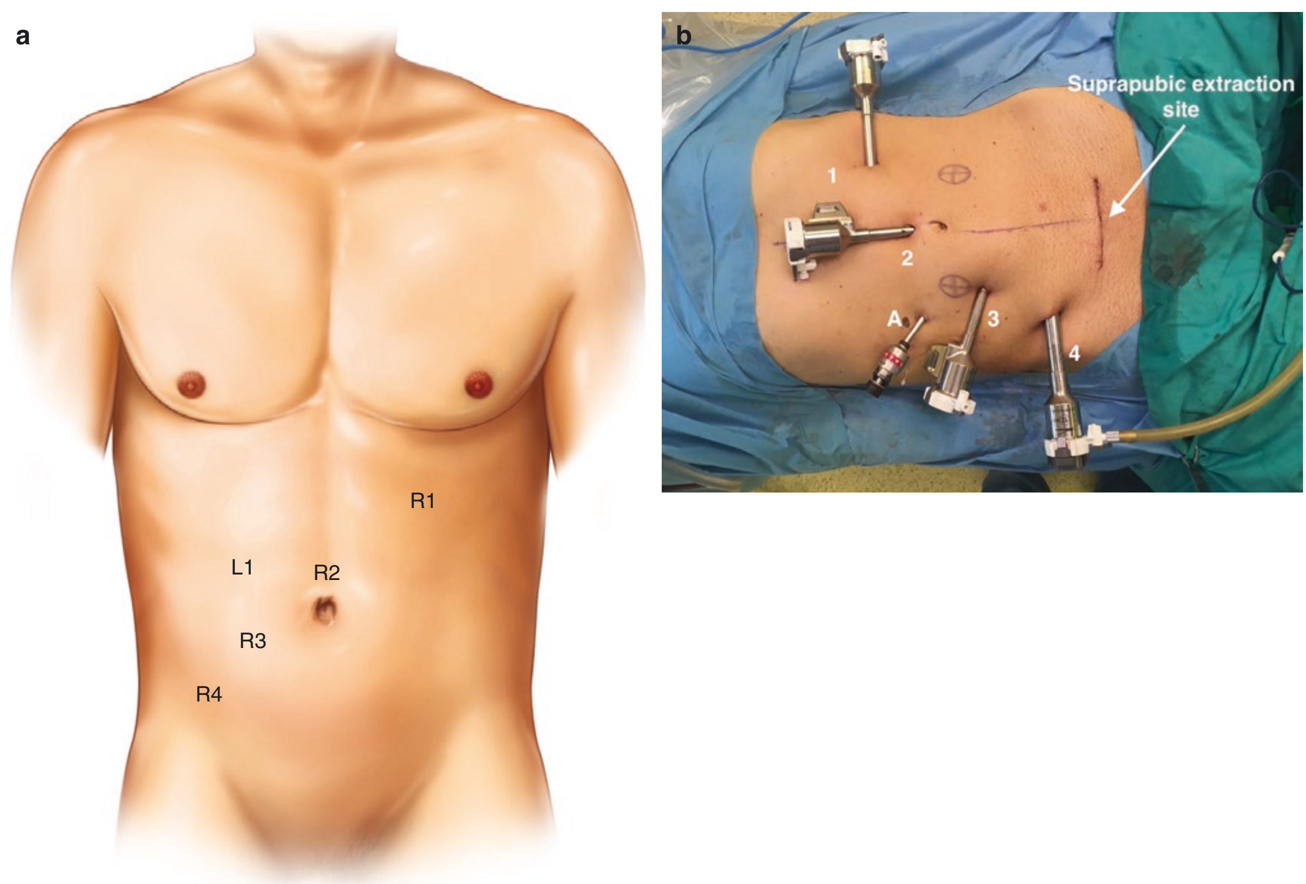

Fig. 8.22 (**a**, **b**) Port placement for sigmoid and descending colon tumor

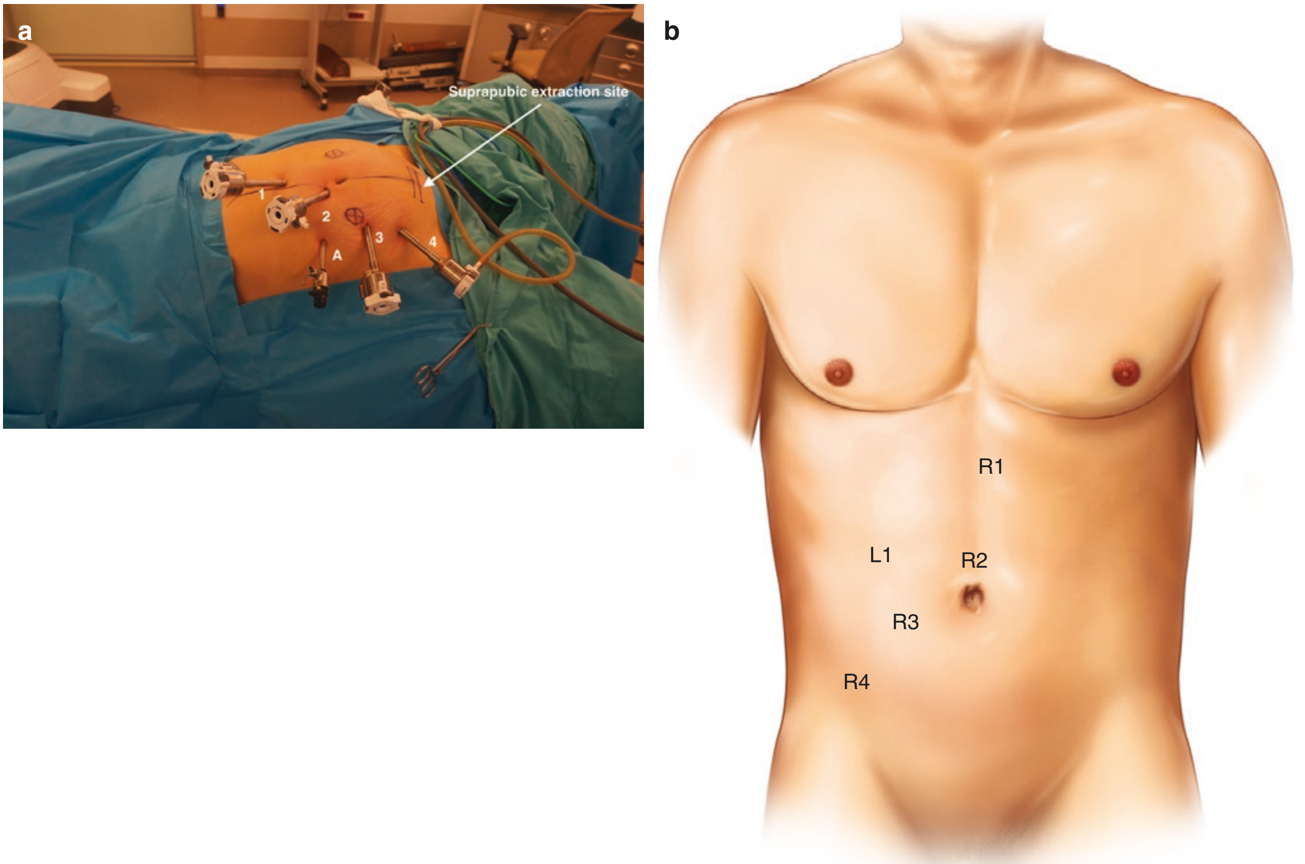

Fig. 8.23 (**a**, **b**) Port placement for splenic flexure or distal transverse colon tumor

are placed into the right quadrant as much as possible. After docking of the robotic platform, the robot is targeted to left inguinal region for sigmoid and left colon tumors. For splenic flexure or distal transverse colon tumor, the robot is targeted to the left colon.

Operative Steps

Operative steps	Degree of technical difficulty (scale 1–10)
1. Exploratory laparoscopy	1
2. Dissection and division of the IMA	5
3. Dissection and division of the IMV	6
4. Mobilization of the sigmoid and descending colon	3
5. Mobilization of the splenic flexure	5
6. Ligation of the superior rectal artery	3
7. Transection of the rectosigmoid junction	3
8. Preparation of the proximal colon for the anastomosis	3
9. Specimen extraction and anastomosis	3

Operative steps	Degree of technical difficulty (scale 1–10)
1. Exploratory laparoscopy	1
2. Dissection of the IMA and division of the left colic vessels	5
3. Dissection and division of the IMV	6
4. Mobilization of the splenic flexure	5
5. Dissection and division of the middle colic vessels	7
6. Colon transection	3
7. Intracorporeal anastomosis and specimen extraction	4

For descending or sigmoid colon cancer, the inferior mesenteric artery (IMA) is clipped and cut 1 cm distal to its root. For left flexure or distal transverse colon cancer, we usually save the superior rectal artery.

Sigmoid Colectomy for Sigmoid Colon Cancer

Dissection and Division of the IMA

The sigmoid colon is retracted anterolaterally (Fig. 8.24). The peritoneum is incised at the level of the promontory. At this step, pneumoperitoneum helps in identifying the embryologic planes.

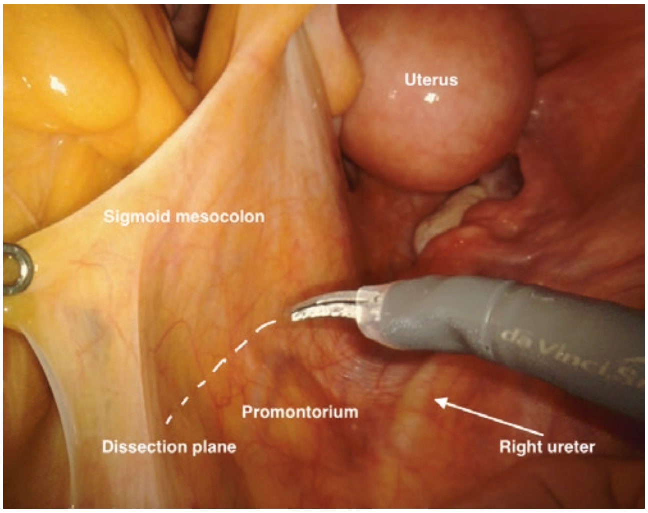

Fig. 8.24 Position of the colon before starting the peritoneal dissection

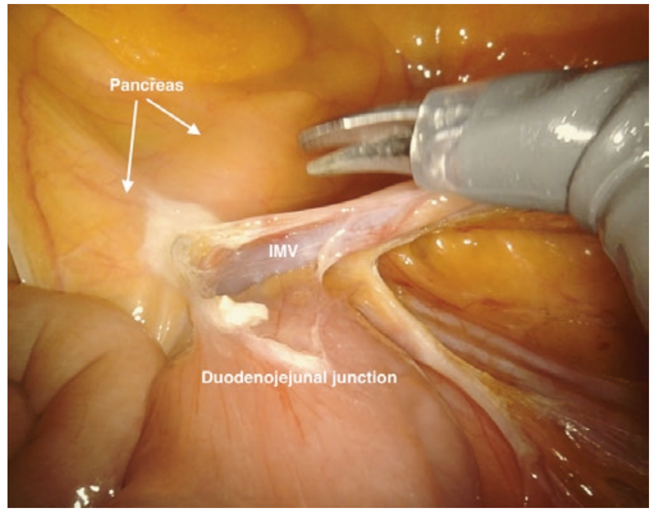

Fig. 8.26 IMV is seen below the lower border of pancreas

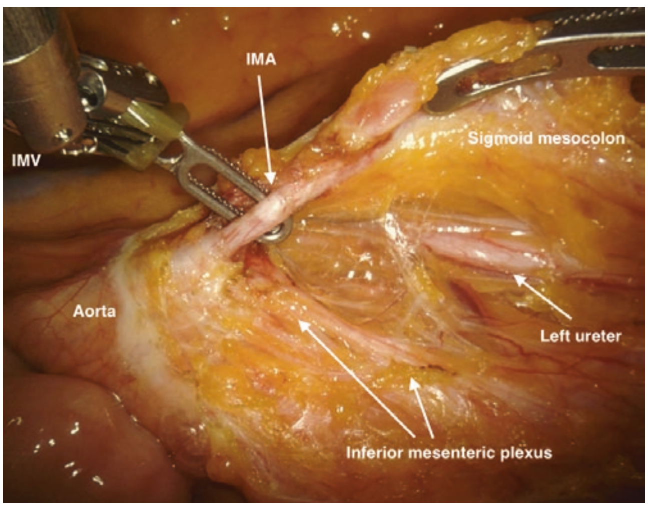

Fig. 8.25 Inferior mesenteric window and associated structures are seen before IMA ligation

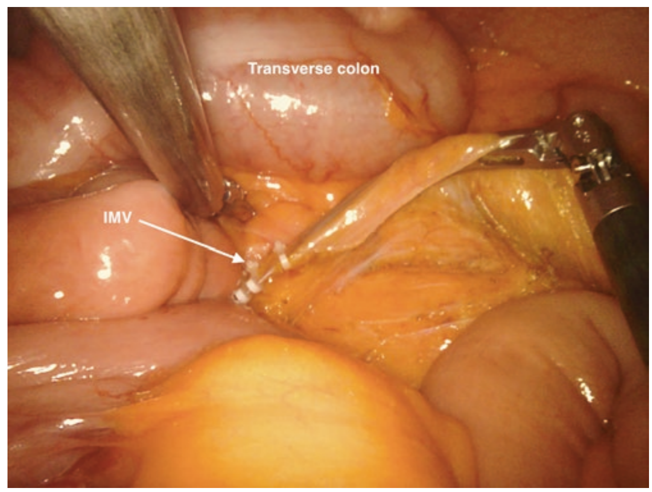

Fig. 8.27 High ligation of the IMV

Dissection is advanced cranially for the dissection of the IMA. It is cut about 1 cm distal to its root between clips with taking care of not to injure the inferior mesenteric plexus (Fig. 8.25).

Identification and Dissection of the IMV

The dissection of the left mesocolon continues toward the IMV. In this step, adhesions to the Treitz ligament may obscure the visualization of the IMV. Adhesions must be meticulously lysed, and the IMV should be dissected to the level of lower pancreatic border (Fig. 8.26). High ligation of the IMV is performed at the lower border of the pancreas (Fig. 8.27, Video 8.8).

Mobilization of the Sigmoid and Descending Colon

The dissection is advanced cranially within the embryologic planes, preserving the left ureter, gonadal vessels, and autonomic nerves (Fig. 8.28). If Toldt's fascia is pre-

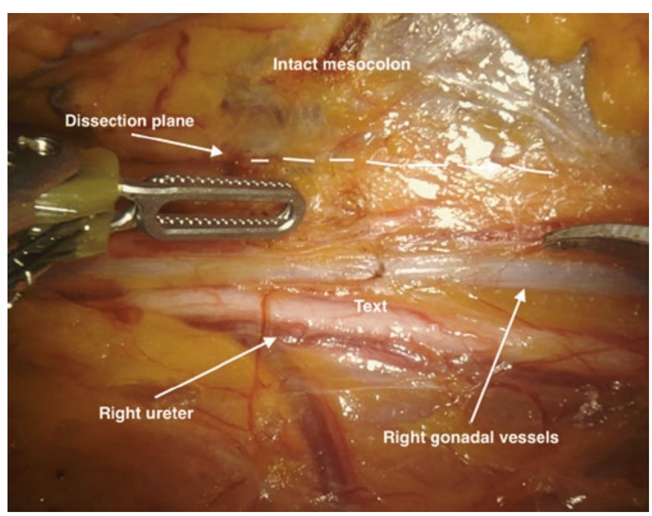

Fig. 8.28 Toldt's fascia is preserved over the retroperitoneal structures

served, the risk of injury of these structures is difficult. We typically progress in a medial-to-lateral fashion. The posterior leaf of the visceral peritoneum of the mesocolon is separated off the retroperitoneum. Alternatively, left or extended left TMCE can be started first with the dissection of the IMV. Following identification of the Treitz ligament, the IMV is dissected and ligated at the lower border of the pancreas. Then, the procedure is advanced toward the IMA. The peritoneum is scored with monopolar energy and scissors.

Mobilization of the Splenic Flexure

We prefer mobilization of the splenic flexure from medial. With traction of the transverse colon anteriorly, the lesser sac is entered through the transverse mesocolon close to the pancreas (Fig. 8.29, Video 8.9). The transverse mesocolon is divided off the pancreas toward the splenic hilum. After finishing the medial dissection, the left colon is retracted medially, and its lateral attachments are divided (Fig. 8.30). Dissection of the splenocolic and gastrocolic ligaments enables splenic flexure mobilization.

Ligation of the Superior Rectal Artery

After separation of the mesocolon from the retroperitoneum, the superior rectal artery is divided. Care should be taken of the superior hypogastric plexus and hypogastric nerves (Fig. 8.31).

Transsection of the Rectosigmoid Junction

The third or fourth robotic arms are undocked, and the 8 mm port is replaced with a 12 mm robotic/laparoscopic trocar for the robotic/laparoscopic linear stapler device, respectively. The rectosigmoid colon is transected with a “green” load stapler (Fig. 8.32).

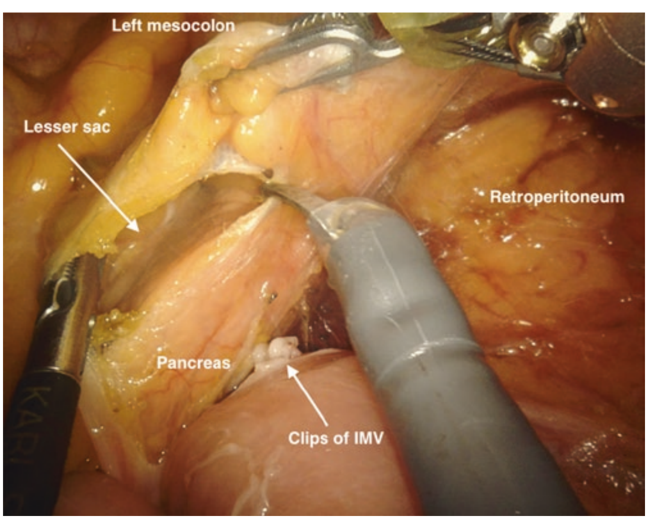

Fig. 8.29 Entrance to the lesser sac medially over the pancreas

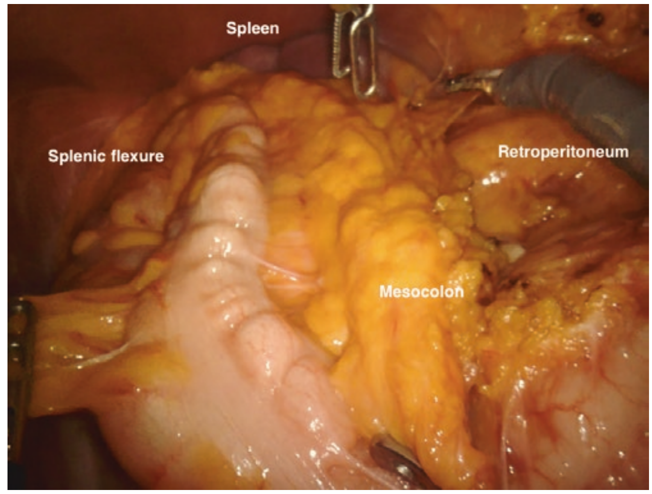

Fig. 8.30 Dividing the lateral attachments of the splenic flexure

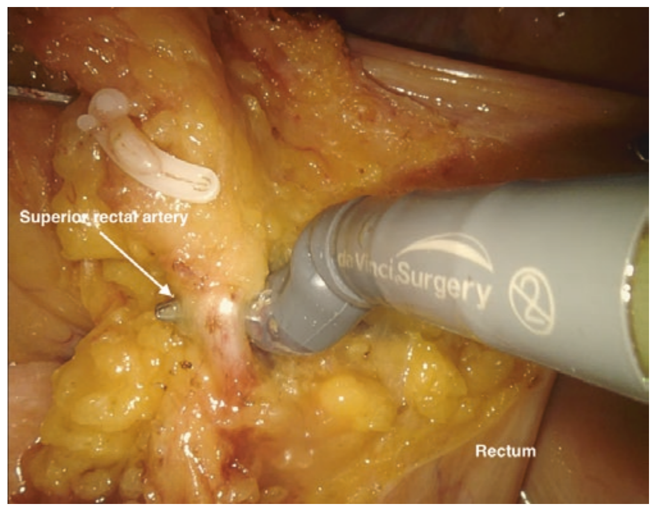

Fig. 8.31 Dissection of the superior rectal vessels

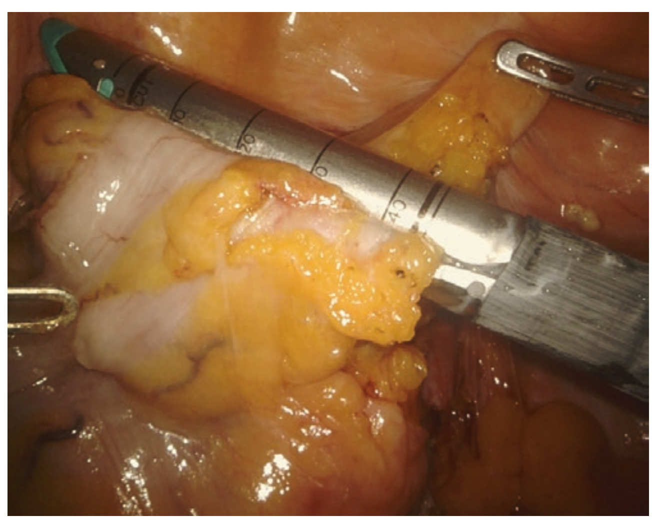

Fig. 8.32 Transection of the rectosigmoid junction

Preparation of the Proximal Colon for Anastomosis

The mesocolon is retracted anteriorly to see the IMV and IMA. We prefer to take the IMV pedicle with the specimen. Therefore, the left colic vessels are clipped, and dissection is advanced to the colon wall to enable the proximal colon to reach the suprapubic incision site for anvil insertion (Fig. 8.33). The anvil placement can also be done intracorporeally. The blood flow of the anticipated transection line is checked with indocyanine green dye intracorporeally or extracorporeally after the proximal colon is skeletonized.

Specimen Extraction and Anastomosis

The robot is undocked, and the specimen is extracted from a suprapubic Pfannenstiel incision within an endobag or through a wound protector secured to the incision (Video 8.10). The anvil is inserted, and a purse-string suture is tied. The proximal colon is returned into the abdomen, and the suprapubic incision is closed. The robotic system is re-docked, and the colorectal anastomosis is completed using a circular stapler placed transanally (Fig. 8.34, Video 8.11). Care is taken not to twist the bowel and not to entrap any tissue in the staple line. An air leak test or intraoperative proctoscopy can be done according to surgeon's discretion.

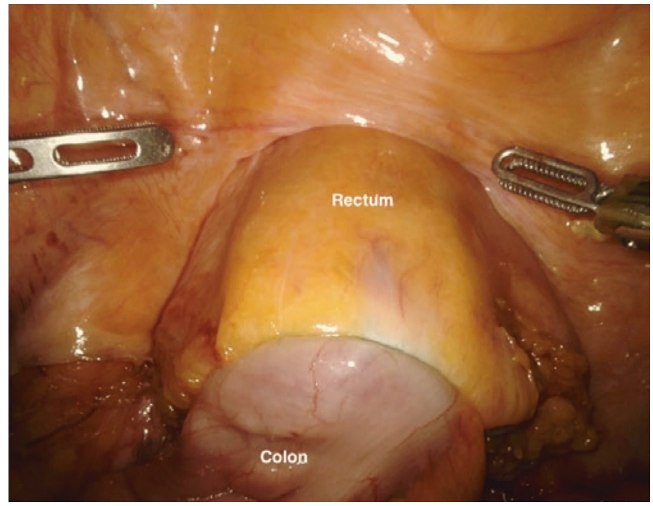

Fig. 8.34 Completed intracorporeal anastomosis

Left Colectomy for Splenic Flexure or Distal Transverse Colon Cancer

Dissection of the IMA and Division of the Left Colic Vessels

The sigmoid colon is retracted anterolaterally, and the peritoneum is incised at the level of the IMA. After identification

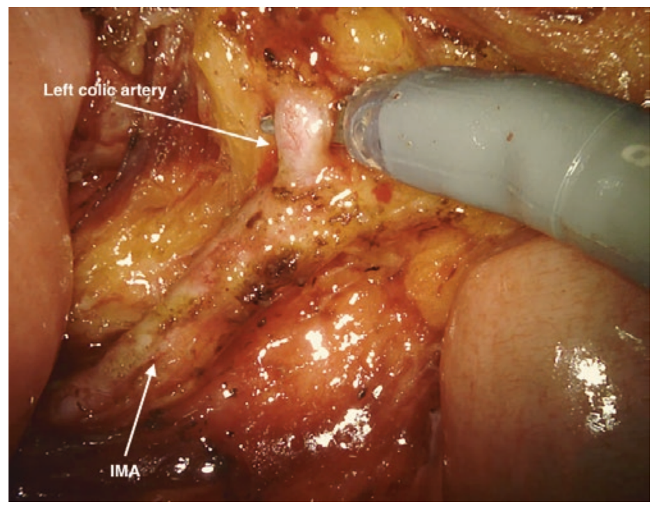

Fig. 8.35 Lymph nodes around the IMA are dissected, and the left colic artery is prepared for ligation

of the IMA, the left colic artery is identified distally and transected at its origin (Fig. 8.35, Video 8.12). The dissection of the mesocolon is advanced to the sigmoid colon, and during this dissection, the left colic branch of the IMV, sigmoidal vessels, and the marginal artery of Drummond are ligated (Figs. 8.36 and 8.37).

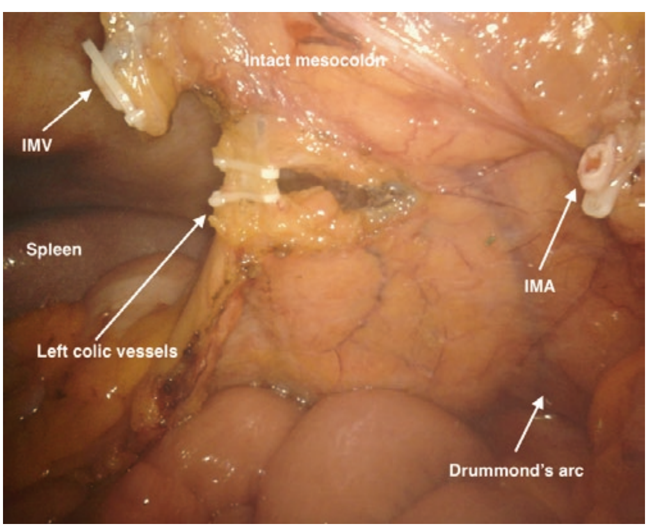

Fig. 8.33 Proximal colon is prepared by clipping the left colic vessels for specimen retrieval

Dissection and Division of the IMV

The dissection of the IMV can be done before the IMA or left colic artery dissection according to the surgeon preference. The adhesions to the Treitz ligament may obscure the visualization of the IMV. These adhesions of the duodenojejunal junction to the left mesocolon are divided. The IMV is clipped and cut at the level of lower pancreatic border as mentioned in the sigmoid resection (Fig. 8.38). After vascular ligation of the left colon, medial dissection is continued to

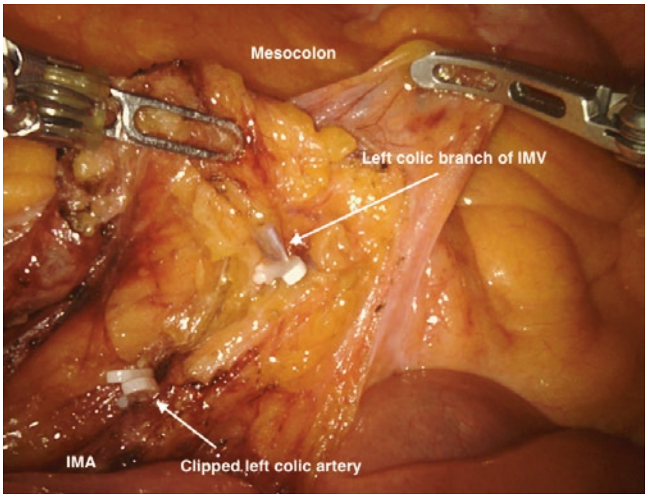

Fig. 8.36 Left colic branch of IMV is clipped

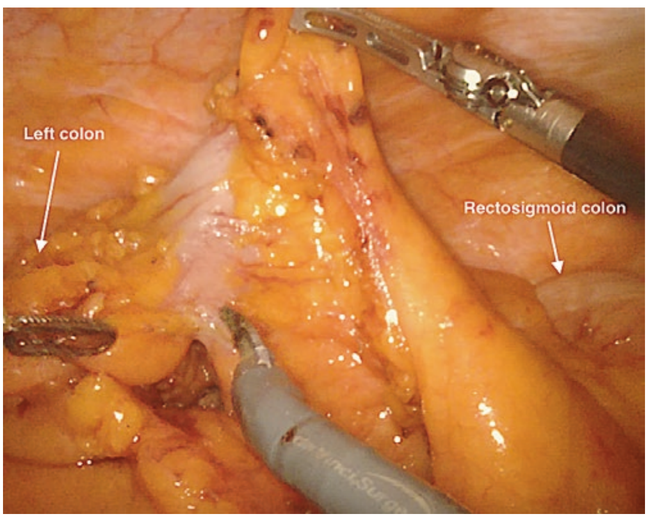

Fig. 8.37 Skeletonization of the distal colon is completed

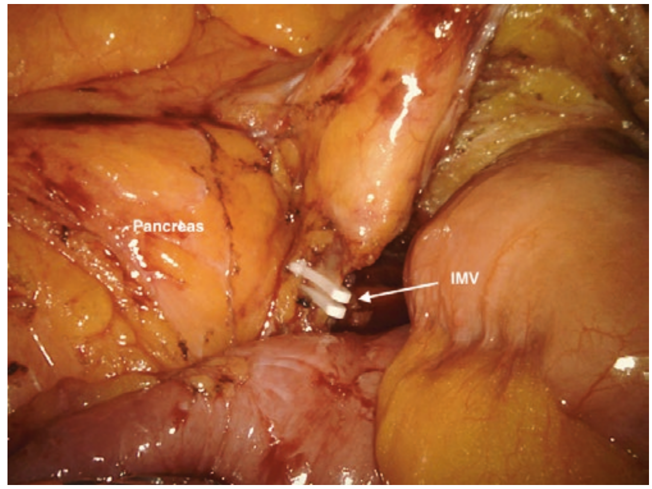

Fig. 8.38 IMV is clipped at the lower border of the pancreas

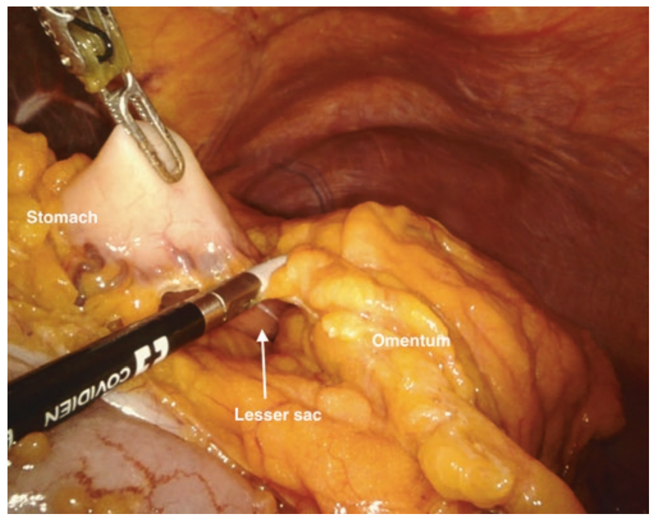

Fig. 8.39 The omentum is divided from the stomach

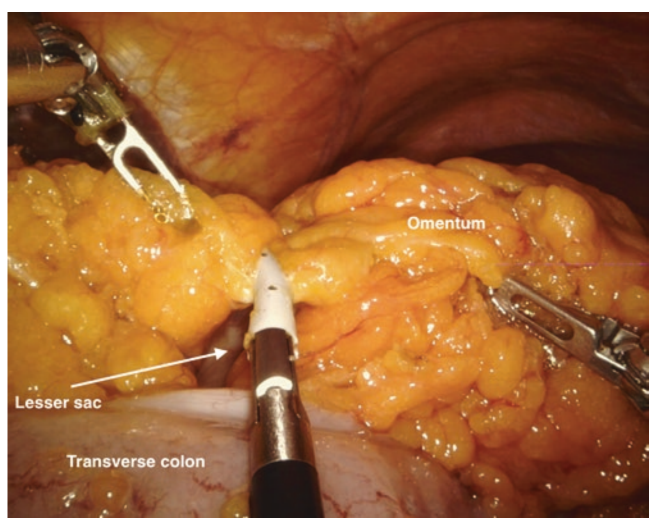

Fig. 8.40 Left half of the omentum is taken out en bloc with the left colon

the lateral attachments of the left colon as well as the tail of the pancreas.

Mobilization of the Splenic Flexure

Splenic flexure is mobilized in the same fashion as described for anterior resection section. For the tumors located on the left colonic flexure, the omentum is included to the specimen. In order to take out the omentum en bloc with the colon, dissection is advanced close to greater curvature of the stomach (Fig. 8.39). The greater omentum is divided, and its adherent part is removed en bloc with the colon (Fig. 8.40).

Dissection and Division of Middle Colic Vessels

For splenic flexure or distal transverse colon tumors, middle colic vessels are ligated. This part of the operation may lead to arm collisions, so the surgeon should be patient. The collision problems may be less if the arms of the robot are targeted toward the greater curvature of the stomach during this part of the operation. Medial dissection is continued toward the middle colic vessels. They are dissected and cut between clips (Fig. 8.41).

Colon Transection

After ligation of the middle colic vessels, the transverse mesocolon is prepared. The fourth robotic port located in the suprapubic area is replaced with a 12 mm robotic/laparoscopic port for the robotic/laparoscopic linear stapler device. Firefly can be used to check the perfusion of the colon at this stage (Fig. 8.42). Previously prepared sigmoid colon is transected similarly with a robotic stapler with a blue cartridge (Fig. 8.43).

Intracorporeal Anastomosis and Specimen Extraction

The sigmoid colon is freed from the lateral attachments in order to do a tension-free anastomosis. In a same manner, the transverse colon is also freed from the omental attachments. The ends of the colon are brought together with a stay suture grabbed by the tip-up fenestrated forceps (Fig. 8.44). Holes are created on the bowel ends for the passage of stapler jaws with monopolar cautery. A side-to-side colocolonic anastomosis is performed with a robotic linear stapler (Fig. 8.45). The defects of stapler entry sites on the large bowels are closed on a two-layer fashion as described before (Fig. 8.46). Again, the blood flow to the anastomosis can be tested with indocyanine dye perfusion (Fig. 8.47).

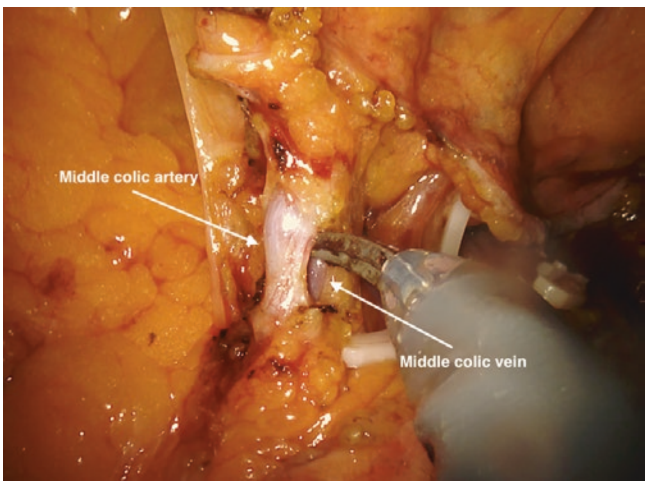

Fig. 8.41 Middle colic vessels are ligated for distal transverse or splenic flexure tumors of the colon

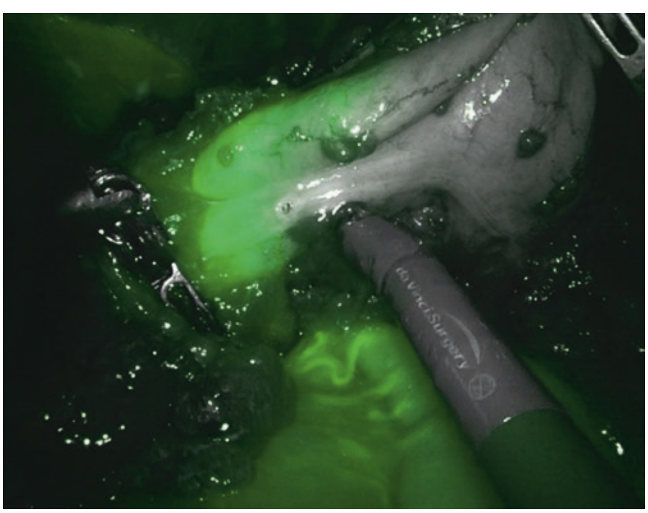

Fig. 8.42 Perfusion of the transverse colon is checked by indocyanine green

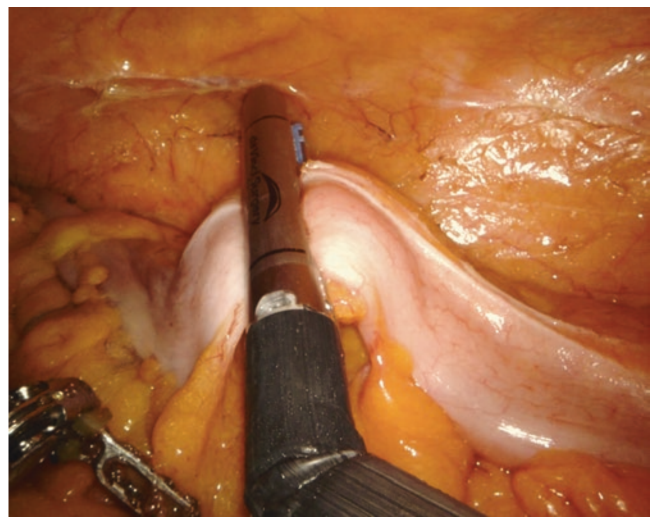

Fig. 8.43 Distal sigmoid colon is transected with robotic stapler

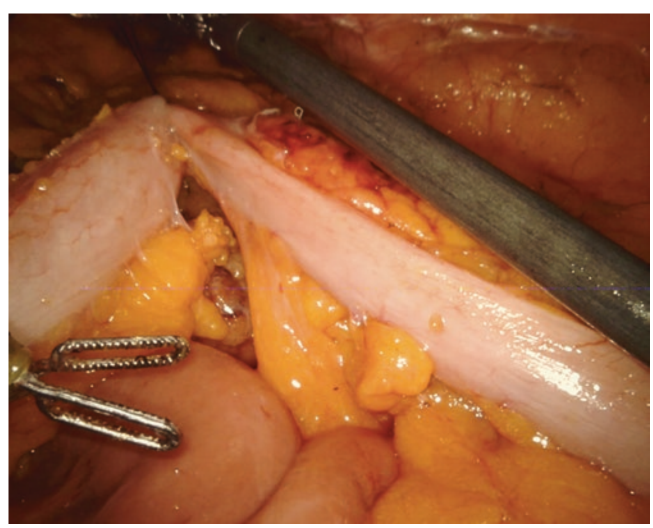

Fig. 8.44 Traction suture may ease the formation of side-to side colocolostomy

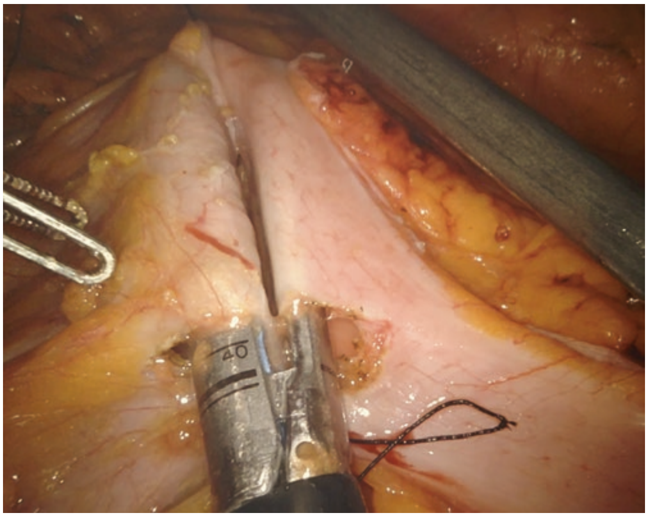

Fig. 8.45 Side-to-side anastomosis is performed with robotic stapler

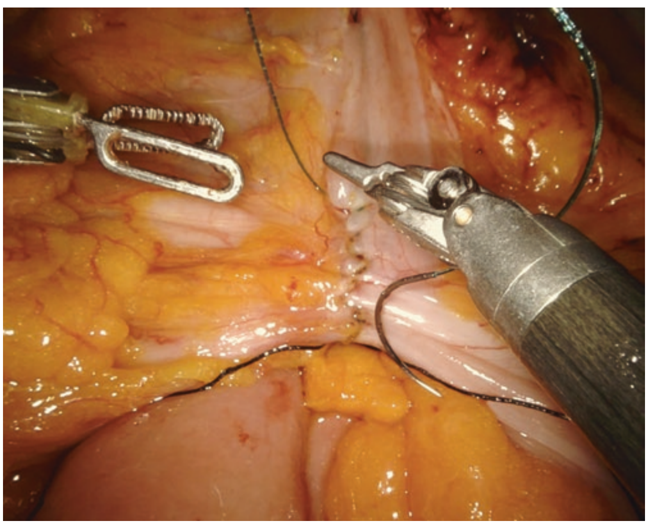

Fig. 8.46 The stapler defects are closed in a two-layer fashion with barbed and silk sutures, respectively

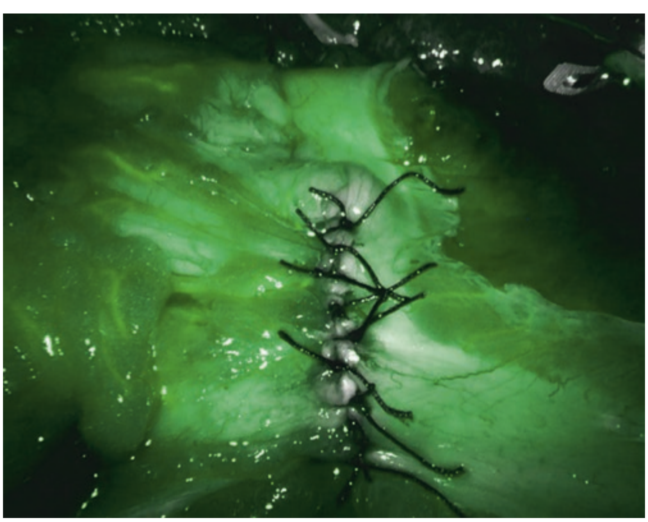

Fig. 8.47 After the formation of the anastomosis, anastomosis is controlled with Firefly just in case for tension-related ischemia

The robot is undocked, and the specimen is extracted from a suprapubic Pfannenstiel incision. The specimen could be extracted within an endobag or through a wound protector secured to the incision. A drain is placed as per surgeon's discretion.

Summary

Total mesocolic excision, specifically during right hemicolectomy, is a challenging procedure due to complex vascular anatomy of the supplying mesenteric vessel roots. This area is traditionally avoided due to unfamiliarity and risk of severe and life-threatening bleeding. The robotic technology described in this chapter maintains benefits of a minimally invasive approach and facilitates precise dissection and isolation of all involved vessels. Improved oncologic outcomes reported utilizing a total mesocolic excision need to be validated in furthers studies.

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9 Robotic Hartmann's Reversal

Patrick Berg and Ovunc Bardakcioglu

Introduction

Hartmann's resection is a left colon resection with creation of an end colostomy and a blind rectal stump or, alternatively, a mucous fistula. The procedure is performed in an emergency setting with otherwise high anastomotic leak rates. Reversal with anastomosis can then be performed in a staged setting with the patient optimized. This chapter describes the robotic approach with significant advantages over a traditional open approach.

Background

A recent systematic literature review has examined the short-term advantages of a minimally invasive approach to Hartmann's reversal. The study used an intention-to-treat analysis comparing an open approach to a laparoscopic approach. The study found that although mortality was comparable between an open and laparoscopic approach, the incidence of short-term complications was lower in the minimally invasive group. These complications included wound infection and ileus, and, in addition, the laparoscopic group had a shorter time to discharge [1].

Patients who have undergone a Hartmann's resection in the past are candidates for reversal if their anatomy permits and if they can be appropriately optimized for reversal. Hartmann's procedures are performed for left colon and upper rectal pathology. Indications include contamination of the abdomen, such as in perforated diverticulitis. An alternative in this setting is a primary anastomosis and diversion with a loop ileostomy if the contamination is localized and the bowel wall to be anastomosed is not inflamed. Colon resections in the setting of hemodynamic instability or sepsis may also require Hartmann's resection, although in this case the patient can be left with an open abdomen and subsequently returned to the operating room when stable and a primary anastomosis performed at that time. This procedure may also be performed if the patient is unlikely to heal a colon anastomosis, such as patients with severe liver disease with ascites, those who are severely nutritionally deficit, or those who are on high-dose steroids.

Preoperative Preparation

Colostomy takedown can be performed 3 months after the initial operation. This waiting time allows adhesions from the operation and disease process to mature and resolve. The proximal colon should always be evaluated prior to end colostomy reversal to ensure no strictures, fistulas, or other lesions are present. The distal bowel is evaluated with a contrast enema. This study will also provide information about the length of the rectal pouch. Alternatively, flexible sigmoidoscopy can be performed at the time of the colonoscopy to examine the distal pouch. The additional benefit to clean the stump from mucous and debris will help the safe advancement of the EEA stapler and creation of the anastomosis.

Due to the waiting period, the patients are better operative candidates. Nutrition can be optimized, and diabetes should be well-controlled and immunosuppressive medication stopped if possible. A preoperative cardiac assessment can be performed for patients who have high risk factors for cardiac disease (those with arrhythmias, known cardiac disease, angina, chronic kidney failure, patients with prior strokes/TIAs) or a combination of low risk factors (those with DM, advanced age, minor ECG abnormalities, or a baseline low level of activity). Debilitated patients with fecal incontinence should not be considered for reversal and may even benefit from the ease of caring for an ostomy.

P. Berg
Department of Surgery, UNLV School of Medicine, Las Vegas, NV, USA

O. Bardakcioglu (✉)
Division of Colon and Rectal Surgery, UNLV School of Medicine, Las Vegas, NV, USA

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Mechanical bowel preparation together with oral antibiotics has now been shown to decrease infectious complications over antibiotic preparation only, or no preparation at all [2]. Mechanical preparation has the practical benefit of minimizing the risk of stool spilling after opening the bowel to perform an anastomosis. For the mechanical preparation, 4 liters of polyethylene glycol achieves an excellent bowel preparation and is usually well-tolerated. If a lower volume prep is desired, 2 liters of polyethylene glycol can be administered with ascorbic acid and achieve an equally good preparation [3]. There are many other options for bowel preparation. Sodium picosulfate has also been administered with magnesium citrate and is very well tolerated as well [4]. Antibiotic bowel preparation can be achieved by administering 1g of neomycin and 500 mg of metronidazole at 1, 3, and 10 pm on the day prior to the operation.

The difficulty of Hartmann's reversal is dependent on the initial indication for Hartmann's procedure and the conduct of that operation. A helpful trick at the time of the initial operation is to surround the colon with antiadhesive barriers before it is delivered through the abdominal wall and subsequently matured. This significantly reduces the adhesions of the ostomy to the subcutaneous tissue and fascia. Hartmann's reversal will also be more difficult if the rectum was initially stapled off very low in the pelvis. This is sometimes unavoidable. However, in this case, extra pelvic dissection will be required to expose the rectum. In addition, splenic flexure mobilization is usually required to obtain enough length for the anastomosis.

Room Setup and Positioning

The da Vinci Xi cart should be positioned perpendicular from the left of the patient. This will allow rotation of the arms toward the deep pelvis and the splenic flexure without the need for redocking which is frequently needed with the prior system generation. The assistant surgeon, scrub technician, and all sterile trays will be on the opposite site. A colonoscopy cart is located toward the feet of the patient and is available for evaluation of the anastomosis.

The patient is placed in lithotomy position with both arms tucked in a secure position to allow maximal movement of the table and retraction by gravity. The feet are placed flat in the stirrups, and the legs kept down low enough that they do not interfere with the robotic arm movements, especially the 4th arm docking through the right lower quadrant port. The legs of the patient are aligned in such a way that an imaginary line can be drawn from the ankle to the knee and to the opposite shoulder. The calves of the patient should not be resting backward on the stirrups without any pressure on the peroneal nerves.

Perioperative antibiotics are administered. Cefoxitin and metronidazole, or ertapenem alone, are good options for prophylaxis [5]. Antibiotics should be stopped within 24 hours after completion of the operation. The ostomy is packed with Surgicel to prevent intestinal contents from spilling out during the case or closed with a purse-string suture. Chlorhexidine or povidone-iodine can be used for skin preparation [6], but the area around the ostomy itself should be prepped with povidone-iodine.

Port Placement

The da Vinci Xi port placement is easier than the previous generation system as the robotic arms were designed to decrease collision and placement is simplified by aligning all trocars along a virtual line. The center target for the Hartmann's reversal is the left lower quadrant, and therefore this line is from the left upper to the right lower quadrant (Fig. 9.1). Initial access is performed in the left upper quadrant at Palmer's point with a Veress needle and/or optical trocar entry. A 5 mm laparoscopic trocar can be used first and then exchanged to a robotic one or an 8 mm optical robotic

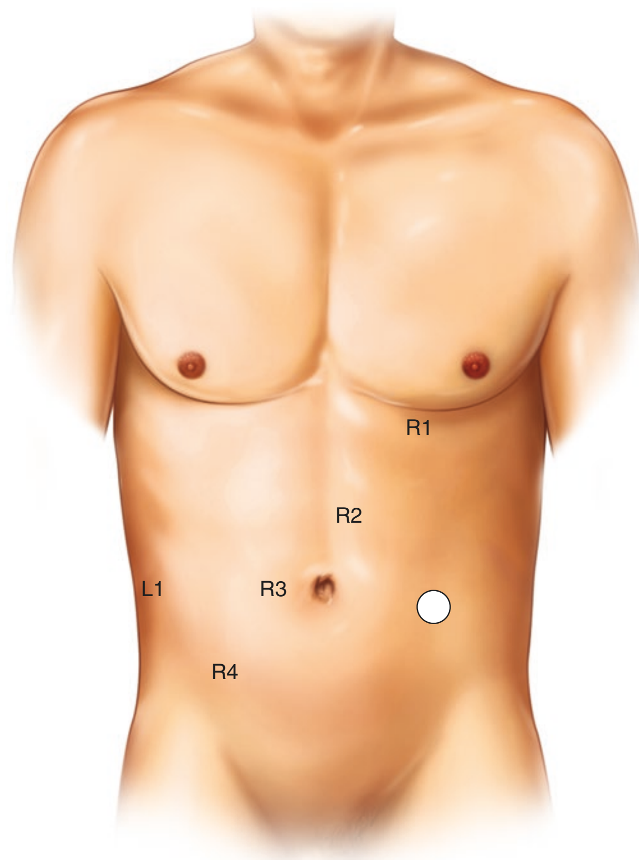

Fig. 9.1 Port placement

trocar initially (R1). With smaller patients this trocar should be placed as close as possible to the lower rib to maximize the distance to the right lower quadrant port, allowing placement of four trocars without arm collision. Assessment of the amount and location of intra-abdominal adhesions is critical at this point in time. Sometimes, it is necessary to clear out adhesions to the anterior abdominal wall before all the trocars can be safely placed. If adhesive disease prevents visualization of one or more of the proposed port sites, ports for the camera and one arm can be placed and used to clear out the adhesions along the anterior abdominal wall until there is enough space to place additional ports. If necessary, a separate 5 mm trocar can be placed for a limited laparoscopic adhesiolysis to achieve this. Once all robotic instruments are inserted, the major benefits of wristed instruments and the third arm will facilitate adhesiolysis significantly. The areas around the colostomy and the deep pelvis are usually the limiting factors why this procedure is not performed laparoscopically routinely. The next port is placed in the right lower quadrant (R4) as a 12 mm port allowing a robotic stapler to be used. The remaining ports are then equidistant in between the outer trocars (R2, R3).

The camera is placed through R3 and scissors through R4 for the right hand. The left hand is using a fenestrated bipolar in R2 alternating with a tip-up grasper or Cadiere forceps in R1.

The abdomen is visualized laparoscopically before the robot is docked. This is helpful to ensure the patient is positioned optimally before the robot is docked. Trendelenburg and left side up positioning will help to move the small bowel away from the colostomy and ensure optimal arrangement of intra-abdominal contents before docking the robot. The robot is docked aimed toward the patient's left inferior abdomen.

Operative Steps

Operative steps	Degree of technical difficulty (scale 1–10)
1. Intra-abdominal colostomy mobilization	3
2. Splenic flexure mobilization	3
3. Rectal stump mobilization	3–6
4. Colostomy takedown	1
5. Anastomosis	2

Intra-abdominal Colostomy Mobilization

Adhesions should be expected because of the inflammatory nature of the condition that initially led to the Hartmann's procedure. Adhesiolysis proceeds with sharp dissection when adhesions are clear or it is otherwise clear where to divide tissue. Blunt dissection can also be employed, using the side of the robot scissors to carefully push on adhesions which may then separate. If this technique is employed, sharply divide firm adhesive bands when necessary. Sufficient traction is necessary to divide adhesions in the safest manner possible, and in this regard, it is always safer to push the bowel to generate traction as opposed to pulling when possible. Serosal tears can otherwise result due to the nature of the robotic arms not transmitting force information to the console unit. Depending on the nature of the pathology that led to the initial Hartmann's procedure, there may be a significant amount of adhesive disease, and lysis of adhesions can take a significant amount of the time of the operation. Dissection should proceed in as bloodless a manner as possible. Vessels that are visualized should be addressed with bipolar cautery before division. Any bleeding should be immediately controlled with monopolar or bipolar cautery.

Once all ports are in place, lysis of adhesions is started to free any small bowel that may overlie the colostomy and left colon. Omentum is frequently adhered to the colon leading to the colostomy and over the splenic flexure, and this needs to be moved cephalad to expose the distal transverse colon. It is critical to distinguish omentum from the mesentery of the colostomy. A 30° up-positioned robotic camera is now very helpful to mobilize the colon and it's mesentery from the surrounding fascia, rectus muscle, and sometimes hernia sac, if present (Figs. 9.1 and 9.2). The flexible scissors and two retracting instruments available for the left hand allow dissection above the fascial level.

Splenic Flexure Mobilization

The left colon should be now sufficiently visualized. The left white line of Toldt can then be divided and the large bowel

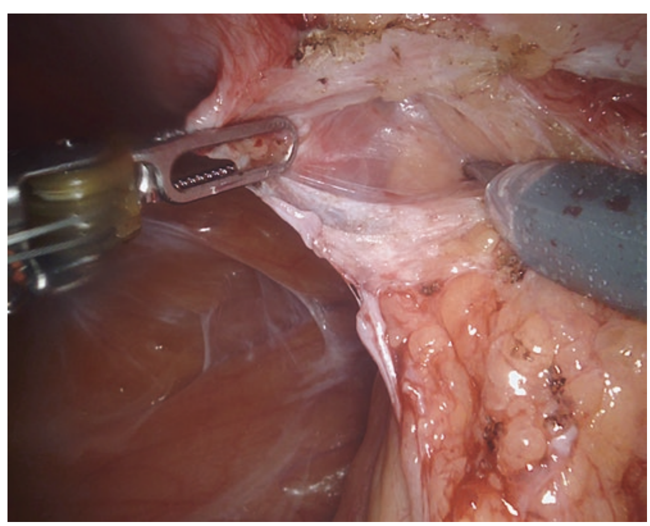

Fig. 9.2 Colostomy mobilization

mobilized on that side from lateral to medial. Frequently it is easier to lift the descending colon mesentery and mobilize from medial to lateral off Gerota's fascia up to the inferior border of the pancreas. The lesser sac is entered after the omentum is divided off the distal transverse colon. Similarly the remaining splenocolic attachments are divided to finish the complete mobilization of the splenic flexure. It might be necessary to isolate the inferior mesenteric vein occasionally for a high division allowing increased length of the descending colon conduit. Bowel perfusion can be checked with IV injection of indocyanine green and the robotic near-infrared camera and "firefly" mode.

Rectal Stump Mobilization

It is also necessary to mobilize the small bowel out of the pelvis sufficiently to visualize the Hartmann's pouch (Fig. 9.3). The common practice during the initial Hartmann's operation in which a suture is left to mark the location of the distal rectal pouch should be discouraged as the sutures occasionally can cause significant dense adhesion formation. A colonoscopy or EEA sizer in the rectum and vagina can be helpful if the pouch is difficult to be localized. Frequently, lateral and anterior peritoneal flaps are obscuring the rectum in this scenario and will need to be lysed (Fig. 9.4). If the rectum is not sufficiently mobilized anteriorly and laterally, some patients will not allow the EEA sizer and stapler to be placed to the end of the previous staple line. The options in this scenario are to perform an end -to-side anastomosis or mobilizing the rectum posteriorly. For this the right lateral peritoneum is incised and the rectum mobilized along the presacral plane.

Fig. 9.3 Adhesiolysis of the descending colon

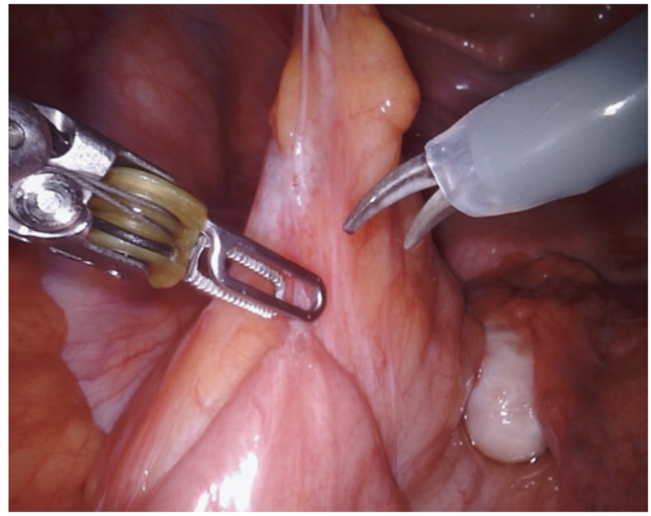

Fig. 9.4 Adhesiolysis of the small bowel

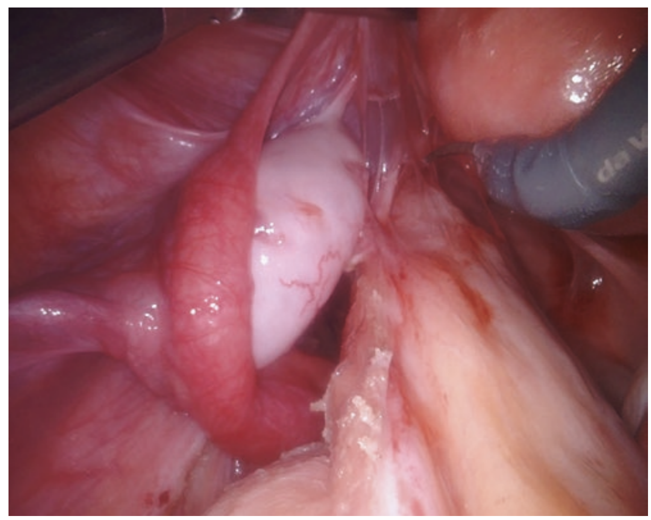

Fig. 9.5 Adhesiolysis of the rectum

Once the pouch is cleared off, the staple line of the distal rectal pouch also needs to be assessed. If there is evidence of chronic inflammatory changes or a retained sigmoid colon, this segment needs to be resected to prevent recurrence of diverticulitis. The previously entered mesorectal plane is dissected cephalad separating sigmoid colon mesentery off the retroperitoneum from medial to lateral (Fig. 9.5). After the left ureter is visualized (Fig. 9.6), the mesentery including the superior rectal artery can be safely divided and the bowel transected at the rectosigmoid junction (Fig. 9.7).

Colostomy Takedown

Attention now turns to taking down the ostomy, which is frequently very easy as the majority of the dissection is already

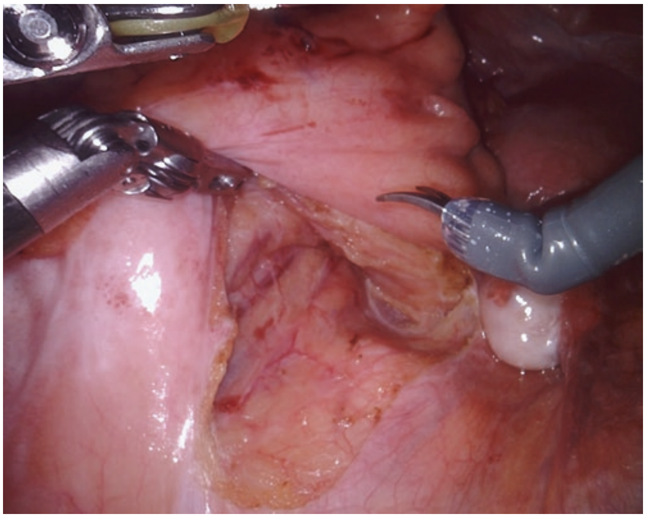

Fig. 9.6 Medial to lateral dissection

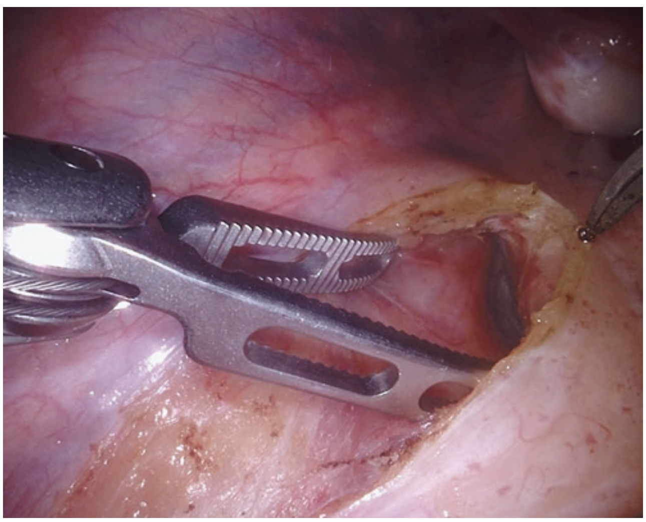

Fig. 9.7 Lateral to medial dissection

performed robotically. An incision is made at the mucocutaneous junction around the ostomy with electrocautery. The skin and subcutaneous tissue are divided in a manner that brings the dissection plane circumferentially onto the surface of the bowel. Dissection proceeds just outside of the bowel or its mesentery down to the fascia. An Allis can be placed on the fascia to provide countertraction and facilitate the division of adhesions between the bowel and the fascia. Metzenbaum scissors are the ideal instrument for precisely dividing adhesions to the bowel wall.

Anastomosis

First the correct size of the EEA stapler that will be necessary for the anastomosis should be determined by EEA sizers. Allis clamps are placed on either end of the staple line (if the proximal loop of colon was stapled after taking down the ostomy) and cut right under the staple line with monopolar energy to make an enterotomy. The anvil with the spike is placed through the enterotomy, placing the plastic spike 5 cm from the end of a planned side-to-end anastomosis. The enterotomy is then closed with a GIA stapler. This is the authors preferred technique as it allows for consistent doughnuts. It also avoids possible diverticula to be pulled into the anastomosis preventing a subsequent leak.

Alternatively, the anvil can be secured with a purse-string suture for an end-to-end anastomosis.

It is also possible to place the spike inside the bowel, staple the enterotomy closed, and then bring the spike through just anterior to the staple line.

Sizers are used to dilate the anorectum if necessary. The EEA stapler is then positioned so it follows the course of the rectum and the spike is either positioned just anterior to the staple line or through the anterior rectal wall at least 3 cm distal to the staple line. The anastomosis is then visualized by colonoscopy, air leak test performed, and anastomotic doughnuts checked for integrity.

Postoperative Care

Many centers have enhanced recovery after surgery (ERAS) protocols for colon and rectal surgery. These protocols have several elements. Under these protocols, patients are allowed to consume fluids up to 2 hours before surgery, especially a fluid that contributes to "carbohydrate loading." Narcotic use is decreased through spinal anesthetics and multimodal anesthesia. Patients are also fed earlier after surgery. Patients are instructed preoperatively on what to expect after the operation, including getting out of bed as soon as possible, pulmonary toilet measures, and what the pain management strategy for them will be. They are given a mechanical and antibiotic bowel preparation. Intraoperatively, goal-directed fluid administration is performed, which generally decreases the total amount of fluid administered. Fluid administration is also limited postoperatively. A European study showed that patients in whom fluid administration could be limited to 3 liters on the day of surgery had decreased complications [7]. Foley catheters are removed on postoperative day 1 if possible. With adherence to these protocols, patients are discharged from the hospital, on average, 2 days earlier [8].

However, it is important to monitor these patients and recognize when they are not progressing as expected in order to de-escalate the protocol's aggressiveness. For example, if an elderly patient has a poor appetite and nausea at mealtimes, the diet should be de-escalated. These patients are more likely to vomit and aspirate, and aspiration can be a fatal event.

Difficult Scenarios

Inadequate Colon Length

Most Hartmann's reversal with a descending colon-to-rectal anastomosis can be performed without any difficulty with regard to proximal length. The complete splenic flexure mobilization as described above is usually the only maneuver needed. A ligation of the inferior mesenteric vein close to the duodenum can also facilitate length. Occasionally patients will present with a high descending colon or distal transverse colon end colostomy. In this scenario the hepatic flexure and entire transverse colon are mobilized. If the transverse colon is not reaching the rectum, the middle colic pedicle should be occluded with a vessel clamp and transected after perfusion to the end of the colon confirmed with indocyanine green and the near-infrared camera. The colon conduit can also be tunneled through the small bowel mesentery underneath the ileal branch of the ileocolic pedicle. The ascending colon can also reach the pelvis if mobilized and rotated along the ileocolic pedicle.

Morbid Obesity

All aspects of the procedure, from trocar placement to omental mobilization, are difficult in the morbidly obese. One of the main challenges particular to the Hartmann's reversal is inadequate reach of the colon due to thickened and shortened mesentery. Frequently a significant portion of the colon proximal to the colostomy is above the fascia and cannot be utilized as the colon conduit.

Preoperative weight loss might be necessitated before a reversal attempt. All of the above measures can be utilized to gain colon reach into the pelvis. If the small bowel cannot be retracted out of the pelvis with patient positioning alone, a lap pad at the base of the mesentery placed through a hand port might be a last measure before converting to an open procedure.

Summary

Hartmann's procedure is a commonly performed procedure in an emergency setting creating a temporary colostomy after colon resection. Frequently though, the colostomy may not be reversed due to concerns of significant morbidity of a traditional open approach to adhesiolysis, colostomy, and rectal stump mobilization with subsequent reanastomosis. A laparoscopic approach with all known benefits in colorectal surgery is not widely adapted due to inherit technical difficulties of performing often extensive adhesiolysis of small bowel loops and mobilization of the rectal stump in the deep pelvis. A robotic approach has been proven to significantly simplify these difficulties with the addition of articulating instruments and a third instrument arm. In addition, this allows easy mobilization of the colostomy at and above the fascial level under direct visualization.

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Robotic Ventral Mesh Rectopexy

10

Kristen Rumer and Brooke Gurland

Introduction

Ventral mesh rectopexy can correct external (full-thickness) rectal prolapse, internal rectal prolapse, rectocele, enterocele, perineal descent, and obstructed defecation syndrome. Laparoscopic ventral approach mesh rectopexy, popularized by Andre D'Hoore, is based on correcting the descent of the posterior and middle pelvic floor compartments [1]. This technique involves dissecting between the rectum and the vagina down to the perineal body and suturing mesh to the anterior rectum and posterior vagina and suspending the mesh to the anterior longitudinal ligament along the sacrum. Using robotic technology for this procedure maximizes the benefits of superior 3-D visualization and wristed instrumentation for operating in the pelvis. Dissection and suturing is more elegant and easier to master than with laparoscopy. In this chapter, we will simplify robotic ventral mesh rectopexy into eight basic steps.

Background

Surgery for rectal prolapse aims to correct an anatomic defect and to improve anorectal function. Throughout the past century, more than 100 different surgical procedures have been described, but there is no consensus regarding the best technique. The goals of the ventral rectopexy (VR) involve correcting the prolapsed rectum by suturing a mesh to the anterior rectum and suspending it to the anterior longitudinal ligament of the sacrum. This technique avoids posterior and lateral rectal dissection and the potential neurological injury, which may result in new-onset constipation. Over the last decade, large patient series have shown that VR is effective at correcting internal and external rectal prolapse, improving bowel continence, and reducing symptoms of obstructed defecation. Robotic ventral mesh rectopexy (RVMR) has been shown to be safe and to have equivalent to superior outcomes compared to laparoscopic and open ventral mesh repairs. Despite longer operative time for RVMR, the duration of surgery is decreasing over time as surgeons become more experienced with robotic surgery and as institutions are developing dedicated teams and protocols for robotic colorectal surgeries.

Patient Selection and Preoperative Preparation

A thorough preoperative history should include urinary or bowel dysfunction, pelvic organ prolapse, sexual dysfunction, and pain. Multidisciplinary pelvic floor evaluation and treatment are recommended. Anorectal testing, urodynamics, and imaging with defecography or MR pelvic floor assessment help to determine the extent of pelvic floor dysfunction.

RVMR is indicated for patients with full-thickness or high-grade internal rectal prolapse and obstructed defecation syndrome or fecal incontinence and enterocele who are suitable candidates for abdominal laparoscopic or robotic surgery. Age, obesity, and the presence of prior prolapse procedures are not contraindications for RVMR, and the use of robotic technology facilitates dissection in the pelvis and enhances suturing capabilities. RVMR can be successfully performed with sacrocolpopexy or other gynecological procedures for women with multicompartment prolapse.

Mechanical bowel preparation is selectively given primarily to patients with constipation. For older more frail patients who cannot tolerate bowel preparation, tap water enemas are administered to empty the lower rectum.

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K. Rumer (✉) · B. Gurland
Department of General Surgery, University of Stanford, Palo Alto, CA, USA
e-mail: krumer@stanford.edu; bgurland@stanford.edu

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Anesthesia Preparation and Communication

Robotic ventral mesh rectopexy is performed under general anesthesia with the patient in steep Trendelenburg position with prolonged pneumoperitoneum. For an experienced surgeon in a technically easy patient, the procedure can take 120 minutes with minimal blood loss. But operative time increases when performing additional gynecological procedures, during reoperative pelvic surgery, and in a patient with a technically difficult body habitus. Whereas bleeding is uncommon, dissection on to the sacrum or rectal vaginal space can cause hemorrhage, and communication with the anesthesiologist in these situations is imperative. Since both arms are tucked, anesthesia should secure adequate venous access preoperatively. The routine used of central venous access or arterial line is not performed. However, in a patient with a higher morbidity, a bleeding risk, or more labile hemodynamics, additional more invasive monitoring should be considered on a case-by-case basis.

Room Setup and Positioning

The table is set up with foam padding or a bean bag beneath the torso to avoid sliding while in the steep Trendelenburg position. A folded sheet is beneath the lower back of the patient to help with lifting and positioning the patient on the table. The buttocks are just below the break in the table to allow access to the rectovaginal area for sizers or additional procedures. The patient is placed in the lithotomy position in Yellow Fin® stirrups with additional foam padding to minimize the risk of peroneal nerve injury. Both arms are carefully padded and tucked at the patient's side with the drawsheet. A foam bolster is placed over the chest, and either wide tape or a Velcro strap is used to secure the patient to the table. After induction of anesthesia, we frequently unlock and angle or move the OR table further away from the ventilator to provide more space for the assistant and docking the robot.

Examination Under Anesthesia

After the patient is positioned, a vaginal and rectal examination is performed to assess the extent of prolapse. The rectal prolapse is exteriorized with special attention to the lead point of the prolapse (the point where the prolapse starts). For individuals with perineal descent and low rectocele, the dissection is taken down to the perineal body and fixed laterally to the levators and anterior rectum for pelvic floor and rectal suspension. For prolapse that starts more proximally, the mesh can be placed on the anterior rectum, and the mesh is sutured to the lead point of the prolapse to avoid recurrent prolapse above the repair.

Port Placement and Instrumentation for the XI

We utilize the four robotic and one accessory port placed above the umbilicus, spaced 8 cm apart in a straight line (Fig. 10.1a, b).

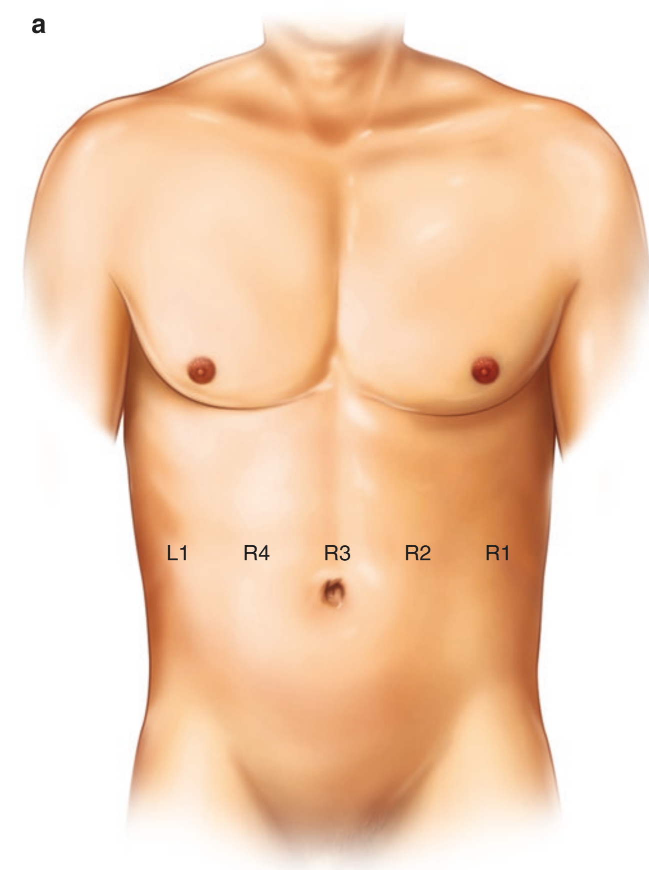
Prior abdominal surgery and body habitus may require modification of the placement. Initial entry into the abdomen with a Veress needle or cut-down technique depends on surgeon's preference. Adhesiolysis may be required to clear the abdominal wall. Measurements for additional port placement are made on the abdominal wall after pneumoperitoneum is established. Two robotic ports, R1 and R2, are placed in the left upper abdomen for robot arms 1 and 2. The camera is positioned in R3 above the umbilicus. The robot port of arm 4 (R4) is placed 8 cm to the right of the umbilicus. The accessory port L1 can be placed 8 cm further laterally along the right side or slightly inferiorly. Targeting of the robot is performed with visualization of the pelvis. A Cadiere or Tip Up instrument is placed in R1 for retraction, and a fenestrated bipolar is in R2. Monopolar scissors or hook is inserted in R4. The 8 mm accessory port L1 permits passage of sutures. After dissection is complete, the fenestrated grasper and scissors are exchanged for a needle driver in R2 and megasuture cut in the right hand (R4).

Operative Steps

Operative steps	Degree of technical difficulty (scale 1–10)
1. Clearing the pelvis	2
2. Dissection on to the sacrum	3
3. Creation of peritoneal flaps	3
4. Dissection of the rectal vaginal septum	5
5. Dissection and excision of the pouch of Douglas	4
6. Placement and suture fixation of mesh to the rectum	5
7. Fixation of the mesh proximally to the sacrum	5
8. Closure of the peritoneum	3

Clearing the Pelvis

The patient is placed in steep Trendelenburg, and gravity helps to move the small bowel out of the pelvis into the upper quadrants. Redundant sigmoid is retracted out of the pelvis. The uterus is fixed to the anterior abdominal wall. The right ureter is usually visible coursing along the side wall. If the



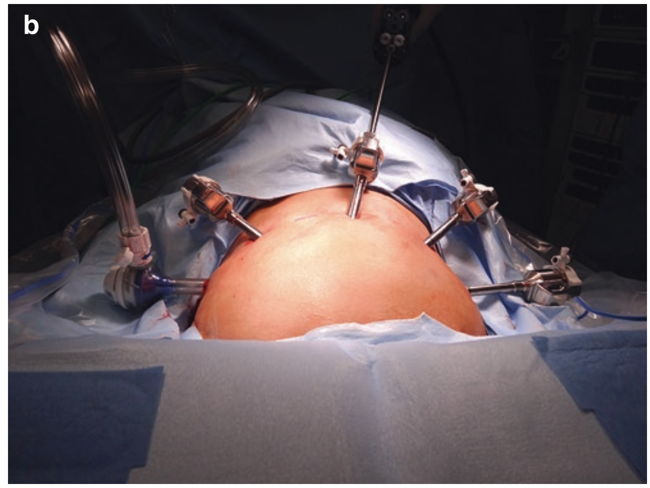


Fig. 10.1 (**a** and **b**) Port placement

sigmoid colon obscures visualization, an endoloop placed on an epiploicae can help to retract the redundant sigmoid colon out of the pelvis.

Dissecting the Anterior Longitudinal Ligament on the Sacrum

The camera is positioned in a 30° down position to visualize the sacrum. Through R1 the sigmoid colon mesentery is gently grasped and moved to the left. The fenestrated grasper in R2 is used to elevate the peritoneum midway between the right ureter and the rectal mesentery, and the peritoneum is opened. With the scissors tips are positioned perpendicular to the sacrum, the dissection is taken directly down onto the anterior longitudinal ligament along the sacrum being careful to avoid the presacral veins (Fig. 10.2, Video 10.1). There is a loss of tactile dexterity using robotic technology, and visualization of the sacrum at the onset of the procedure helps to define the proximal mesh fixation point. The assistant can help to identify the sacrum by pushing on the sacrum with a laparoscopic instrument.

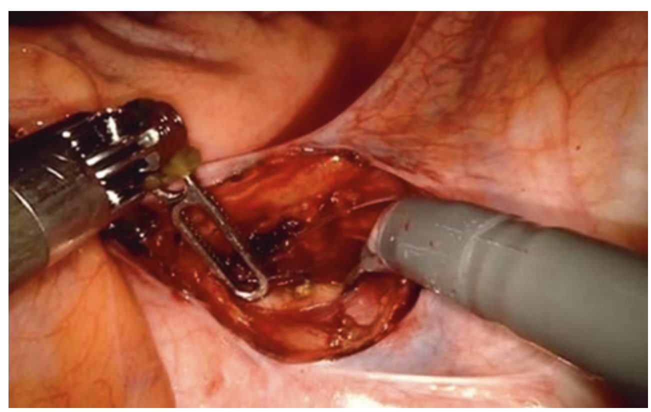


Fig. 10.2 Exposing the anterior ligament along the sacral promontory

Creating Peritoneal Flaps

The right lateral peritoneum is dissected off the underlying tissue. The lateral rectal ligaments are left intact as flaps of peritoneum are created to later be used to cover the mesh (Video 10.2).

Dissection of the Rectovaginal Septum

Dissect the rectal vaginal septum by retracting the pouch of Douglas up and out of the pelvis and scoring the peritoneum in the midline. The robotic camera is rotated to a 30° up position and sharp and blunt dissection of the plane is developed down to the perineal body. The levators can be visualized laterally (Figs. 10.3 and 10.4). An assistant sits between the legs and places an EEA sizer in the vagina. The sizer is pushed up and toward the pubic bone to elevate the vagina.

Dissection and Excision of the Pouch of Douglas

The pouch of Douglas is excised off of the anterior rectum so that the lead point of the prolapse is exposed. Excess pouch of Douglas is excised making sure to leave enough peritoneum to completely cover the mesh. If concurrent anterior repair or hysteropexy is being performed, leave excess pouch of Douglas to facilitate covering of the mesh.

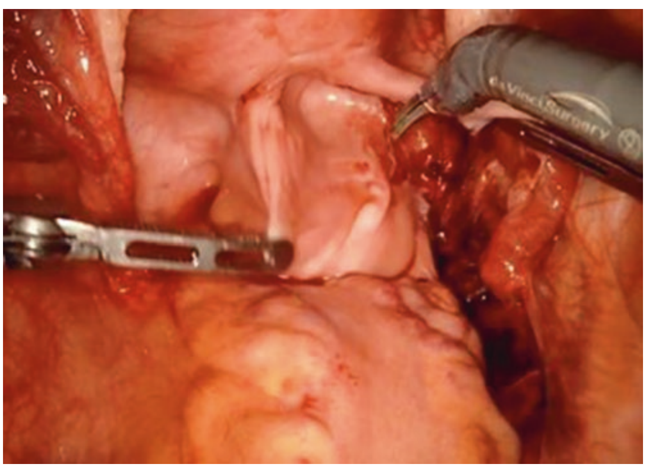


Fig. 10.3 Elevating the pouch of Douglas for dissection in the rectovaginal septum

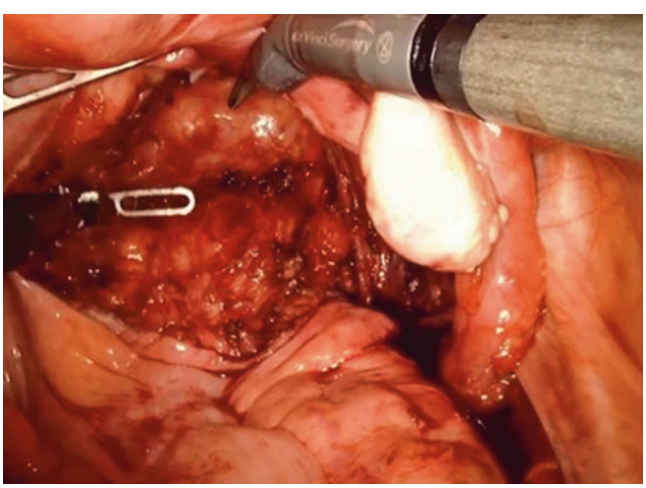


Fig. 10.4 Exposing the rectovaginal space down to the perineal body

Placement and Suture Fixation of Mesh or Biological Graft to the Anterior Rectum

After dissection is complete, the fenestrated bipolar (R2) and scissors (R4) are exchanged for a needle driver on the left and a megasuture cut on the right. A polypropylene mesh or biological graft is cut in a hockey stick fashion about 5 × 5 cm tapered up to 2 cm (Figs. 10.5 and 10.6). Taking seromuscular bites, the mesh is sutured to the anterior rectum using 2-0 PDS sutures. Approximately 12 sutures are placed (Fig. 10.7, Video 10.3) A sizer in the rectum helps to delineate the anatomy, and moving the sizer to the left or right helps to ensure adequate coverage of mesh over the distal rectum.

Fixation of the Mesh Proximally to the Sacrum

The camera is repositioned to a 30° down angle. The mesentery is retracted laterally to expose the spot on the

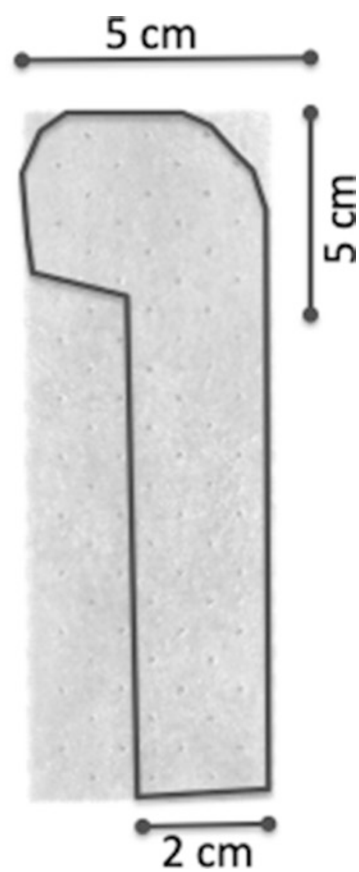


Fig. 10.5 Biological graft cut in a hockey stick configuration

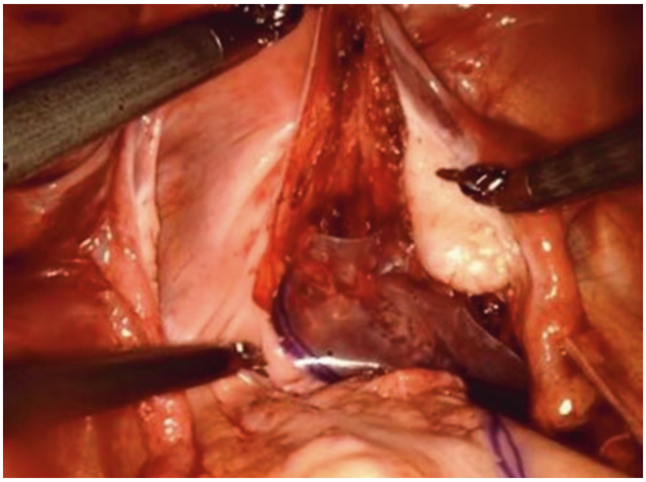


Fig. 10.6 The biological graft is placed into the rectovaginal space

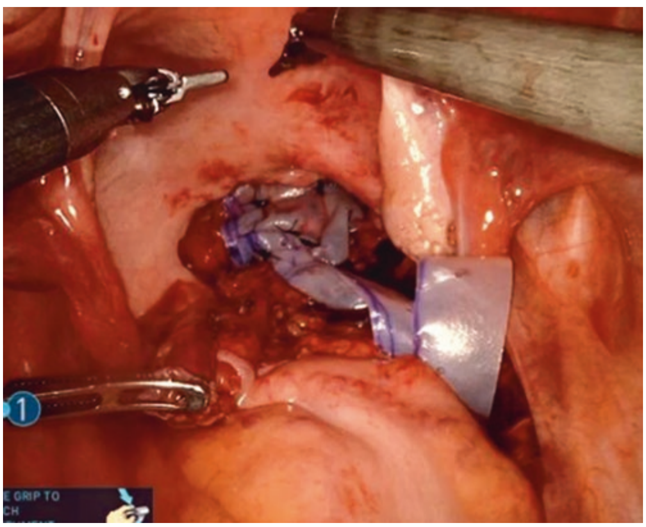


Fig. 10.7 Distal fixation of the graft to the rectum

sacrum that was previously dissected. Since the prolapse is reduced and in anatomic position, the mesh should lay flat up to the sacrum. No additional tension is placed on the mesh, and the mesh is fixed using a nonabsorbable suture. The needle is placed so that it skives the ligament to avoid suture placement that is too deep or within a disc space. We place at least two sutures (Fig. 10.8, Video 10.4). When concomitant colpopexy is performed, the suture is placed through the anterior mesh, posterior rectal mesh, and the sacrum and then back through the mesh (Video 10.5). Examination of the prolapse is performed to assess that the lead point has been adequately incorporated on the repair and that there are no inadvertent sutures in the rectum or vagina.

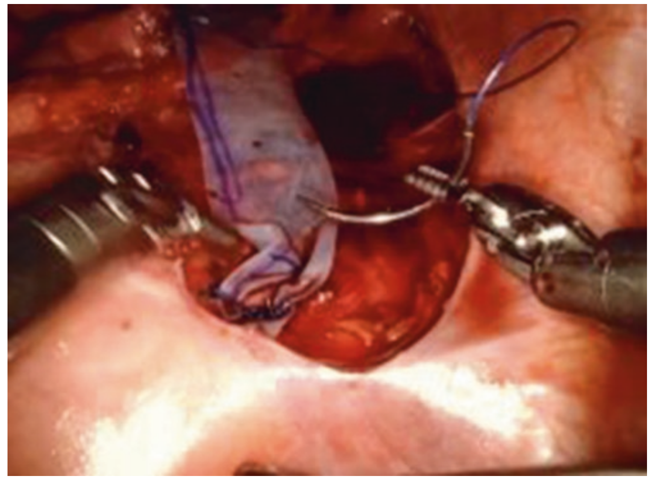


Fig. 10.8 Fixation to the anterior longitudinal ligament

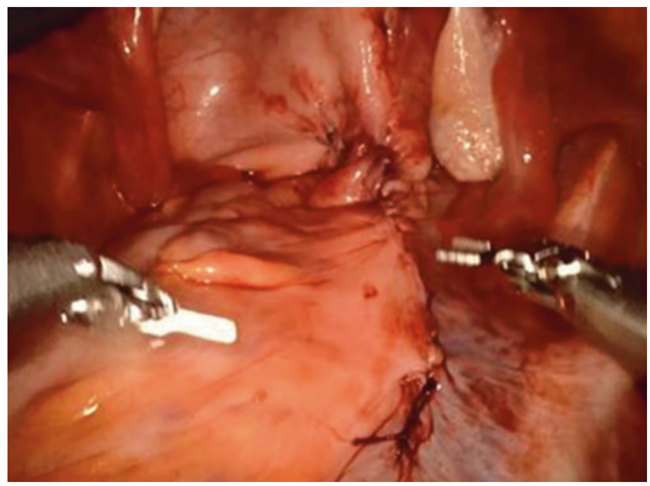


Fig. 10.9 Closure of the peritoneum over the mesh

Closure of the Peritoneum

The peritoneum is closed over the mesh (Fig. 10.9). Only suture the lateral edge of the peritoneum since the right lateral peritoneum can retract and aggressive bites can cause tenting or injury to the right ureter. Creating adequate flaps of peritoneum in the beginning of the case facilitates peritoneal closure.

Outcomes

Robotic ventral mesh rectopexy has been found to be safe and feasible in a variety of settings including same-day surgery [2] and in patients over 75 years of age [3]. Patients experience anatomical correction, improvements in fecal incontinence, obstructive defecation, and sexual dysfunction. The vast majority of patients in these studies are normal-weight females in their 50s–60s. The follow-up time of most series is short, and long-term outcomes and durability of repair still need to be evaluated.

A meta-analysis of 789 patients in 12 published series of laparoscopic ventral rectopexy (LVMR) reported recurrence rates for pelvic organ prolapse at 3.4% (95% CI 2.0–4.8). Complication rates varied from 14% to 47%. The overall mean decrease in fecal incontinence scores was 44.9% (95% CI 6. 4–22.3), and a significant decrease in constipation scores was noted: 23.9% (95% CI 6.8–40.9) [4].

Gouvas et al. reported recurrence rates after laparoscopic anterior mesh rectopexy for external rectal prolapse in nine studies which ranged from 0% to 15% with a mean of 2.4% [5]. Length of follow-up ranged from several months to 7 years. Consten et al. reported on 919 consecutive patients, 242 with external rectal prolapse [6]. Thirteen patients developed prolapse recurrence generating Kaplan-Meier recurrence estimates of 4.2%, 7.2%, and 8.2% (95% CI, 3.7–12.7) after 3, 5, and 10 years.

One concern with the adoption of new technology is the durability of repair. Using MRI to look at anatomical correction as well as function, the benefits of RVMR are equivalent to LVMR [7]. Recurrence rates for robotic repair have been mixed among various studies when compared to laparoscopic repair or open repair. Although De Hoog et al. initially found that RVMR had higher recurrence rates than LVMR or open VMR [8], this difference was no longer present when they controlled for patient age. In a case-matched study comparing robotic to laparoscopic repair, 3/44 (7%) RVMR and 3/74 (4%) LVMR patients developed prolapse recurrence within 6 months [9]. Two meta-analyses comparing RVMR and LVMR have shown recurrence rates to be equivalent [10, 11]. In a study of over 250 patients with a 2-year follow-up, the estimated 5-year recurrence rate of RVMR was 13% for external rectal prolapse and 10% for internal rectal prolapse [12].

Functional outcomes for RVMR are good for all parameters so far measured, and patient satisfaction is high. A variety of techniques for assessing outcomes have all shown symptom improvement with RVMR including validated patient surveys, clinician evaluation, and MRI functional and anatomical evaluation [7]. A 5-year RVMR observation on 258 patients reports a significant decrease in obstructed defecation in 78.6% and fecal incontinence in 63.7% [12].

Complications

The safety of robotic VMR has been demonstrated in a number of studies. Postoperative adverse events tend to be minor and occur less frequently than in laparoscopic and open repair, a finding that is true in both individual studies and meta-analyses [9, 11, 13]. The most commonly reported complications include hematoma, wound infection, urinary retention, urinary tract infection, ileus, and pain. Reported severe perioperative complications are infrequent and have included vaginal perforation, bladder perforation, bleeding, and rectal injury [14]. With regard to vaginal perforation, in one instance, it was managed robotically [14], whereas in another it resulted in abscess requiring surgical drainage, development of colovesicular fistula, and ultimately colostomy [12]. Blood loss is reported to be equivalent or less during RVMR than in LVMR and open approaches in both individual studies [9, 14] and in meta-analyses [11]. Postoperative pain and opioid use are equivalent between RMVR and LVMR [15].

Mesh-related complications need to be considered carefully and discussed with the patients since it is an ongoing source of concern and litigation. The use of both synthetic and biological grafts is reported in the literature for ventral mesh rectopexy [16]. Superiority with regards to complications or durability of material type has not been demonstrated. An international collaboration of surgeons reported on 2203 anterior rectopexy procedures – 1764 (80.1%) used synthetic mesh, and 439 (19.9%) used a biological graft. Forty-five (2%) patients had mesh erosions including vaginal [20], rectal [17], rectovaginal [7], and perineal erosions [1] [17].

Feasibility studies showed infrequent conversions to open or laparoscopic repair; there were no conversions to open surgery among ten RVMR and ten LVMR operations in a matched-pair study [14]. In a prospective randomized controlled trial, there were no conversions to open among 16 patients who had RVMR [15]. Similarly low rates were seen with 1/16 (6%) RVMR and 2/25 (8%) LVMR [18]. Reasons for conversion to open have been due to excess blood loss, adhesive burden, inability to tolerate pneumoperitoneum, retrieval of a missing needle, and difficulty exposing the sacrum for stitch placement. Ultimately, meta-analyses failed to reveal differences in conversion to open surgery for laparoscopic or robotic surgery [10]. In a recent study of 258 RVMR, there were 3 conversions to open surgery for "frozen abdomen," but otherwise no conversions from robotic to open approach [12].

In general, longer operative times are reported with RVMR [10, 11]. Operative time decreases after a level of proficiency with the robot and technique is achieved. A prospective RCT comparing RVMR ($n = 16$) to LVMR ($n = 14$) demonstrated no difference in operative time, 131 vs 125 minutes; preparation time, 25 vs 30 minutes; and total theater time, 202 vs 195 minutes; the console time for RVMR was 96 minutes [15]. More recently, a large retrospective cross-sectional series showed operative time of 87 minutes [12].

Summary

Robotic ventral mesh rectopexy demonstrates advantages over a laparoscopic approach with regards to visualization and suturing in the pelvis. Complication profiles and outcomes seem to be similar and possibly improved with a robotic approach. Standardization of technique using the steps we have outlined in this chapter is a framework to help achieve technical proficiency. Long-term outcomes for prolapse repair have yet to be determined but seem to align with recurrence models reported for laparoscopic repair.

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Robotic Total Colectomy

11

Mark Soliman and Rachel Martin

Introduction

Recent advances in the da Vinci robotic platform have made it a relevant adjunct to colorectal surgery. Although initial applications were reserved for challenging pelvic dissections, as technology has improved and the Xi ecosystem matured, procedures such as the total colectomy (which mandates a multi-quadrant approach for surgical extirpation) have become both feasible and desirable to perform robotically. This chapter will review the operative techniques of performing a robotic total colectomy.

Background

Though robotic surgery has been utilized since the early 2000s in urologic and gynecologic specialties, its adoption in general surgery and colorectal surgery has been relatively recent. Over the past decade, it has been shown to be a safe and feasible option when compared to laparoscopic and open techniques. Most studies report less estimated blood loss, shorter hospital stay, and lower complication and conversion rates when robotic surgery is utilized [1]. Robotic surgery also has been shown to have comparable oncologic outcomes to open and laparoscopic surgery [2, 3]. The first and most common use of the robot in colorectal surgery was in deep pelvic surgery, where laparoscopic and open mobilization can be technically very challenging. The endo-wristed instruments, three-dimensional visualization, and decreased surgeon fatigue the robot affords are all factors that battle the difficulty in performing a low pelvic dissection. With the advent of the da Vinci Xi robotic platform in 2014, multi-quadrant surgery became feasible. Prior to this, the inability to access multiple abdominal quadrants robotically had been prohibitive to the robotic application of total colectomy. Recently, robotic total colectomy has been compared to open and laparoscopic techniques and was found to have decreased morbidity and mortality when compared to open surgery and decreased conversion to an open operation when compared to laparoscopic surgery [4].

Preoperative Planning

Regardless of the indication for total colectomy, a thorough history and physical examination must be performed preoperatively. Prior abdominal surgical history and colonoscopy results are of the utmost importance when counseling a patient on length of recovery, possibility of a stoma, and likelihood of the operation being converted to an open procedure.

Room Setup and Positioning

Proper patient positioning is of paramount importance in robotic surgery. For a robotic total colectomy, the patient should be placed in lithotomy position with their buttocks aligned at the lower edge of the table. A foam nonslip pad underneath the patient as well as padded tape straps across the chest should be used to prevent sliding during the extremes of positioning during the operation. The patient's arms are tucked and all pressure points are attentively padded with the legs positioned in a neutral position to avoid neurovascular injuries.

Room setup should be consistent and standardized for robotic procedures. In general, room configuration is influenced by the location of anesthesia, equipment size, and room orientation. Furthermore, the robot may be docked to whatever side is convenient for the operating room staff.

M. Soliman (✉) · R. Martin
Department of Colorectal Surgery, Colon and Rectal Clinic of Orlando, Orlando, FL, USA

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Port Placement

Optimizing port placement is crucial to access all quadrants of the abdomen during a total colectomy. Ideal placement will allow the surgeon better visualization during dissection while avoiding external and internal collisions and at the same time providing working room for a bedside assistant. Pneumoperitoneum is established with optical entry technique in the right upper quadrant 2 cm below the costal margin at the midclavicular line using a 5 mm 0-degree scope and a 5 mm AirSeal® port.

After the abdomen is insufflated, robotic trocars are placed in a linear pattern spanning from the right lower quadrant to the left upper quadrant (Fig. 11.1a). The first right upper quadrant trocar serves as an assistant port, while a second assistant port is placed in either the left lower quadrant or the Pfannenstiel position. Ideally, the distance between each of the robotic trocars will be minimum 7 cm or approximately 4 fingerbreadths apart. This port configuration is a combination of the standard right colon and low anterior resection arrangements for the author. One of the 12 mm stapler ports is placed halfway between the anterior superior iliac spine and the umbilicus. A second 12 mm stapler port is placed between the left subcostal and umbilical port. Alternatively, ports may be placed in a transverse orientation from the left to right mid-abdomen (Fig. 11.1b).

Operative Steps

Operative steps	Degree of technical difficulty (scale 1–10)
1. Ileocolic pedicle isolation and division	3
2. Medial-to-lateral ascending colon mobilization	3
3. Transverse mesocolic dissection	5
4. Transverse colon lateral mobilization	3
5. Ascending colon lateral mobilization	2
6. Terminal ileum transection	2
7. Identification and ligation of the inferior mesenteric artery	4
8. Splenic flexure mobilization	4
9. Descending and sigmoid colon mobilization	2
10. Rectal division	2

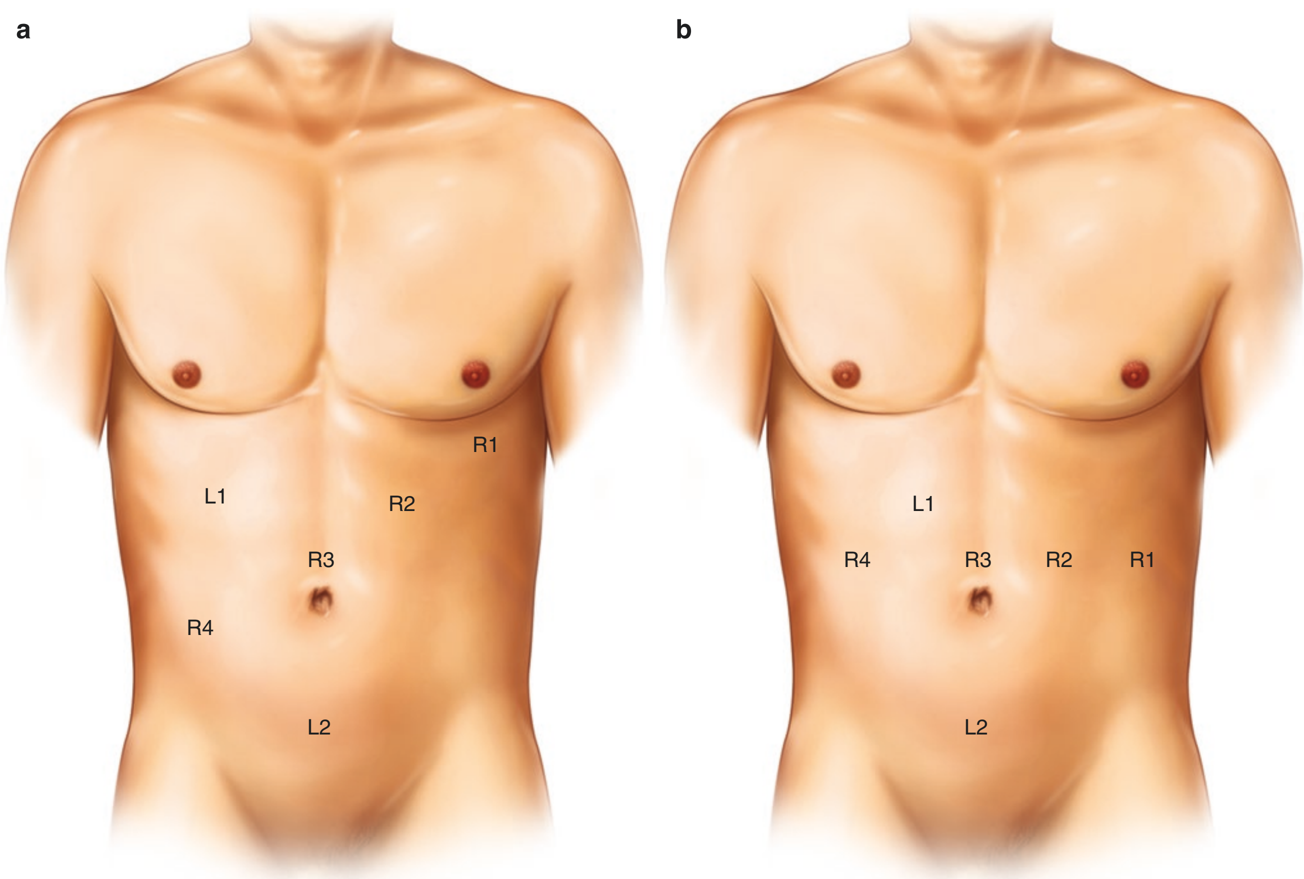

Fig. 11.1 (**a**) Author's preferred trocar placement. (**b**) Optional transversely oriented trocar placement

As a general overview, the author prefers to begin the colonic mobilization from proximal to distal (i.e., from cecum to rectum).

Positioning for Right-Sided Mobilization

Once the all trocars have been placed, laparoscopic instruments are used to position the bowel in a manner that passively exposes the ileocolic pedicle. On average, this is accomplished by positioning the bed in a slightly reverse Trendelenburg and a gradual 8–10 degrees right-side-down tilt. (Author's note: This step cannot be overemphasized. Premature docking of robotic arms without proper laparoscopic positioning of bowel will lend itself to frustration and difficult case progression.)

The robotic boom is positioned for an upper abdominal case, and the instrument arms are docked as indicated in Table 11.1.

Ileocolic Pedicle Isolation and Division

The takeoff of the ileocolic vessels is identified by anterior retraction of the mesentery to reveal a sulcus just inferior to the pedicle. This area, which is relatively translucent, is scored and an avascular plane entered. Blunt dissection is used to further develop the plane sweeping the mesocolon anteriorly and the retroperitoneal structures posteriorly. Dissection is carried initially medially to identify the second portion of the duodenum, which should be noted with 1–2 cm of medial mobilization. A window is created immediately distal to the takeoff of the ileocolic pedicle from the superior mesenteric artery and the pedicle divided according to a manner comfortable for the surgeon. The author prefers selective dissection of both the artery and the vein from each other and division using the vessel sealer in a tension-free manner.

Medial-to-Lateral Ascending Colon Mobilization

Using the fenestrated bipolar to retract the mesocolon toward the anterior abdominal wall, the vessel sealer is used to bluntly develop the avascular plane between the mesentery and retroperitoneum. The dissection is then extended toward the proximal transverse colon taking care to gently separate the duodenal attachments from the mesentery. This plane is matured first toward the patient's right lower quadrant and then to the right upper quadrant with the objective to create a defect within the translucent hepatocolic ligament so that the edge of the liver may be seen.

Table 11.1 Distribution of instruments per robotic arm based on side being operated on

	Arm 1	Arm 2	Arm 3	Arm 4
Right-sided dissection	Fenestrated bipolar	Camera	Scissors Vessel sealer Stapler	Tip-up fenestrated grasper
Left-sided dissection	Tip-up fenestrated grasper	Fenestrated bipolar	Camera	Scissors Vessel sealer Stapler

Transverse Mesocolic Dissection

The medial dissection is continued to the patient's left or distally on the mesocolon. The transverse mesocolon is tented anteriorly, while the second portion of the duodenum and head of the pancreas are gently brushed posteriorly. The middle colic vessels will be encountered next, which should be circumferentially dissected and divided. Following the division of the middle colic vessels, the dissection continues distally on the mesocolon as far as the robotic platform will allow. The author aims to divide the inferior mesenteric vein at the inferior edge of the pancreas as the distal-most aspect of this medial dissection. Once IMV division is accomplished, the lesser is easily entered by reflecting the transverse mesocolon anteriorly and the body of the pancreas posteriorly.

At this point of the transverse mesocolic mobilization, it is common that the robotic platform has reached its rightward limits. The author now transitions into division of the lateral attachments from this distal dissection point back to the cecum.

Transverse Colon Lateral Mobilization

The omentum is reflected over the liver cephalad to expose the omentocolic attachments. These are taken with electrocautery to enter the lesser sac. This plane is matured proximally to meet the previously dissected proximal defect in the hepatocolic ligament that was created during the medial-to-lateral mobilization of the ascending colon.

Ascending Colon Lateral Mobilization

Once the transverse colic dissection is complete, the ascending colon is retracted medially, and the white line of Toldt is incised with electrocautery. The dissection is carried proximally on the colon to the cecum and terminal ileum to completely detach the ascending and transverse colon off the retroperitoneum and duodenum.

Terminal Ileum Transection

If indicated, the terminal ileum may be divided at this point. If desired, this is accomplished by stretching the ileocolic pedicle with arm 4 of the robot and retracted to the patient's left upper quadrant. This tension is used to guide division of the remaining mesentery toward the terminal ileum. The terminal ileum is then transected using the robotic stapler in the right upper quadrant 12 mm port site.

Positioning for Left-Sided and Rectal Mobilization

Once the proximal colonic mobilization has been completed, attention is then turned to the more distal or left-sided dissection. This is accomplished first by undocking all robotic arms and positioning the patient in a Trendelenburg with left-side up position. The goal of positioning is to laparoscopically place the small bowel out of the pelvis, providing exposure to the inferior mesenteric arterial pedicle. Taking time to position bowel and using gravity to assist in exposure is vital in the progression of a frustration-free operation. The robotic arms are docked with the boom positioned for a lower abdominal case with the instruments arranged as follows: tip-up grasper in arm 1, the fenestrated bipolar in arm 2, the camera in arm 2, and the scissors in arm 4 (Table 11.1).

Identification and Ligation of the Inferior Mesenteric Artery and Identification of the Ureter

The medial-to-lateral approach begins by first retracting the rectosigmoid junction anteriorly toward the abdominal wall with the third arm. This helps expose a sulcus just inferior to the mesenteric pedicle where a subtle color change may be noted between the junction of the mesocolon and retroperitoneal tissues (Fig. 11.2).

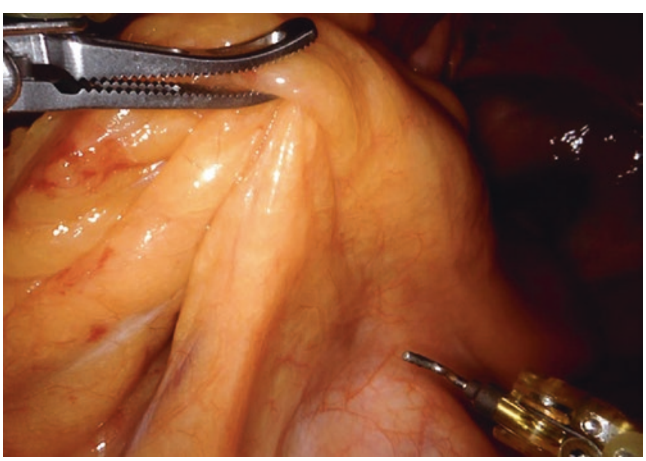

Fig. 11.2 Mesenteric pedicle

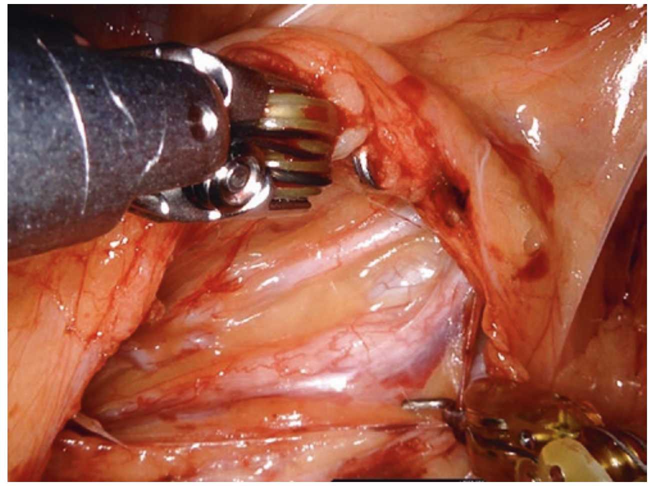

Fig. 11.3 Ureteral identification

This junction is scored and the avascular plane developed using blunt dissection. The hypogastric nerves are swept posteriorly, and the superior hemorrhoidal artery is swept anteriorly in an attempt to preserve these structures. Laterally, the ureter is identified and swept posteriorly, and the dissection is continued cephalad toward the splenic flexure (Fig. 11.3). Once the inferior mesenteric artery (IMA) is isolated, a mesenteric window is created proximally, and it is circumferentially dissected until it is skeletonized from its takeoff from the aorta. The scissors are exchanged for the robotic vessel sealer device, which is used to ligate the IMA. During division of the vessel, the retracting arms should be positioned to decrease any tension, and the bipolar should be prepared to grasp the pedicle upon transection in case of uncontrolled bleeding.

Splenic Flexure Mobilization

With the IMA divided, dissection continues in a medial-to-lateral fashion toward the splenic flexure. Retraction of the mesentery off the retroperitoneum is provided by the bipolar, and blunt dissection with the vessel sealer is used to develop this plane. To avoid working in a hole, additional mesentery is taken along the way to facilitate exposure.

The medial dissection is continued until the previously divided IMV pedicle is identified. The lesser sac is then entered, which is accomplished by "stepping" cephalad and anterior to the inferior border of the pancreas. This allows complete mobilization of the descending and transverse mesocolon off the retroperitoneal structures. Special care must be taken at this step to ensure that the pancreas is identified and swept posteriorly instead of mobilized along with the colon. Once the medial dissection is complete, and the right-sided dissection planes have been joined, attention is turned to the lateral dissection.

The omentum is then elevated to expose the omentocolic attachments. At this point, the surgeon should be able to identify the previously divided omentocolic attachments from the right-sided dissection. The splenic flexure is grasped by the assistant and retracted to the right lower quadrant, and these attachments are divided, thus affording complete mobilization of the distal transverse colon and splenic flexure.

Descending and Sigmoid Colon Mobilization

After complete splenic flexure mobilization, attention is turned back to the sigmoid colon. Mobilization is achieved by retracting the sigmoid colon medially to expose the white line of Toldt. This line is incised at its medial border, and the lateral abdominal wall attachments are taken down to the level of the peritoneal reflection (Fig. 11.4).

Rectal Mobilization (If Applicable, See Other Chapters)

Posterior Rectal Mobilization

Mobilization of the rectum begins posteriorly by retracting the rectum anteriorly with the third arm. Gentle tension exposes the thin, avascular areolar tissue of the presacral space (Fig. 11.5). Exposure during this dissection begins with the third arm, but as the dissection continues deeper in the pelvis, traction is provided mostly by the bedside assistant. An atraumatic grasper is used through the assist port to retract the rectum out of the pelvis by grasping the distal sigmoid or proximal rectum. The hypogastric nerves are swept posteriorly, and electrocautery with the hook or scissors is used to develop this plane to the most distal aspect of the posterior dissection possible, before turning our attention to the anterior dissection.

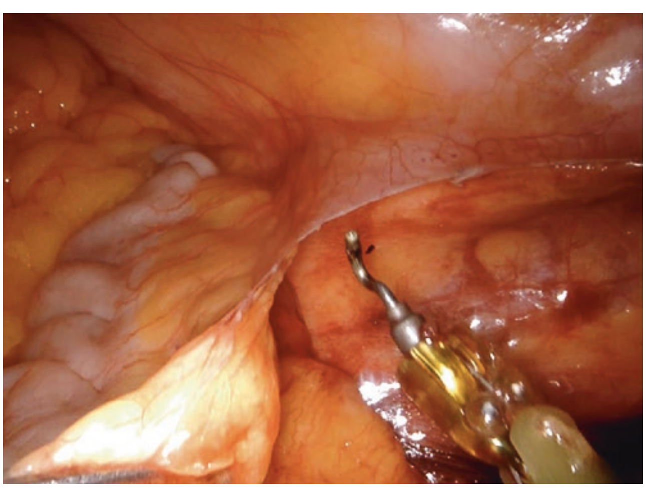

Fig. 11.4 Lateral mobilization

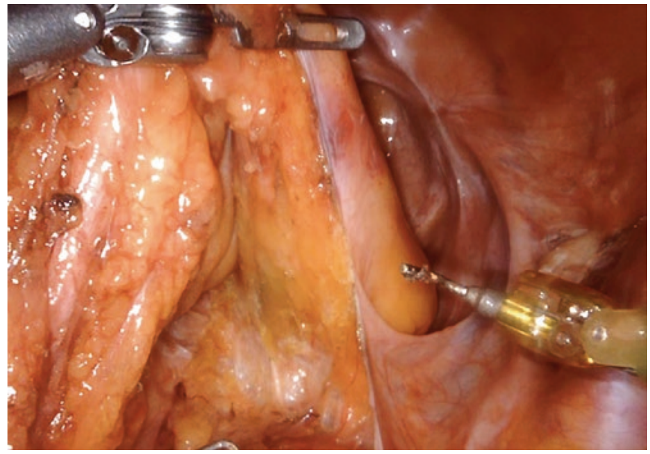

Fig. 11.5 Posterior rectal mobilization

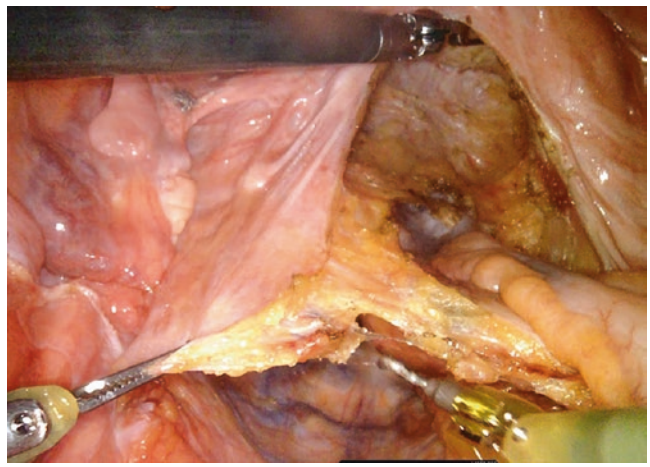

Fig. 11.6 Lateral stalk mobilization

Anterior Rectal Mobilization

Electrocautery is used to score the anterior peritoneal reflection. The bedside assistant retracts the rectum out of the pelvis, while the third arm of the robot retracts the anterior pelvic structures off the rectum. This exposes the rectovaginal septum in the female patient and the prostate and seminal vesicles in the male patient. Denonvilliers' fascia is then incised, and the anterior rectal dissection is carried down to the level of the distal rectum and proximal anal canal.

Lateral Rectal Mobilization

After the anterior and posterior rectal planes have been developed, the lateral stalks are addressed (Fig. 11.6). Contralateral tension to the side of dissection is provided by the bedside assistant. During the left lateral stalk dissection, the assistant pulls the rectosigmoid to the right upper quadrant. Electrocautery is used for dissection and the bipolar used to provide countertraction at the medial aspect of the lateral stalk. This is repeated on the right side with the rectosigmoid retracted to the left upper quadrant by the assistant. Once the level of the distal rectum and proximal anal canal is reached, circumferential dissection should be complete.

Rectal Division

Once circumferential rectal mobilization has been achieved to the level of the levator plate, or whatever the desired dissection level is, a distal transection margin is then selected, and the mesorectum is divided at a right angle to the rectum. A robotic stapler is then introduced through the 12 mm trocar in the right lower quadrant for division of the bowel. Introduction of the stapler in the deep pelvis in an anterior to posterior orientation has been found by the author to be the most efficient technique in dividing the rectum (Fig. 11.7).

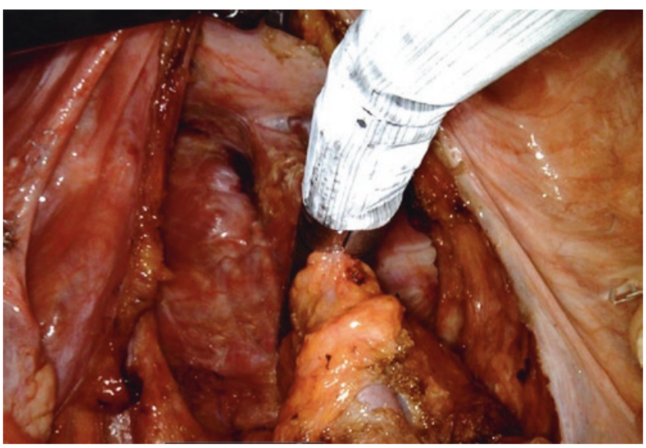

Fig. 11.7 Rectal division

Final Steps

Once the specimen has been isolated, the final steps of the operation are based on the treatment goals. If an end ileostomy is preferred, the specimen may be extracted through whichever site is desired and the stoma matured. Alternatively, if an anastomosis is preferred, or even the construction of an ileal-pouch anal anastomosis is desired in the setting of ulcerative colitis, these all may be performed this point of the operation.

Summary

The release of the Xi Davinci robotic platform was specifically designed to allow multi-quadrant robotic surgery, and the system significantly facilitates a robotic total abdominal colectomy maintaining all benefits of robotic surgery including precise dissection using flexible instruments, vessel sealers, a third surgeon arm, and stable 3D visualization.

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12 Robotic Proctectomy and Ileoanal Pouch Creation

Amy L. Lightner and David W. Larson

Introduction

Since its introduction in 1978 by Parks and Nicholls [1], restorative proctocolectomy with ileal pouch-anal anastomosis (IPAA) has become the procedure of choice for ulcerative colitis (UC) and familial adenomatous polyposis (FAP) [2]. The operation is traditionally performed in two or three stages by using either an open, hand-assisted laparoscopic or a totally laparoscopic approach. In the past decade, the use of laparoscopy has greatly increased due to shorter length of stay postoperatively [3, 4], improved body image [5], decreased infertility rates [6, 7], and decreased intravenous narcotic use [3].

In recent years, the da Vinci robot (Intuitive Surgical, Sunnyvale, California) has become an increasingly popular and accepted modality in colorectal surgery for both benign and malignant conditions [8, 9]. Many studies including meta-analyses have now reported equivalent safety and efficacy with a robotic approach in colorectal operations as compared to conventional laparoscopy [10]. The improved dexterity, visualization, and ergonomics of the robotic platform have contributed to the surge in robotics seen in rectal cancer. This same surge in use may be seen in those surgeons performing IPAAs in the coming years despite possible increased cost [11] and lack of haptic feedback [12, 13]. We herein describe our technique for a robotic IPAA and highlight steps that may require intraoperative troubleshooting.

Background

Traditionally, IPAA was performed as a two-stage operation, the first stage being a total proctocolectomy with diverting loop ileostomy and the second stage as a reversal of the protective diverting loop ileostomy. In the era of biologic therapy, an increasing number of IPAAs are being performed as a three-stage procedure due to increased patient immunosuppression, anemia, and malnutrition. In a three-stage approach, the first stage is a subtotal colectomy with end ileostomy, second stage is completion proctectomy with IPAA and diverting loop ileostomy, and third stage is diverting ileostomy reversal. For the purposes of our discussion, a robotic IPAA, we will assume a three-stage approach with the robotic IPAA representing the second stage of surgery. Thus, patients will have previously undergone a laparoscopic subtotal colectomy with end ileostomy.

Patient Positioning and Port Placement

After induction, the patient is placed into a combined lithotomy position with both arms tucked.

The 15 mm balloon trocar serves as an accessory port for the assistant. A 30° camera is then placed into this port. Four robotic ports are then placed under direct visualization in a transverse fashion across the abdomen approximately 20 cm from the pubis, each 6–8 cm apart for the Xi system in order to avoid external or internal collisions (Fig. 12.1).

Issues are critical to consider when placing ports are the distance to the target anatomy, and the potential for the boney aspects of the pelvic sidewall and sacral promontory to impede surgical dissection. For example, the monopolar scissors are 57 cm in length with a working length of 27 cm from the remote center to tip. Therefore, trocars placed too far cephalad in a patient with a long torso will make the presacral dissection toward the pelvic floor difficult secondary to reach. Likewise, the sacral promontory acting as a fulcrum can lead to a poor angle of dissection into the presacral space. Finally, trocars placed too far laterally (particularly in a male patient) will make the low pelvic dissection difficult secondary to collisions with the lateral pelvic sidewall.

A. L. Lightner (✉) · D. W. Larson
Division of Colon and Rectal Surgery, Mayo Clinic, Rochester, MN, USA
e-mail: lightner.amy@mayo.edu

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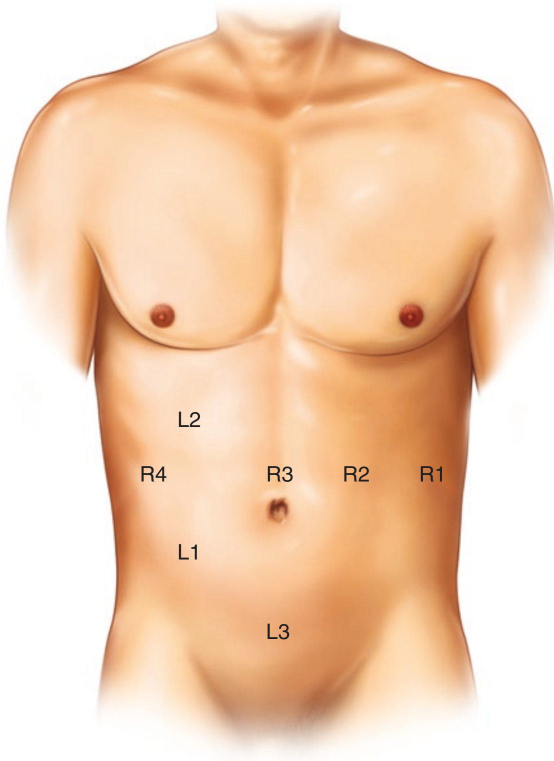

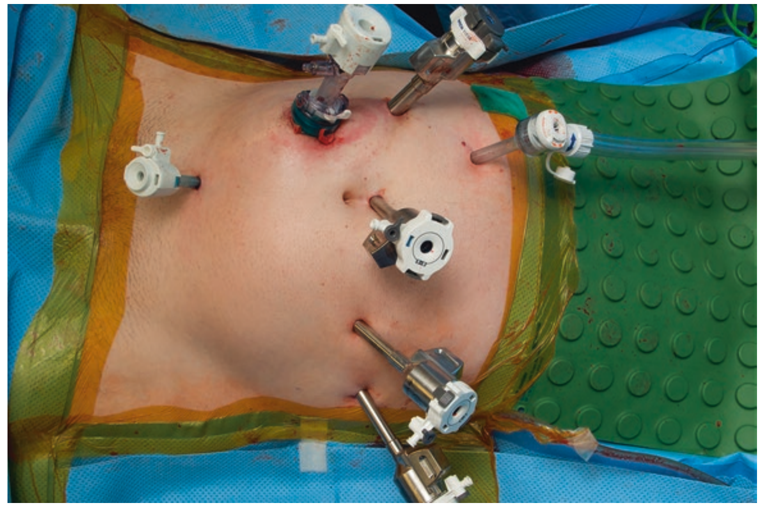

Fig. 12.1 Four robotic ports and 15 mm balloon trocar (working port) on the abdomen

Operative Steps

Operative steps	Degree of technical difficulty (scale 1–10)
1. Mobilization of the ileal mesentery	4
2. Posterior rectal mobilization and division of the superior rectal artery	5
3. Anterior rectal mobilization and rectal transection	5
4. Construction of the anastomosis	3
5. Testing the anastomosis	1
6. Diverting loop ileostomy	2

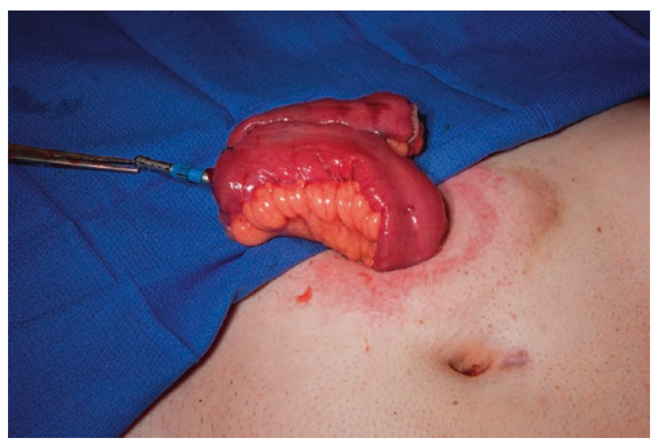

Fig. 12.2 Construction of the ileal pouch through the previously made ileostomy site

Construction of the Pouch

Prior to robotic port placement, the terminal ileostomy is incised in its circumference to the peritoneum by using sharp dissection and electrocautery. Once dissected to the level of the fascia, a linear stapler is used to seal the terminal ileum. The distal ileum is exteriorized through the ileostomy site. Approximately 16–20 cm proximal from the distal ileal staple line, the bowel is opened on the antimesenteric side with the use of electrocautery. This marks the apex of the pouch. A 15–20 cm J pouch is constructed using two fires of the 100 mm extracorporeal linear staples (GIA100, Covidien, Boulder CO). A 2-0 nylon is placed as a purse string suture, and the anvil to the circular stapler (EEA 25, 27, or 29 mm) is then placed into the apex (Fig. 12.2). The blind limb of the pouch and the linear staple line is then oversewn with 3-0 silk sutures. Once created the anvil and pouch, they are then dropped back into the abdomen, and the 15 mm balloon trocar replaced in the ileostomy site to achieve insufflation.

Mobilization of the Ileal Mesentery

The length of the mesentery will determine the ability to construct a pouch. Inability to construct a pouch is associated with increased body mass index, likely due to the foreshortening of the mesentery [14]. With mobilization and stair stepping of the mesentery, additional length can be gained and will likely be required in order to prevent tension on the pouch anastomosis. This portion of the case can be performed laparoscopically through the robotic trocars with methods previously described [15–18]. The first step in mesenteric mobilization is mobilizing the lateral attachments cephalad until the inferior border of the duodenum and pancreas are reached (Fig. 12.3a), making sure to identify and protect the superior mesenteric artery (SMA) (Fig. 12.3b). If reach remains inadequate, a series of stepwise incisions on the anterior and posterior mesentery can be made to increased mesenteric length (Fig. 12.3c) using electrocautery to score the mesentery superficial to the vasculature (Fig. 12.3d). In this particular technique, it may be required that these peritoneal incisions be made prior to pouch creation in step one, if there is any concern that reach might be an issue (male, increased BMI, increased height).

Posterior Rectal Mobilization and Division of the Superior Rectal Artery

Once the mesentery has been adequately mobilized, the attention is turned to the proctectomy portion of the operation. In female patients, the uterus can be retracted to the abdominal wall by using a transabdominally placed Keith needle through the abdominal wall and through the fundus or round ligaments of the uterus which is then removed at the end of the case. Alternatively, a uterine manipulator may be

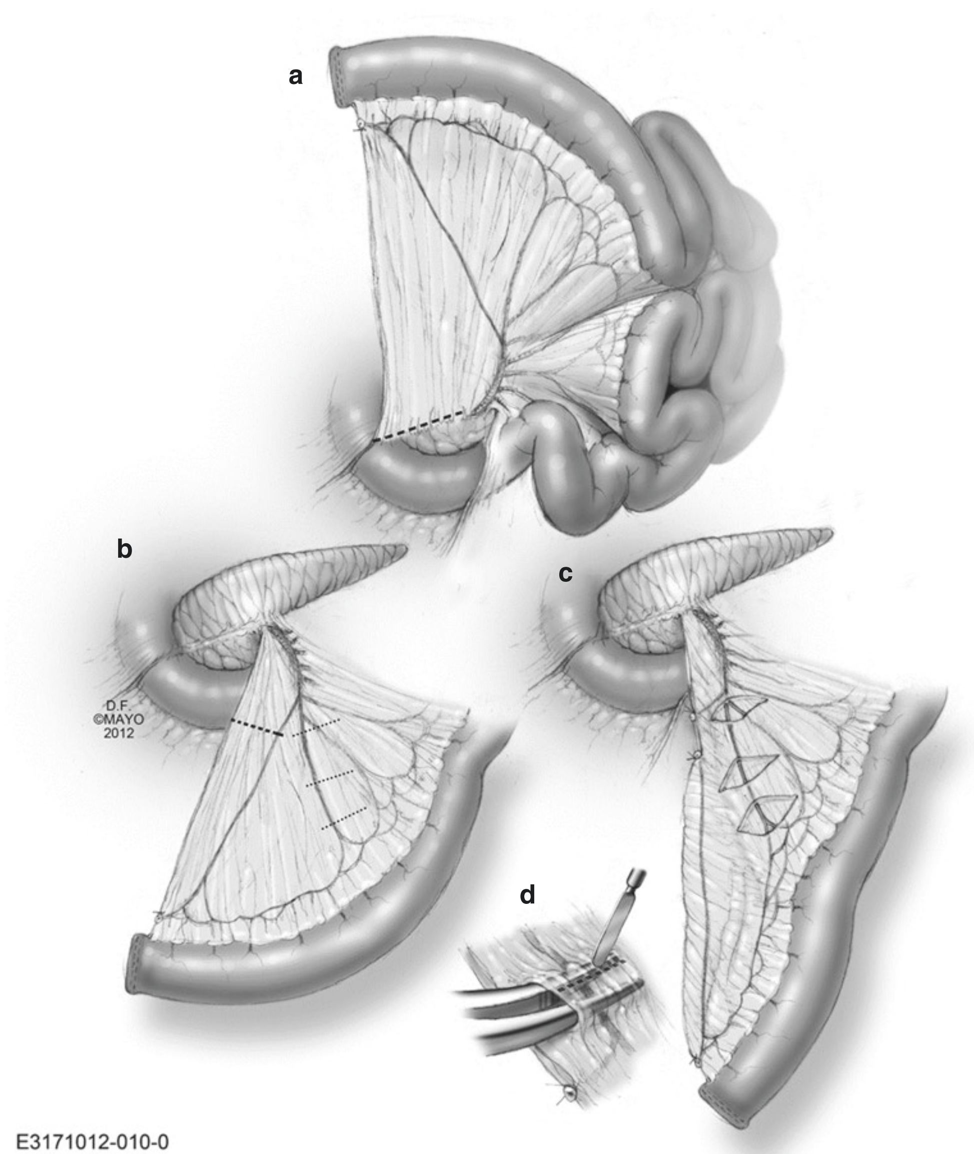

Fig. 12.3 The first step in mesenteric mobilization is mobilizing the lateral attachments cephalad until the inferior border of the duodenum and pancreas are reached (**a**), making sure to identify and protect the superior mesenteric artery (SMA) (**b**). If reach remains inadequate, a series of stepwise incisions on the anterior and posterior mesentery can be made to increase mesenteric length (**c**) using electrocautery to score the mesentery superficial to the vasculature (**d**)

placed transvaginally to suspend the uterus and vagina away from the rectum to allow easier dissection in the rectovaginal septum. The robot device (da Vinci Surgical System, Intuitive Surgical Inc.) is then docked on the patient's left lateral side (Fig. 12.4). In the Xi robotic system, the robot can come in straight from the left side, and with the camera focused on the pelvis, the robot will automatically rotate to the correction position. The scissors are placed in arm 1, camera in arm 2, bipolar fenestrated in arm 3, and small graptor in arm 4.

The top of the rectal stump is identified, the sacral promontory is identified, and the ureter and iliac vessels are on the right side. The proctectomy begins entering the presacral space from the right side. The dissection is initiated by lifting the rectum in such a way that the peritoneum overlying the right pelvic gutter is placed on stretch, and the monopolar scissors are then used to score the peritoneum (Fig. 12.5a). A filmy, avascular plane should be revealed which can be followed posteriorly and to the contralateral side, lifting the mesentery anteriorly and keeping the retroperitoneal structures posteriorly (Fig. 12.5b).

The posterior dissection is continued toward the pelvic floor (Fig. 12.5c) and then extended to the contralateral side, identifying the left-sided ureter, gonadal vessels, and iliac vessels. The superior hypogastric nerves are also identified during the dissection and preserved by gently sweeping them posteriorly toward the sacrum. Once the posterior space has been dissected, the lateral stalks are taken, again appreciating the ureter on both right and left sides. The mesentery (which includes the remaining superior rectal artery) is divided using the da Vinci® EndoWrist® One™ Vessel Sealer (*Intuitive Surgical Inc., Sunnyvale, CA*).

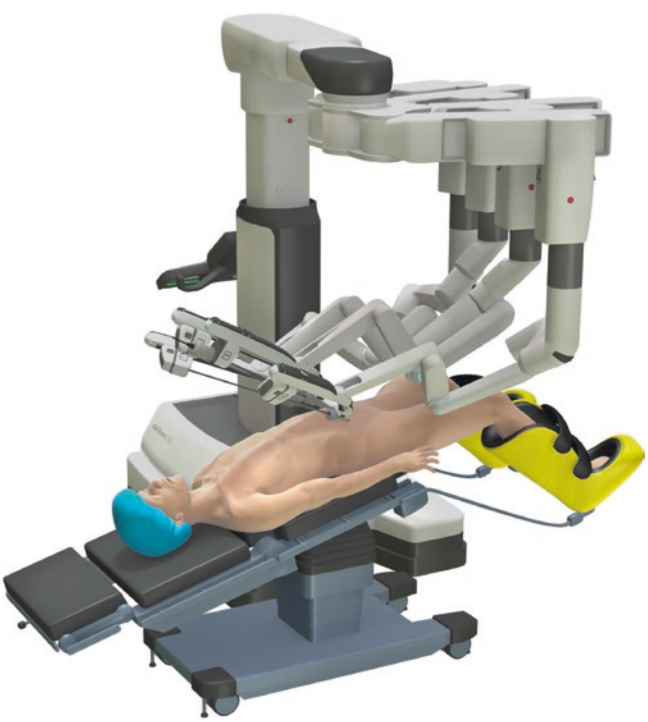

Fig. 12.4 The robot device (da Vinci Surgical System, Intuitive Surgical Inc.) is then docked on the patient's left lateral side

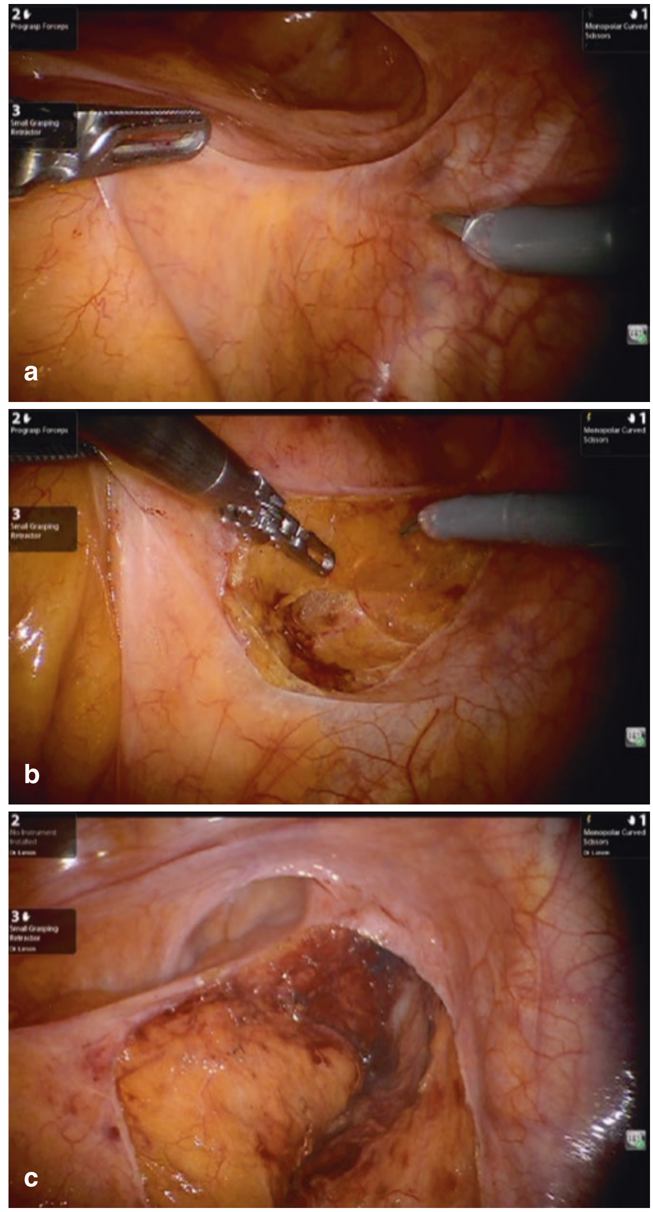

Fig. 12.5 The dissection is initiated by placing the peritoneum overlying the right pelvic gutter on stretch to identify the best location to score the peritoneum. (**a**) An avascular plane is then identified which is followed posteriorly (**b**), and the posterior dissection is continued toward the pelvic floor (**c**)

Anterior Rectal Mobilization and Rectal Transection

The anterior dissection is performed last (Fig. 12.6). Arm 3 is used to pull the rectal stump down and out of the pelvis to

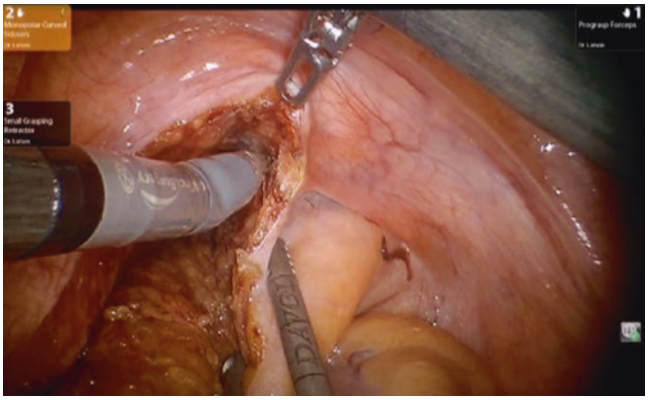

Fig. 12.6 The anterior dissection is performed following the posterior and lateral dissections

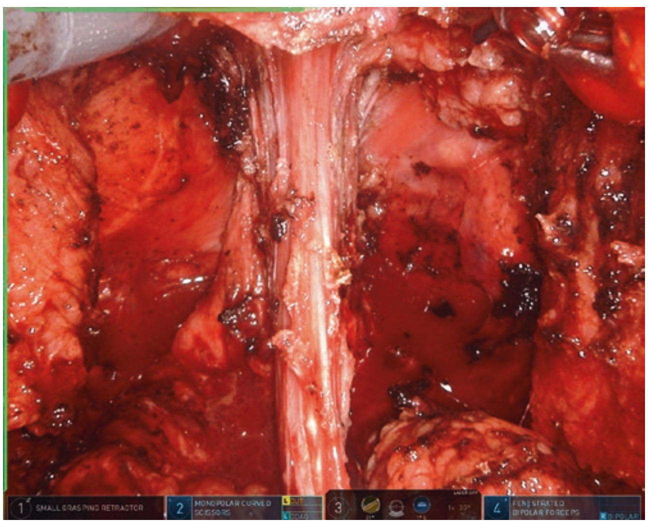

Fig. 12.7 Upon completion of the posterior, anterior, and lateral dissections, the rectum should be skeletonized at the level of the pelvic floor, prior to firing the robotic stapler

provide proper tension on the anterior structures. The assistant aids the dissection by placing a suction device or grasper anterior at the level of the seminal vesicle or posterior vagina and lifting anteriorly. This countertraction anterior to the rectum allows the dissection to progress to the level of the pelvic floor (Fig. 12.7). Once the pelvic floor is identified, the rectum is digitized transanally to determine adequate dissection and ensure that the anastomosis will be performed approximately 1–2 cm above the dentate line. The rectum is then stapled 1–1.5 cm above the dentate line using an endoscopic stapling device (iDrive Ultra, Covidien) (Fig. 12.8) and the specimen extracted through the ileostomy site after the IPAA has been stapled to the anal canal and prior to loop ileostomy creation.

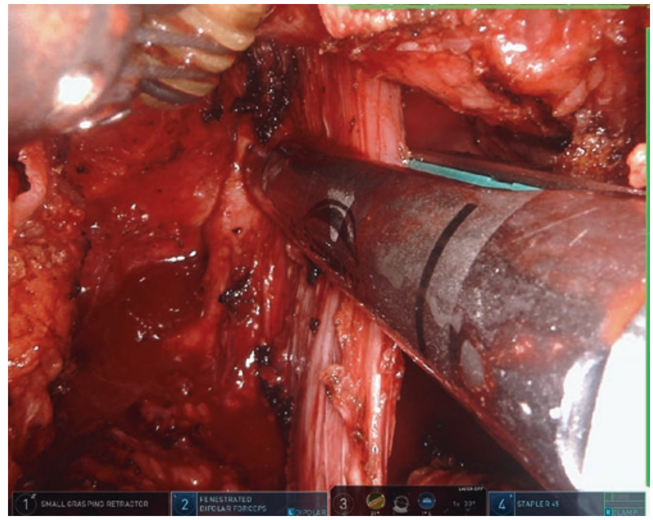

Fig. 12.8 Firing the 60 mm green load robotic stapler across the lower rectum just above the pelvic floor

Construction of the Anastomosis

Moving the transected rectum out of the pelvis, the pouch is connected to the anus under robotic visualization. Under robotic control the pouch and the anvil are brought toward the pelvis. A series of rectal dilators are inserted into the anal canal followed by the EEA 29 mm stapler. The stapler pin is deployed, and the anvil is then married under direct robotic visualization (Fig. 12.9).

Testing the Anastomosis

As is typical, once the pouch has been successfully connected to the anus, the patient is placed into reverse Trendelenburg, and irrigation is placed into the pelvis. Proctoscopic visualization and insufflation of the pouch under saline assure the surgeon that there are no leaks.

Diverting Loop Ileostomy

A diverting loop ileostomy is fashioned at the previous ileostomy site to protect the ileal pouch-anal anastomosis. A site is picked proximal to the pouch inlet that allows no tension to be placed on the pouch. This is typically 25–50 cm proximal from the pouch inlet. A 19 French JP drain is then placed through the left-sided robotic trocar site into the pelvis.

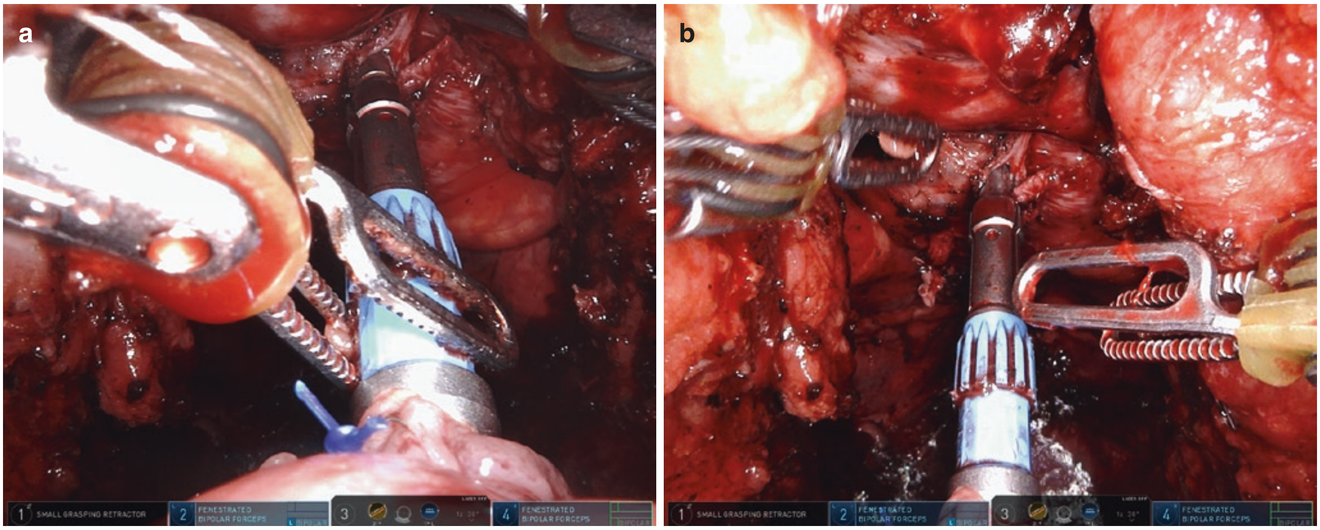

Fig. 12.9 Constructing the ileal pouch-anal anastomosis intracorporeally under direct robotic visualization. (**a**) Bringing the anvil into view; (**b**) beginning to close the stapler

Conclusions

A robotic approach provides an additional tool for a minimally invasive approach to IPAA. While there are no RCTs comparing robotic and laparoscopic IPAA, known advantages include improved visualization of neurovascular bundles, especially in a narrow male pelvis, and improved ergonomics. In the near future, the robot may become the preferred minimally invasive approach for IPAA.

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Robotic Abdominoperineal Resection: Cylindrical and Selective Cylindrical Approach

13

Slawomir Marecik, Ahmed Al-Khamis, Kunal Kochar, and John J. Park

Introduction

This chapter will review the specific advantages that robotic technology has to offer when performing abdominoperineal resection (APR), which historically has been considered a challenging operation. Several operative techniques will be discussed, including (1) robotic rectal mobilization with conventional perineal dissection, (2) the use of transabdominal levator and extralevator transection to simplify the perineal dissection, and (3) selective eccentric extralevator transection for eccentrically located tumors.

Background

In 1982, Bill Heald re-emphasized the principle of rectal dissection when he defined total mesorectal excision (TME) as the "*optimal dissection around the cancer which must clear all forms of extension and circumscribe predictably uninvolved tissue*" [1]. Heald labeled this the "holy plane" of rectal surgery.

Since then, oncological outcomes following low anterior resection (LAR) have improved significantly. Unfortunately, outcomes following APR continue to be poor [2, 3]. APR is associated with higher local recurrence rates, ranging from 15% to 30%, and worse survival outcomes as compared to LAR [2, 4]. These outcomes are related to higher perforation rates of the resected specimens and a higher rate of positive circumferential resection margins (CRM). As surgeons have become more experienced with sphincter-saving procedures, the frequency, with which APRs are performed, has significantly decreased. Surgeon's inexperience, combined with technical difficulties associated with operating in the confined space of the lower pelvis, particularly when dealing with advanced pathology, may contribute to the worse outcomes noted in APR.

In an effort to improve outcomes of APR, Holm and colleagues, from Sweden, published encouraging results on a radical new technique called extralevator abdominoperineal resection (ELAPR) [5]. The Holm technique standardizes the way APR is performed by avoiding dissecting the mesorectum from the levator muscles and resecting a significant portion of the levator muscles en bloc with the mesorectum and the perianal tissues. Coccygectomy (or even very distal sacrectomy) is also a frequently performed maneuver used to facilitate this extensive complete resection [6]. ELAPR results in a cylindrical specimen with more tissue surrounding the tumor in the lower rectum. This translates to a lower risk of bowel perforation and tumor involvement of the CRM, thus leading to a lower risk of local recurrence. Moreover, this technique provides excellent exposure during the perineal part of the procedure [7–10].

Still, the Holm technique has its limitations. The authors of this chapter, along with others [11, 12], have found this technique to be associated with more challenging perineal wound closure, often requiring flap reconstruction. It is also associated with more genitourinary complications and chronic pain, in addition to perineal hernias [13, 14]. The genitourinary impairment mainly results from the injury to the pelvic plexi when the levators are incised more laterally in relation to pelvic plexi and also from the injury to the neurovascular prostatic bundles (Fig. 13.1a, b, c). In order to minimize these issues, the surgeon could consider adopting a selective modified extralevator APR, when appropriate. This

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S. Marecik (✉)
Department of Colon and Rectal Surgery, Advocate Lutheran General Hospital, Park Ridge, IL, USA

Department of Colorectal Surgery, University of Illinois at Chicago, Chicago, IL, USA
e-mail: smarecik@uic.edu

A. Al-Khamis · K. Kochar · J. J. Park
Department of Colon and Rectal Surgery, Advocate Lutheran General Hospital, Park Ridge, IL, USA
e-mail: kunal.kochar@advocatehealth.com

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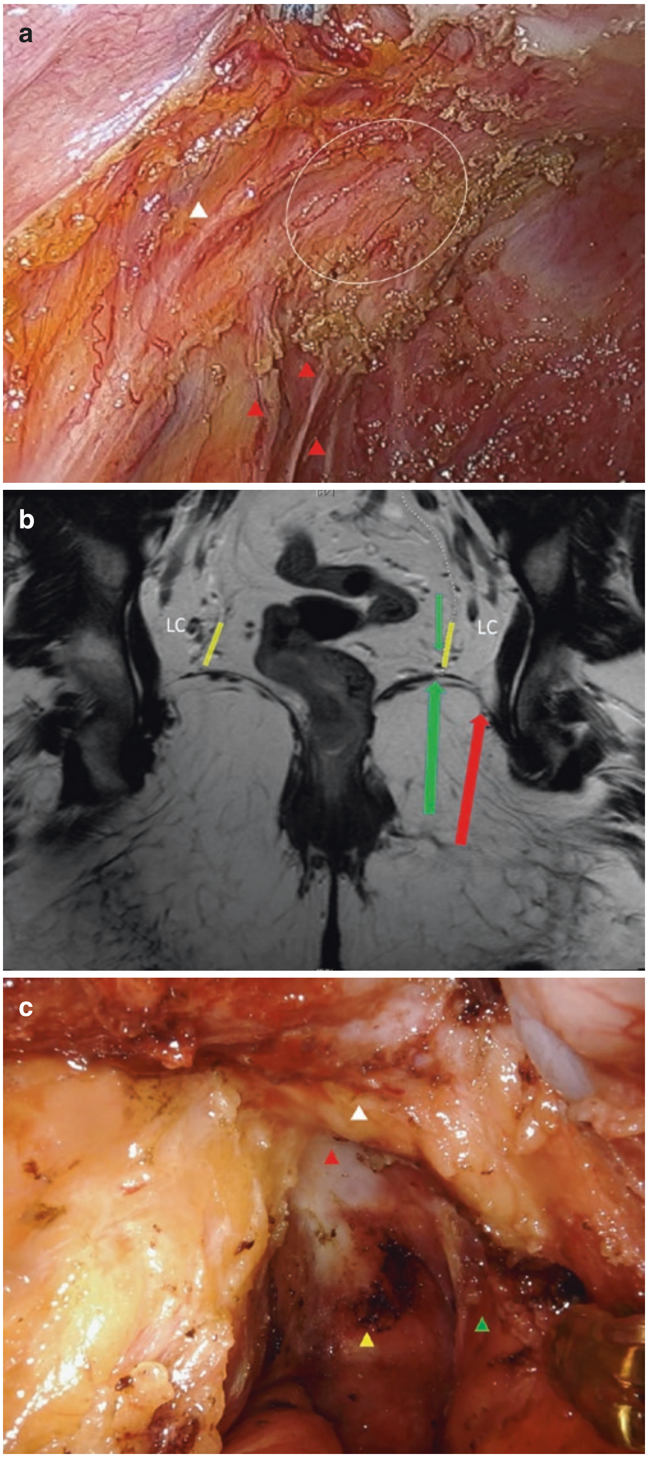

Fig. 13.1 (**a**) Left pelvic plexus after total mesorectal excision during restorative surgery; located just above the levators, created by the hypogastric nerve (white mark), splanchnic sacral nerves (red marks), and splanchnic pelvic nerves (also known as *nervi erigentes*, not visible since they run in the lateral compartment). (**b**) Levator incision in relation to pelvic plexus (yellow); correct (green arrow) – just medial to the pelvic plexus; incorrect (red arrow) – lateral to the pelvic plexus, into the lateral compartment (LC). (**c**) Right neurovascular prostatic bundle (white mark) during ultra-low anterior resection, right pubococcygeus (red mark) and iliococcygeus (yellow mark) muscles exposed; pelvic plexus (green mark)

involves a wide levator transection which is performed eccentrically at the site of the tumor, with conservative resection of the levators on the unaffected side. This approach appears to provide equivalent oncological outcomes but with less perioperative morbidity [4, 15].

Laparoscopic rectal resection has been a widely accepted modality for standard surgical management of rectal cancer. This minimally invasive approach provides equivalent oncological outcomes to open surgery, with faster recovery, shorter length of hospital stay, and significantly less perioperative morbidity [16]. Laparoscopic rectal surgery does, however, have its limitations. It has been associated with significant conversion rates and a high proportion of positive CRM rates [17, 18]. Furthermore, visualization is more difficult due to poor stability of the assistant-controlled camera, in addition to poor ergonomics of the straight tip instruments which have been associated with enhanced tremor effect. Finally, the camera often provides only two-dimensional views of the deep surgical field [17].

The da Vinci® Surgical System (Intuitive Surgical, Sunnyvale, CA) was the first robotic surgical system to be approved by the US Food and Drug Administration in 2000. It was introduced as an innovative device that could overcome many of the limitations of laparoscopic surgery. In rectal surgery, the robotic platform demonstrated that it could alleviate the anatomical limitation of the bony pelvis and provide precise stable dissection in a confined pelvic space, facilitated by efficient third-arm retraction, fine instrument movement with flexible EndoWrist® instruments that allowed 7° of freedom, and a magnified three-dimensional view [19, 20]. Since its introduction, various studies have reported the safety and oncological efficacy of robotic rectal resection [21–25]. In fact, when compared to laparoscopic surgery, robotic resection has proven to have similar postoperative complications and oncological outcomes, with data showing trends toward lower conversion rates when performed by an experienced robotic surgeon [26].

Preoperative Preparation

The optimal stoma site is marked preoperatively, typically in the left lower quadrant by the ostomy therapy nurse.

Room Setup and Positioning

The patient is placed in a modified lithotomy position with minimal flexion at the hips, keeping thighs relatively level with the rest of the body. A Trendelenburg position is maintained during the rectal dissection, with an additional right lateral tilt during dissection in the left lower quadrant and vascular control. When the Xi system is used, the robotic cart can be placed in any location, since the boom of the robotic cart can be rotated. It is the authors' practice to target it on the left side of the pelvis in order to cover the left lower quadrant, inferior mesenteric vessels, and the rectum.

Port Placement and Extraction Site

The robot is used to control the inferior mesenteric artery, sigmoid mobilization, rectal mobilization, and often the levator muscle transection. Standard laparoscopy is used for initial exploration and later for sigmoid transection and formation of the omental pedicle flap. Four robotic arms (3 + camera) with two laparoscopic assistant ports maximize exposure and control over the operative field (Fig. 13.2). In the Xi da Vinci® system, the robotic camera is introduced through an 8 mm port (R3) just at the umbilicus. The right lower quadrant port (R4) is placed approximately 3 to 5 fingerbreadths from the anterior superior iliac spine on the line toward the umbilicus and is used for the cautery hook/hot shears. If chosen and exchanged for a 12 mm robotic port later, it can also introduce the robotic stapler for the sigmoid transection. Two remaining 8 mm ports are placed as follows: on the transection of the left anterior axillary line and above the umbilical level (R1) and halfway between the umbilicus and the latter port (R2). This typically corresponds to the midclavicular line. The assistant port placement is described below. The left hand of the assistant is supplied with a bowel grasper, while a short/medium length suction irrigator is placed at the right hand. The assistant is situated on the right side.

The most lateral robotic port on the left is generally used for macro-retraction and accommodates the Cadière forceps. The medial left robotic port is used for micro-retraction and accommodates double-fenestrated bipolar forceps. The stoma site often coincides with the medial left 8 mm port (R2) which is enlarged at the end of the procedure in order to fashion the permanent stoma.

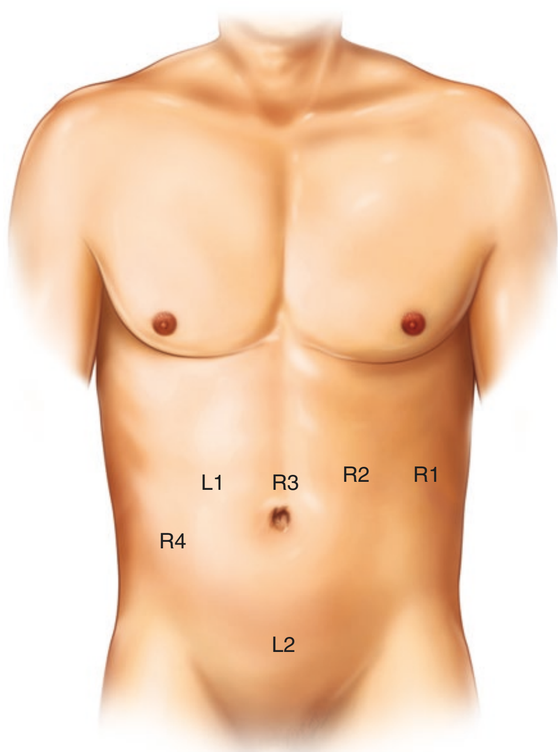

Fig. 13.2 Authors' preferred port placement for robotic APR

Operative Steps

Operative steps	Degree of technical difficulty (scale 1–10)
1. Exploratory Laparoscopy	1
2. Dissection and Isolation of the Inferior Mesenteric Pedicle	4
3. Posterior Rectal Mobilization	4
4. Lateral Rectal Mobilization	5
5. Anterior Rectal Mobilization	5
6. Distal Rectal Dissection and extralevator Transection	6
7. Colostomy Formation	1
8. Perineal Dissection	4
9. Perineal Closure	3

Exploratory Laparoscopy

Both the surgeon and the assistant stand on the right side of the patient. An 8 mm umbilical robotic port, an 8 mm right lower quadrant port, a 5 mm (or 6–8 mm AirSeal® port) in the right mid-abdomen (assistant port), and a 5 mm suprapubic port are initially inserted. These ports are used for exploratory laparoscopy before inserting further robotic ports. Both lobes of the liver, the abdominal wall peritoneum, and the omentum are examined for evidence of metastasis. If none is identified, two additional 8 mm robotic ports are placed in the left mid-abdomen as described above (Fig. 13.2).

Abdominal Phase

Dissection and Ligation of the Inferior Mesenteric Pedicle

At the level of sacral promontory, dissection begins by incising the right leaflet of the rectal mesentery to enter the avascular plane below the superior rectal artery. The vessel is then followed to its origin from the inferior mesenteric artery.

Dissection is continued at the origin of the inferior mesenteric artery, where it is circumferentially dissected, isolated, and then divided. Several methods can be used for this, including an energy device such as ENSEAL (Ethicon Endo-Surgery Inc., Cincinnati, OH), a robotic sealer, clips, or even the vascular stapler.

The dissection is then continued from the medial to the lateral aspect of the left mesocolon by dissecting the embryological avascular plane between the retroperitoneal and the mesocolic fascia. This ensures that the retroperitoneal fascia is kept intact. The dissection is extended into the sigmoid fossa and then onto the white line of Toldt. This limited mobilization is often enough to form a colostomy in the left lower or upper quadrant under no tension. There are some instances when access to the base of the mesentery can be difficult, such as in obese patients, and where the lateral to medical technique may be easier.

Rectal Mobilization

Posterior Dissection

The rectum is mobilized posteriorly to the level of the lower sacrum. During the upper part of the dissection, care should be taken to preserve the pre-hypogastric nerve fascia (innermost layer of the presacral (Waldeyer's) fascia), as it covers the superior hypogastric plexus, the right and left hypogastric nerves, and a significant portion of the sacral splanchnic nerves, all of which are essential for both sexual and urinary functions (Fig. 13.3a, b). Because the posterior avascular plane is easily identified, it is often advantageous to continue this plane of dissection around the rectum, mobilizing the mesorectum from the right and left lateral pelvic compartments. In order to provide the best exposure, the robotic arm with the Cadière forceps (R1) is used to provide a macro-retraction of the rectum in the cephalad and anterior direction and then the robotic arm with the fenestrated bipolar grasper (R2) to provide a gentle micro-retraction on the mesorectum close to the area of hook/scissors dissection (performed with R4).

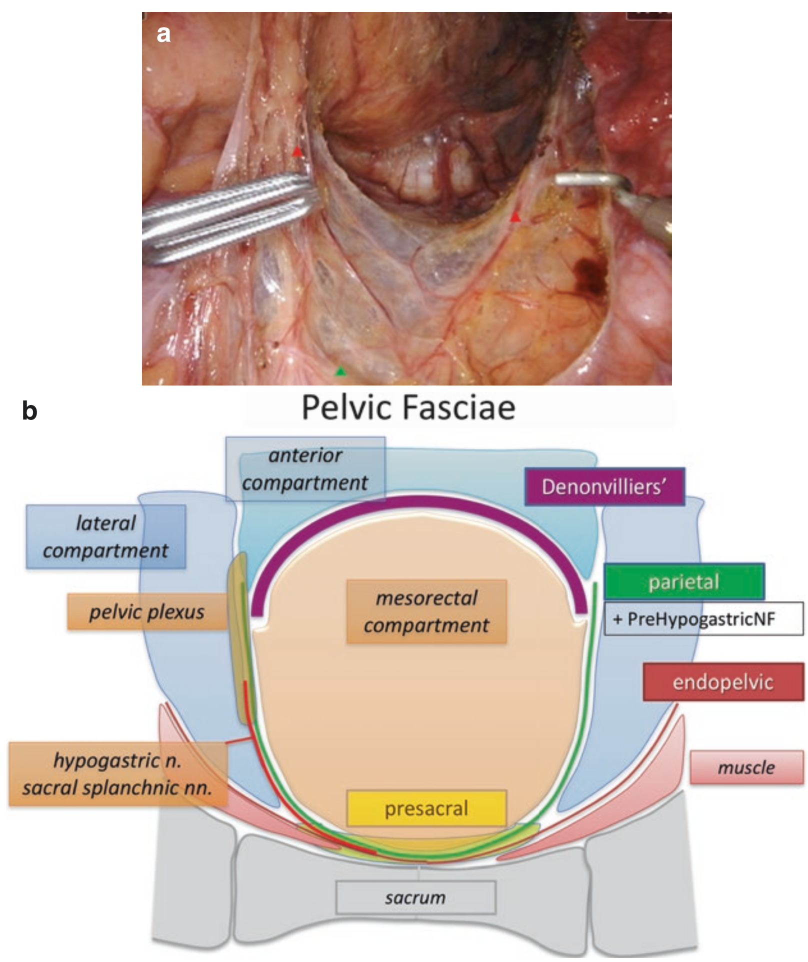

Fig. 13.3 (**a**) Pre-hypogastric nerve fascia covering the superior hypogastric plexus (green mark), as well as the hypogastric (red marks) and sacral splanchnic nerves (below the promontory, not well seen on this picture). (**b**) Nerves and fasciae around the mesorectal compartment [31]

Lateral Dissection

As for the lateral rectal attachments (this area is referred to as "lateral tethered surface"), they are often taken down by cautery and sharp dissection. When most of the lateral mobilization is completed as a continuum of the posterior dissection around the rectum, this part of the dissection is relatively easy, especially if line of anterior dissection has been marked. Care should be taken, however, not to injure the lateral pelvic plexi, where the sympathetic hypogastric nerves and sacral splanchnic nerves, as well as the parasympathetic sacral pelvic nerves (nervi erigentes located in the posterior aspect of the lateral compartment), converge (Fig. 13.1a).

Anterior Dissection

The rectovaginal/rectovesical fold of the peritoneum is incised to expose Denonvilliers' fascia, and the rectum is mobilized from the vagina/prostate. The key to avoid potential bleeding from the fine vascular plexus that surrounds the seminal vesicles or posterior vaginal wall (venous sinuses) is to maintain the plane of dissection just posterior to Denonvilliers' fascia (unless the tumor is threatening it). This also helps to avoid injury to the neurovascular bundles of the prostate (and vagina), covered by the lower portion of Denonvilliers' fascia, right at its junction with the pubococcygeus levator muscle (anterolateral portion of the mesorectal compartment) (Fig. 13.1c). The fixed macro-retraction provided by R1 on the bladder/prostate/vagina significantly facilitates surgical access and visualization during anterior rectal dissection, while the micro-retracting arm pushes the mesorectum posteriorly (downward).

Distal Rectal Dissection and Extralevator Transection

When approaching the lower third of the mesorectal compartment, the surgeon must determine how to address this difficult and most important part of dissection. Two options are available: (1) complete the perineal dissection from below in a traditional manner or (2) performing intra-abdominal levator transection to facilitate the perineal phase.

Traditional Perineal Dissection

The traditional perineal dissection requires proper training and appropriate exposure. Today, in majority of cases, it should be performed according to the principles of the extralevator (ELAPE or ELAPR) concept [27, 28]. In other words, by staying as far away from the tumor and rectal tube as possible. This technique can be performed in the lithotomy as well as prone positions [29, 30]. Thin patients with a wide pelvis and early tumors can have perineal dissection performed in lithotomy. Conversely, large and/or muscular patients, with advanced tumors, particularly in the anterior location, can be better served by prone positioning which allows for better control of the operating field.

Change of the position to prone is associated with approximately 30–60 minutes additional operating time. Coccygectomy (or even very distal sacrectomy) is a frequent maneuver in the ELAPE technique because it widely opens the operative field, allowing for excellent exposure. A frequently quoted recommendation to divide the levators close to the pelvic bone (pubic or ischial bone, ischial tuberosity) is ill advised, because the levators originate from the internal obturator muscle (specifically its *arcus tendinous*) and the internal obturator muscle should be preserved. It must also be recognized that the lateral portion of the levators is also a floor of the lateral compartment and should remain intact during standard dissections (Fig. 13.1b).

Of importance are the pelvic plexi, located just above the levators and embedded in the parietal fascia separating the mesorectal and lateral compartments (Figs. 13.1a, b and 13.3b) [31]. Not infrequently, genitourinary (GU) dysfunction is reported following the ELAPE technique and is likely the result of injury to the pelvic plexi and their afferent and efferent extensions, done during the perineal dissection and resulting from not recognizing this important anatomical fact (Fig. 13.1b). The benefit of excellent exposure provided by the ELAPE technique, frequently associated with coccygectomy and wide levator resection, must be weighed against the morbidity of a large perineal defect [11, 14]. The ELAPE technique is an inherently maximally invasive approach to the perineum. It is associated with large post-resection tissue defects frequently necessitating flap closure, complicated wound healing, chronic postoperative pain, partly related to coccyx resection, perineal hernias, and GU dysfunction [14].

Intra-abdominal Levator Transection

The second option to address the levators relates to the benefits that the robotic platform can bring for dissection in the deep and difficult field of the pelvis. Intra-abdominal transection of the levators was introduced into clinical practice by Marecik et al. in 2010 for multiple reasons, including (1) to perform the most difficult phase of the abdominoperineal resection under a direct vision, in full control of the operating field, (2) to simplify the perineal part, and (3) to maintain the minimally invasive approach of the whole procedure with its postoperative benefits (preserving all tissue that can safely be preserved) [8].

The concept of minimally invasive (robotic) intra-abdominal levator transection has further evolved into a more conservative approach of eccentrically situated tumors [15]. In these cases, the side not affected by the tumor does not have to be subjected to wide levator excision. This selective approach can be successfully used in clinical practice after careful study of the tumor and patient anatomy. The abovementioned evolution, the abdominoperineal resection technique, is aimed not only to improve control over the operating field, which should translate into improved oncological outcomes, but also to take advantage of the minimally invasive benefits that the robotic technique has to offer.

Important Anatomical Considerations

The pelvic floor anatomy can be complex and is often poorly understood, even by experienced surgeons (Fig. 13.4). Knowledge of patient and tumor anatomy, with appropriate clinical correlation, and attention to details during the APR procedure are key factors leading to success [32]. During the distal part of the rectal dissection, while performing APR, the crucial question is when to stop the abdominal dissection and start the perineal phase?

More mobilization from the top translates into an easier perineal phase. It also, however, brings the line of dissection closer to the area of the tumor, due to convergence of the operating field caused by funnel-like levator configuration. When one aims to use only the robot for TME and complete the procedure using traditional perineal ELAPE technique, the robotic dissection should be stopped at the level of the sacrococcygeal junction, posteriorly and laterally, where the posterior levators (flat coccygeus muscle) are visualized and when the lateral tethered surface is dissected from the mesorectum (a characteristic iliococcygeus muscle with dome-like configuration) (Fig. 13.5).

For the robotic intra-abdominal levator transection (RILT), the first goal is to identify and expose the posterolateral surface of the iliococcygeus muscle (a characteristic dome-like shape), the part that is routinely excised during a standard ELAPE technique (Fig. 13.6). Only then can these

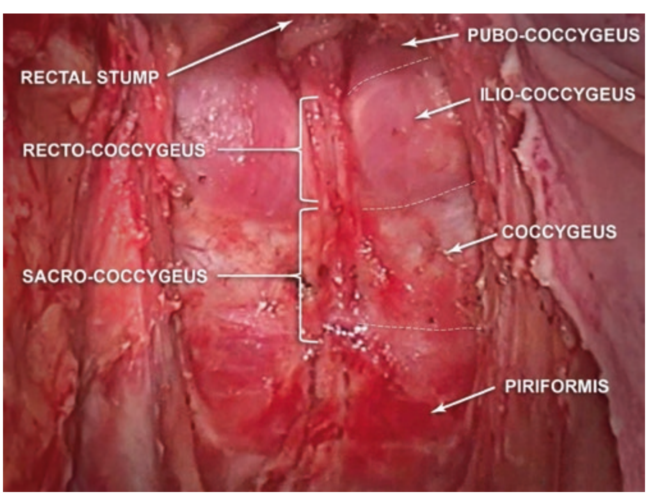

Fig. 13.4 Pelvic floor muscles (after total mesorectal excision)

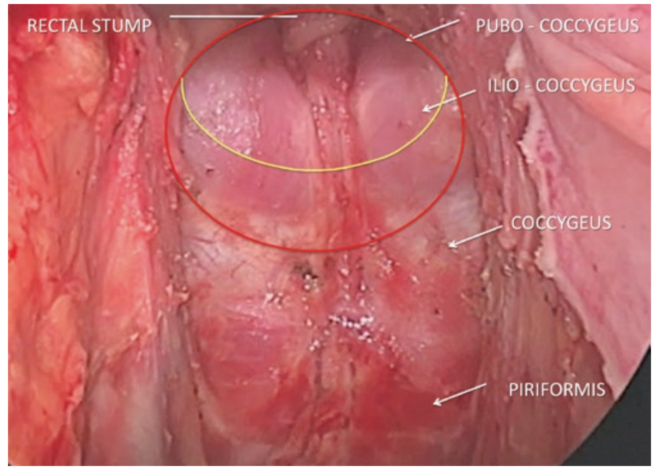

Fig. 13.5 Extent of levator excision during the traditional ELAPE (red) and during RILT (yellow); *ELAPE* extralevator abdominoperineal excision, *RILT* robotic intra-abdominal levator transection

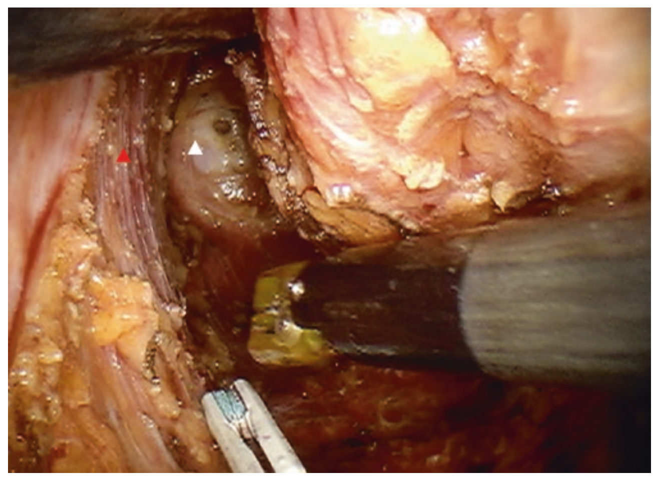

Fig. 13.6 Extent of mesorectal mobilization during RILT, just before levator transection; left iliococcygeus muscle (white mark); left pelvic plexus (red mark)

muscles be obliquely incised starting just off the midline while extending the incision laterally along the contour of the mesorectal compartment and ending with incision of the pubococcygeus muscle in the anterolateral aspect of the mesorectal compartment. Once the levators are transected, the adipose tissue of the ischioanal fossa can be visualized (Fig. 13.7 series) [8].

For surgeons not familiar but planning to try the intra-abdominal levator transection, the authors suggest ending the abdominal phase with posterolateral levator transection [33]. The midline part of the pelvic floor transection does not have to be completed. This leaves the levators raphe and the anococcygeal ligament intact. Because the levators were properly incised lateroposteriorly, the surgeon should be able to easily identify and access the dissected pelvic space,

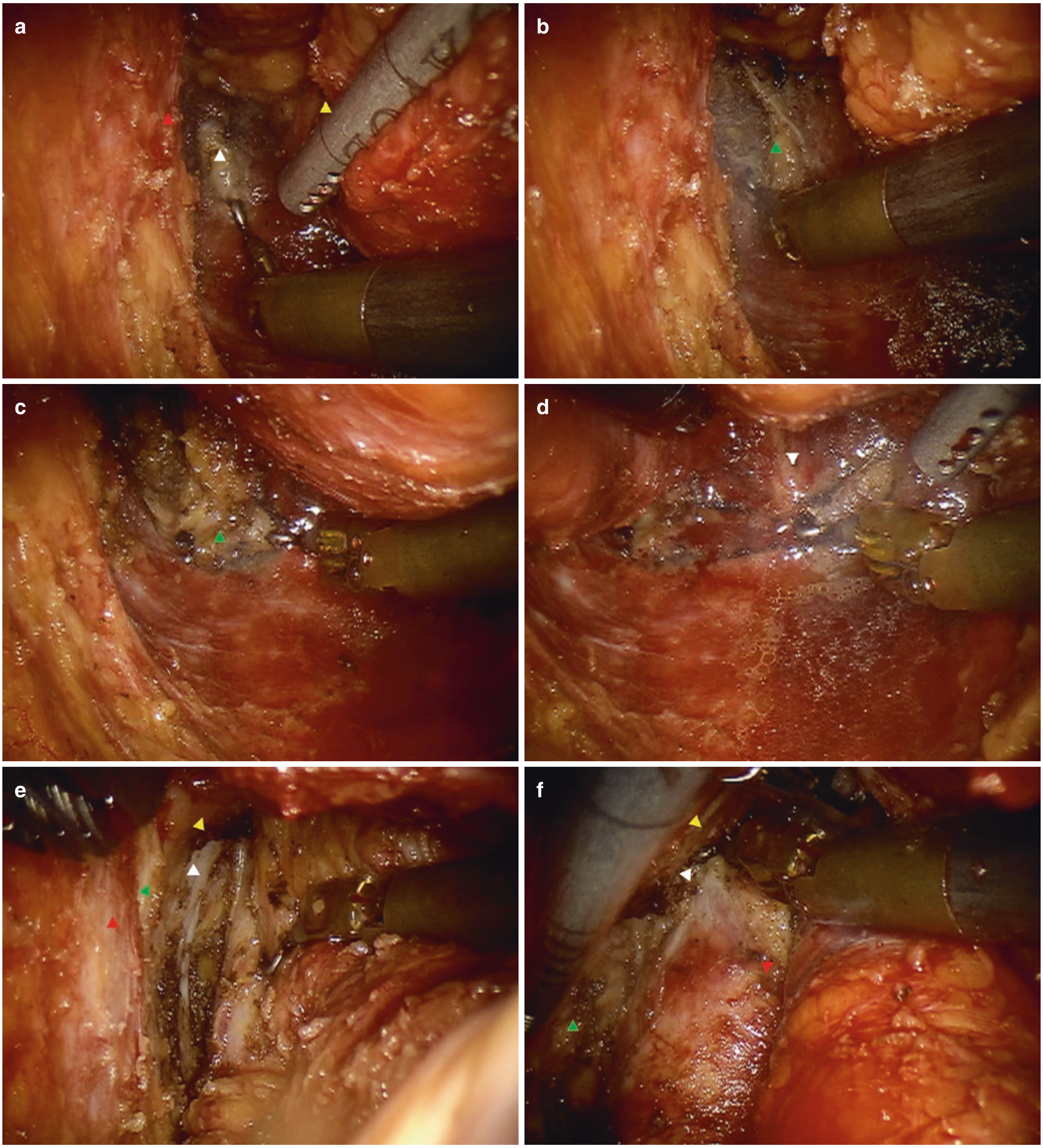

Fig. 13.7 (**a**) Left posterior incision of the iliococcygeus muscle (white mark) after detachment of the lateral tethered surface of the mesorectum (yellow mark) just medial from the left pelvic plexus (red mark). (**b**) Iliococcygeus muscle transection with exposure of the left ischioanal fossa (green mark). (**c**) Iliococcygeus muscle transection toward the midline; ischioanal fossa's adipose tissue (green mark). (**d**) Transection of the levators' raphe (white mark) at the level of the lower coccyx. (**e**) Anterolateral levator transection (white mark – left pubococcygeus muscle), along the contour of Denonvilliers' fascia (yellow mark), just medial from the left pelvic plexus (red mark) and the left edge of Denonvilliers' fascia (green mark). (**f**) Transection of the left pubococcygeus muscle (white mark) along the contour of Denonvilliers' fascia (yellow mark); the impression of the mesorectum (red mark) was created by the left robotic arm; yellow ischioanal fat exposed next to the suction tip (green mark). (**g**) Transection of the left pubococcygeus muscle along the base (contour) of Denonvilliers' fascia into the left ischioanal fossa (green mark); prominent left neurovascular prostatic bundle (white mark). (**h**) Transection of the right pubococcygeus muscle (white mark) along the contour (base) of Denonvilliers fascia and the right neurovascular prostatic bundle (yellow mark). (**i**) Transection of the right iliococcygeus muscle (white mark) into the right ischioanal fossa (green mark) just medial from the right pelvic plexus (red mark) and the right edge of Denonvilliers' fascia (hidden behind the instrument)

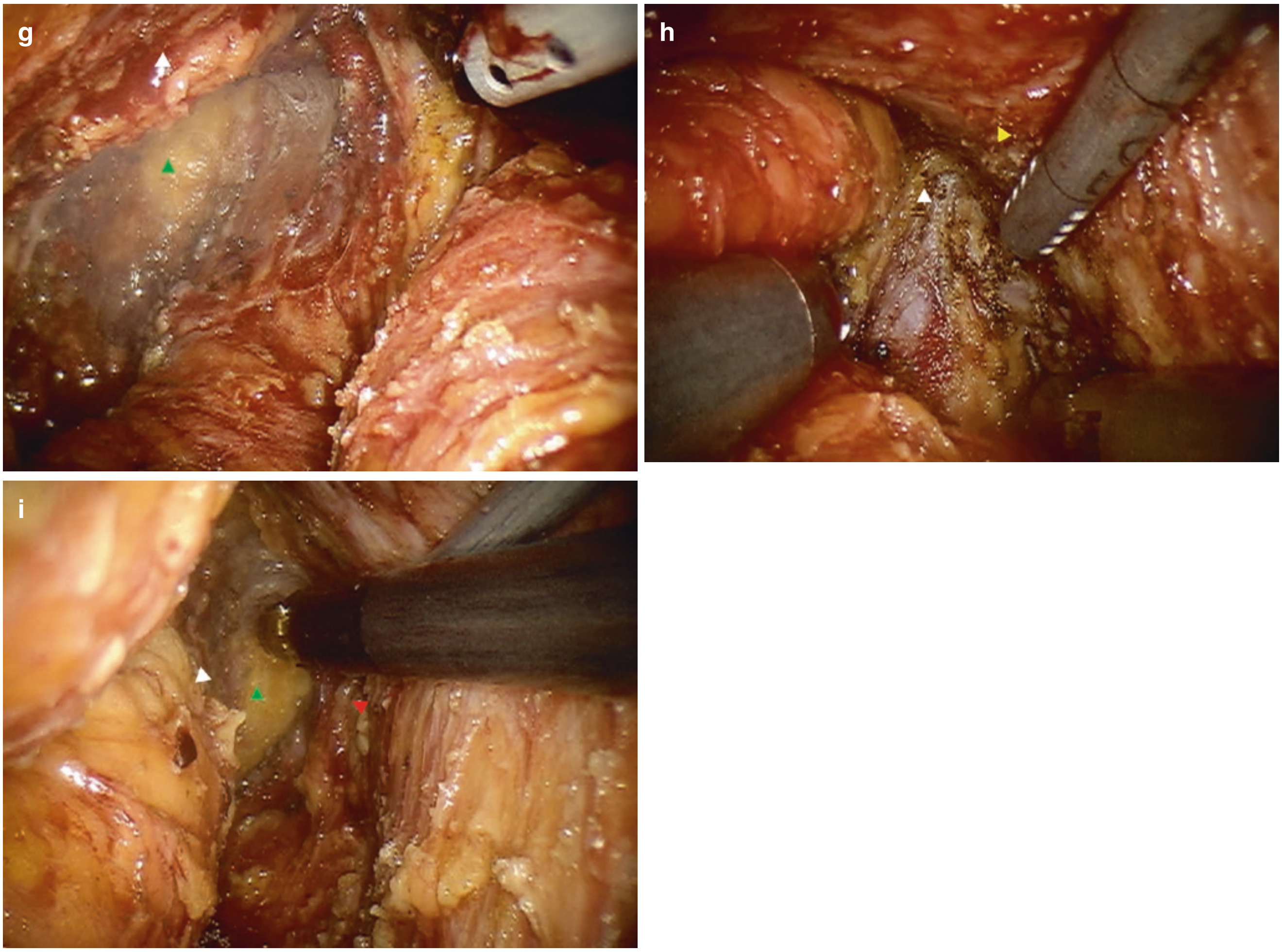

Fig. 13.7 (continued)

"finger hook" the raphe and the ligament, and divide it relatively easily during the perineal phase.

The second goal is to spare the coccyx (unless threatened by the tumor), thus sparing the (ischio)coccygeus muscle, the part also routinely sacrificed during a conventional ELAPE technique (Fig. 13.5). It is the authors' belief that the coccyx is important in patients who undergo the APR procedure. Coccyx preservation makes the postoperative defect smaller, able to be closed without the need for flap reconstruction, and less prone to form a perineal hernia. Decrease of the wound diameter by half translates on average into fourfold decrease in the area of the defect ($A = \pi r^2$). Lack of coccygectomy (or lower sacrectomy) results in no exposed bone or cartilage, which is important when perineal wound infection occurs and the risk of osteomyelitis exists.

The third goal is to preserve all tissue that is not in close proximity to the tumor [15]. Because the pelvis can be very narrow, particularly in its distal part, this goal may not be achievable, and oncological safety should dictate a more radical approach, which is complete ELAPE. The conservative (selective) approach should only be used for eccentrically located tumors by surgeons with a thorough understanding of tumor and patient anatomy, as well as experience in intra-abdominal levator transection (Fig. 13.8a, b). Important anatomical reference points include piriformis muscle impression (narrowing the pelvic floor between S2 and S4 segments), acute anterior deflection of S5 segment (including the coccyx), flat and tendinous portion of the (ischio)coccygeus muscle, and dome-like-shaped iliococcygeus muscles.

There is a tendency to begin the intra-abdominal levator transection too proximal (caudal), resulting in lower sacral or coccygeal exposure and bleeding from the lateral sacral arteries or even midline venous structures. Important other reference points are the lateral tethered surfaces with exposed posterior parts of pelvic plexi and the concave contour of Denonvilliers' fascia, delineating the anterior mesorectal compartment outline, while covering the anterior part of the pelvic plexus. The lateral edges of Denonvilliers' fascia and the pubococcygeus muscles (anterior part of levators in the mesorectal compartment) are also important reference structures.

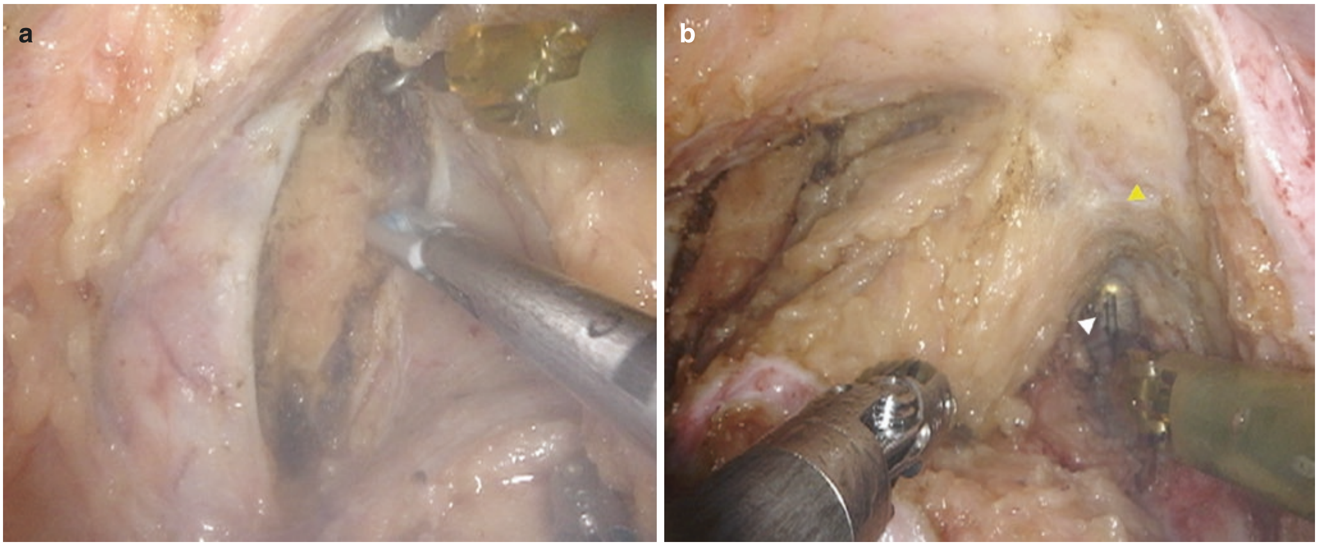

Fig. 13.8 (**a**) Conservative (selective) levator transection on the left side for right-sided tumor (haziness from smoke artifact). (**b**) Wide levator transection on the right side, where the tumor is located; right ischiococcygeus muscle (white mark), right neurovascular bundle (yellow mark)

Important Technical Considerations

Controlled dissection at the bottom of the pelvis requires ergonomic port and instrument setup in order to avoid internal or external collisions. Effective utilization of the camera, three robotic arms, and two assistant instruments allow for such control in most cases. It is important not to commit to inserting the left medial port exactly where the colostomy mark is placed, as this can compromise the ergonomic instrument setup. At the end of the case, a separate 12 mm port is often placed through the colostomy site for the conventional laparoscopy endo stapler to divide the bowel, in case a decision is made not to use the robotic stapler through R4.

When the levators are transected too proximal, bleeding from the lateral sacral arteries can be controlled using bipolar forceps. Occasionally, simple compression of the vessel for 2–5 minutes is more sufficient when cautery is not very effective. The levator transection just medial from the lateral tethered surface and the latero-anterior portion of Denonvilliers' fascia allow for complete preservation of the autonomic nerve structures (pelvic plexi and neurovascular bundles), thus minimizing the risk of GU dysfunction.

If possible, following completion of the robotic portion of the procedure, an omental pedicle flap is created based on the right gastroepiploic artery in order to fill the void left by the proctectomy [34].

Colostomy Formation

The end colostomy is then matured at the pre-marked stoma site in the left lower or upper quadrant with minimal eversion.

Perineal Dissection

The patient can be placed in the lithotomy or prone position. The lithotomy position involves less setup time, as well as the ability to perform the procedure with two teams working simultaneously. The prone position involves more setup time, thus longer total operative time (additional 30–60 minutes). It does, however, allow for more comfortable dissection and better exposure for both the surgeon and the assistant (facilitates better learning). The authors typically use the lithotomy position because the majority of rectal dissections including the levators are performed transabdominally. Still, as mentioned above, for resection of anterior lesions with the intent of preserving GU organs and bulky tumors requiring ELAPE with or without distal sacrectomy, the prone approach is preferred.

There has been a great deal of debate about whether the lithotomy or prone approach is superior. Shihab et al. [27] reported lower perforation rates in prone patients as compared to lithotomy (6.4% vs. 20.6%, $p = 0.027$). On multivariate analysis, the prone position was an independent factor for the protection against perforation (OR 0.12; 95% CI 0.2–0.67) [28]. Other studies, however, found no difference in the rate of perforation or in the circumferential margin involvement between the two positions [29, 30, 35]. In addition, the authors have found that use of the robot to perform levator transection transabdominally was associated with a significant drop in the rate of circumferential margin involvement, thus making the perineal dissection much easier and with no need to turn the patient prone [8, 15, 36]. In the authors' opinion, the surgeon needs to be comfortable with both approaches.

When the patient is in the lithotomy position, the perineal portion of the operation begins by making an elliptical incision around the sphincter complex from the tip of the coccyx to the perineal body. The perineal and abdominal dissections are then connected with the tip of the coccyx serving as a constant safe landmark. If the coccyx is not threatened, the anococcygeal ligament is incised at the tip of the coccyx. Pneumoperitoneum will be easily identified as gas bubbles into the perineal wound. Because the levator muscles have already been transected robotically, all that remains is the ischioanal fossa adipose tissue. During the anterior dissection, care must be taken not to injure the vagina or membranous portion of the urethra in males. The omental flap is then delivered and tacked in position with a few interrupted sutures to fill the mesorectal compartment. A pelvic drain placed transabdominally is laid down in the field, and the perineal wound is closed loosely with 2-0 absorbable sutures, to allow for some drainage if needed.

Perineal Closure

Most perineal wounds following robotic intra-abdominal levator transection can be closed primarily with or without omental pedicle flap. The majority of ischioanal fossa tissue is preserved, unless involved by a tumor. Large tissue defects, which cannot be successfully approximated, will require either a biologic mesh closure or flap closure. The gluteal fasciocutaneous flaps are preferred [5]. Vertical rectus abdominis myocutaneous flaps can also be used, although they are typically used when combined with open APR procedures when no ports are placed thru the donor rectus muscle.

Special Considerations, Difficulties, and Complications

Genitourinary Structures Preservation

Identification and knowledge of the course of the ureter is essential in rectal surgery. The ureter crosses the pelvic brim near the bifurcation of the common iliac artery and runs underneath the peritoneum and underneath the parietal fascia extraperitoneally, anterior to the internal iliac vessels. In men, deeper in the pelvis, it runs in front of Denonvilliers' fascia anteromedially, wrapping in front of the vas deferens before entering the bladder. In women, it continues its course toward the bladder through the cardinal ligament, crossing underneath the uterine artery. The mid-ureter should be easily visualized during routine robotic colonic mobilization and should remain lateral to the plane of dissection during rectal mobilization unless extension by tumor necessitates en bloc ureteral resection.

Bleeding during anterior dissection usually results from a dissection that is too close to the seminal vesicles or the vaginal wall, potentially also injuring the parasympathetic nerve fibers. Exuberant cauterization in this area can lead to erectile dysfunction and should be avoided.

Peripheral Neuropathy

Postoperative peripheral neuropathy is an uncommon but well-recognized complication of colorectal surgery. It appears that minimal invasive surgery is an independent risk factor for postoperative neuropathy, particularly when the patient is obese [37]. Surgeons should be aware of this potential avoidable complication in order to reduce it. Risk-reducing strategies such as using special operating tables with ample special paddings, avoiding extreme tilts, and changing the position of patients during long operations should be used routinely. However, patients should be advised that even when all preventative strategies are used, postoperative neuropathy may still occur, though in the majority of cases it is self-limiting.

Omental Flap Infarction

The clinical problem associated with perineal wounds after APR and the presence of an unoccupied "presacral space" after TME proctectomy has led surgeons to advocate for the routine use of omental flaps to fill this space [38]. The aim is to potentially reduce the incidence of wound infections, wound dehiscence, perineal hernias, and pelvic sepsis. If done appropriately, omentoplasty is a simple procedure with minimal comorbidity [34]. To avoid omental flap infarction, a well-designed graft is formed by separating the left omentum from the spleen and the transverse colon attachments, thus ligating the left gastroepiploic pedicle and short gastric vessels. A tongue of a well-vascularized left omentum, based on the right gastroepiploic artery, is then formed and rotated to the pelvis. Rotation of the right omentum, based on the left gastroepiploic artery, can also be done.

Perineal Hernia

Symptomatic perineal hernias occur in less than 1% after APR and 3% after pelvic exenteration, while asymptomatic perineal hernias are much more frequent [13]. Symptomatic perineal hernias are rare but can lead to significant postoperative complication. Major risk factors include pelvic irradiation, failure to close the perineal defect, and excision of levators [13]. This became more apparent as ELAPE became more popular [14]. In an effort to reduce the amount of perineal soft tissue removed while maintaining radicality, the authors and others have modified the cylindrical transection to remove only a wide cuff of levators on the side of the lesion, thus preserving more of the levators on the side remote from the tumor (for eccentrically located tumors) [15]. This technique does not appear to jeopardize long-term oncological outcomes but should be reserved for surgeons with experience in intra-abdominal levator transection.

Coccygectomy

Resection of the coccyx in order to facilitate surgical exposure is sometimes required when the levators are incised through the perineum. Holm routinely performed it as part of ELAPE [5]. The authors found, however, that using the robotic platform deemed this step unnecessary, and, in fact, by leaving the coccyx in place, more of the pelvic floor muscles were preserved which resulted in a smaller wound and thus an easier perineal wound closure [8, 15, 36]. In addition, a lower incident of perineal wound pain was identified, as was a much lower chance of developing osteomyelitis at the site of the disarticulation.

Robotic Arms Collision

Because the anatomy of the pelvis can be challenging, particularly at the bottom of the narrow male pelvis, it is vitally important to ensure appropriate spacing of the robotic arms, so as to avoid collision among the arms, the pelvic brim, and the surrounding vital structures. This requires multiple attempts of trial and error because no instruction book can accurately map the body habitus of all patients. The important thing is to be aware of the surrounding organs and to keep adjusting exposure and hand movements while not hesitating to move or add extra ports as deemed necessary.

Extralevator Approach, Recurrence, and Overall Survival

Attention to detail during APR, specifically when performing an appropriate sharp dissection of the mesorectum, has been associated with improved local control and survival rates. However, in contrast to the upper and midrectum which offer a circumferential margin of adequate thickness, the lower rectum has a relatively thin mesorectal envelope due to its coning effect along the levator muscles. This anatomical coning, together with the poor visibility in the deep pelvis, is a possible reason for the high CRM positivity for tumors within 5 cm of the anal verge, resulting in higher recurrence and worse overall survival rates. The extralevator approach to APR is associated with lower CRM positivity (4–14%), lower perforation rate (0%), lower local recurrence (1.7–10%), and thus improved overall survival (60–80%) [5, 12, 29, 39, 40]. Robotic approach aims to improve these results while reducing the operative trauma and morbidity.

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Robotic Rectus Muscle Flap for Reconstruction in the Pelvis

14

Shawna R. Kleban, Joshua J. Goldman, and Richard C. Baynosa

Introduction

This chapter will explore the justification and technique for performing robotic harvest of the rectus abdominis muscle flap for pelvic reconstruction. The advent of robotic surgery has created new challenges for plastic surgeons to provide reconstructive solutions while minimizing abdominal incisions and morbidity.

Background

Minimally invasive surgery has found a place in many surgical subspecialties. Over the last 10 years, developments in robotic surgery have allowed for greater maneuverability and visualization in the deep pelvis and other difficult-to-access locations around the body. This innovation has led to applications in general surgery and its subspecialties, urology, gynecology, and otolaryngology. New applications of the technology are being "discovered" with each passing day.

Many of the advantages of minimally invasive surgery align with the principles of plastic surgery including decreased incision length and morbidity. However, because the defects they are asked to reconstruct are often large and already easily accessible, plastic surgeons have not found widespread robotic indications. Other surgical specialties continue to challenge plastic surgeons to adapt to these new problems as they increase their use of minimally invasive techniques. Traditional reconstructions often involve large incisions that would negate many of the advantages of the minimally invasive approach used by these consulting surgeons. That said, the many advantages of the robot certainly provide ample opportunity for niche uses. Tremor elimination and motion scaling increase surgical precision. Clear, magnified, high-resolution 3D stereoscopic views afford enhanced visualization in classically difficult-to-expose areas like the deep pelvis, further increased by exposure with multiple, low-profile robotic arms for precise traction. Wristed movements, camera retroflexion, and instruments with extra-human articulation allow maneuverability in confined spaces not possible with open or even laparoscopic surgery. Robotic rectus abdominis muscle flap harvest for pelvic reconstructions, after minimally invasive procedures by general surgery, colorectal surgery, and gynecology, makes use of the superior functionality of the robot.

Rationale in Pelvic Reconstruction

Plastic surgeons are often asked to aid in the reconstruction of pelvic defects after oncologic resection. Extirpation often leaves significant pelvic dead space that allows for fluid accumulation. This pelvic fluid can serve as a nidus for infection leading to deep pelvic abscesses and/or wound breakdown. Wound healing complications can be as high as 25–60% in irradiated patients undergoing primary closure [1].

Given these complications, myocutaneous and muscle flaps were introduced as an alternative to primary closure. Flap reconstruction serves to obliterate pelvic dead space and bring healthy, vascularized tissue into an irradiated field to promote wound healing. Numerous studies have purported the advantages of bringing in well-vascularized tissue into the irradiated pelvis [2–8]. Specifically, irradiated pelvic defects after abdominoperineal resection (APR) have improved outcomes when vascularized tissue is brought into

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S. R. Kleban, MD · J. J. Goldman, MD · R. C. Baynosa, MD, FACS (✉)
Department of Plastic Surgery, University of Nevada,
Las Vegas School of Medicine, Las Vegas, NV, USA
e-mail: shawna.kleban@unlv.edu; Joshua.goldman@unlv.edu; richard.baynosa@unlv.edu

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the wound [9–11]. There are substantially lower rates of major wound dehiscence, pelvic abscess, and fistula formation when muscle flaps are used to reconstruct these defects [12, 13].

The gracilis muscle flap was initially described for perineal defect closure and has been since supplanted by the vertical rectus abdominis myocutaneous flap (VRAM). The rectus abdominis flap has clear advantages including larger muscle bulk, more reliable skin paddle, and no need for additional incisions. It has been demonstrated that the rectus abdominis muscle flap has a lower major complication rate when compared with the gracilis flap, including a lower rate of donor site and recipient site cellulitis, pelvic abscess, and wound dehiscence [14].

The rectus abdominis muscle is a commonly used flap for a variety of reconstructive needs [15–28]. There are several advantages to the rectus abdominis muscle flap for pelvic reconstruction including the bulk of the flap and a long, reliable, axial blood supply that allows for pedicled reconstruction of almost any pelvic defect [29–34]. Traditionally, the rectus abdominis flap required an open approach, usually via a long midline or paramedian incision, necessitating violation of the anterior rectus sheath. The anterior rectus sheath serves as the strength layer of the abdominal wall, and violation of this layer can lead to abdominal morbidity including abdominal bulge and hernia.

With the rise in popularity of robotic approaches for pelvic tumor extirpation, plastic surgeons were challenged with finding a minimally invasive way to perform pelvic and perineal reconstruction. In accordance with this need, a technique for robotic rectus muscle flap harvest was developed. The technique was first described and published in 2010 [35], and subsequent publications have demonstrated the safety and feasibility of this technique for several reconstructive applications [36–38]. In our practice, we have applied this technique in cases of robotic abdominoperineal resection (APR) and robotic rectovaginal fistula takedowns.

The robotic approach to rectus muscle harvest has several advantages to the traditional open approach. For the patient, the most obvious benefit is the decreased incision burden, which leads to decreased wound healing problems and improved cosmesis. The intraperitoneal approach also keeps the anterior rectus sheath intact which helps maintain abdominal wall integrity. In addition, the rectus muscle is more easily visualized along its entire length through the thin posterior rectus sheath compared with the thick anterior rectus sheath. Most importantly, the deep inferior epigastric pedicle is easily seen through the peritoneum on the undersurface of the muscle, which allows the surgeon to preserve it during the flap dissection (Fig. 14.1).

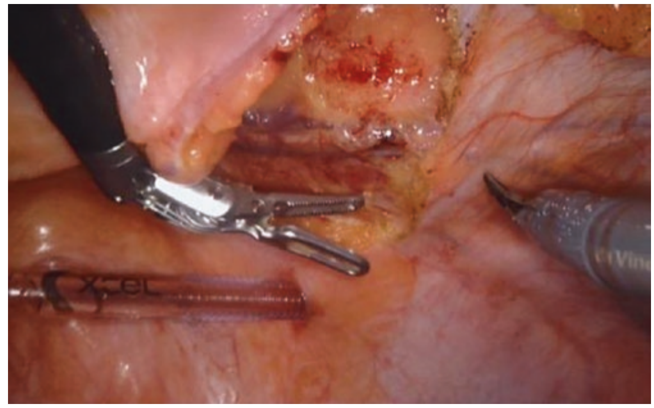

Fig. 14.1 Intraperitoneal view of the deep inferior epigastric vascular pedicle. The left side of the vessel has the peritoneum dissected free, but the continuation to the right (superiorly) is still readily seen through the intact peritoneum and posterior rectus fascia

Patient Selection

Attaining reliable outcomes for any novel technique involves the development of inclusion and exclusion criteria for appropriate patient selection. During the initial learning curve, operative times may be significantly longer for the robotic approach. Patients with minimal comorbidities who are capable of tolerating a longer anesthetic should be selected during this time period. As the surgeon's experience increases, the average operative time for robotic rectus muscle harvest will typically be under 1 hour [37]. Although long-term data and outcomes still need to be evaluated, the decreased pain, narcotic use, hospital stay, and overall decreased morbidity should in theory justify the initially longer operative time. Therefore, robotic rectus muscle flap reconstruction should be considered in any patient undergoing robotic APR.

The robotic rectus flap can also be considered for resurfacing posterior vaginal defects. We feel that the peritoneum and posterior rectus sheath serve as an ideal substitute for vaginal mucosa. The literature has shown that these tissues readily mucosalize and provide a good reconstructive option in this area [39].

Given that no skin paddle is harvested with the robotic approach, patients with significant soft tissue defects necessitating reconstruction with a large skin paddle are not appropriate for this technique and would be better suited with a vertical rectus abdominis myocutaneous flap or gracilis flap. Other exclusion criteria include patients with excessive BMI and patients with a large intra-abdominal fat component. Our experience has shown an increased rate of postoperative abdominal bulge in these patients when the posterior rectus sheath is incorporated into the reconstruction. For these patients, we recommend repair of the posterior rectus sheath and reinforcement with underlay biologic mesh to help prevent abdominal bulge postoperatively.

Room Setup and Positioning

Patients should be in the supine or low lithotomy position as dictated by the resecting surgeon. Importantly, the contralateral arm may need to be placed on an arm board and abducted to allow for better maneuverability, especially in larger patients.

Port Placement

Accurate port placement is critical in obtaining the necessary exposure for flap harvest and retaining freedom of movement of the robotic arms. The ports should be placed contralateral to the rectus muscle to be harvested. Typically, the right rectus muscle is harvested for robotic APR reconstruction to allow for an end colostomy to be placed in the left lower quadrant through the left rectus muscle.

Robotic harvest of the rectus muscle can be accomplished with three 8 mm robotic ports, although a 12 mm camera port was utilized in our early experience. The camera port (R2) is placed centrally approximately 2 fingerbreadths or 2–3 cm posterior to the contralateral anterior axillary line at the midpoint between the costal margin and the anterior superior iliac spine (ASIS). The two working ports (R1, R3) are placed in line with the central port with one located at 2 cm inferior to the costal margin and the other located at 2 cm superior to the ASIS (Fig. 14.2a, b). Importantly, when the robotic rectus flap is used for reconstruction after robotic APR, preoperative communication will allow one of the ports to be used as one of the colorectal surgeon's working ports. The AirSeal insufflation system (Conmed, Utica, NY) can also be used to help maintain appropriate insufflation after creation of the perineal defect. If the harvest is being planned for free tissue transfer outside of the abdomen, the standard Veress needle technique should be used for insufflation.

After port placement, the table is positioned in slight Trendelenburg with the side ipsilateral to the planned muscle harvest upward. This allows for the abdominal contents to fall away from the harvest site. The robot is then docked in the standard fashion ensuring that the elbows of the working arms are bent out of the way of the central camera arm.

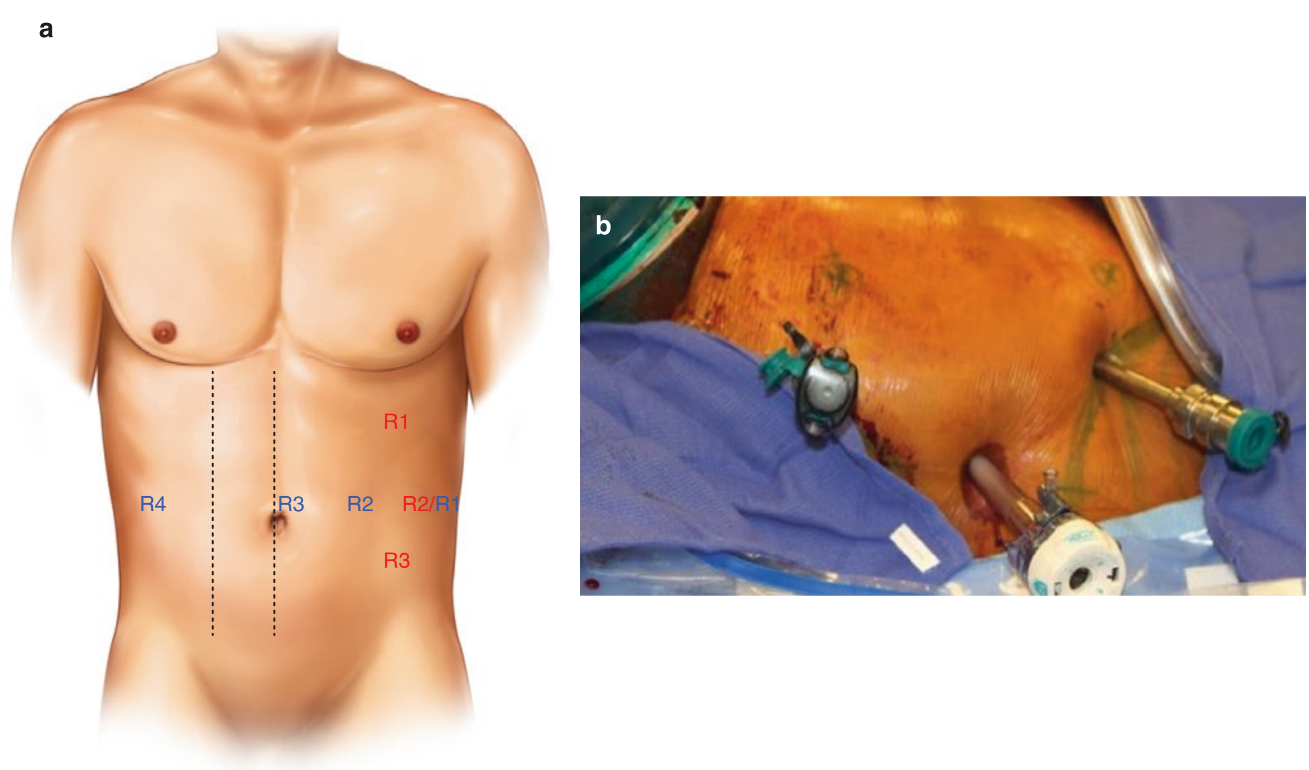

Fig. 14.2 (**a**) Black dotted line: left rectus muscle. R1–3 red: robotic ports for right rectus muscle harvest. R1–4 blue: robotic ports for abdominoperineal resection, R2 at colostomy site. (**b**) Standard port placement at the contralateral hemiabdomen in an early case with 12 mm camera port on the da Vinci Si robot. Newer applications allow three 8 mm ports throughout

Operative Steps

Operative steps	Degree of technical difficulty (scale 1–10)
1. Identification and preservation of the deep inferior epigastric pedicle	3
2. Dissection of the posterior rectus sheath	3
3. Division of the rectus muscle and mesh placement	4
4. Inset of the rectus muscle	2

Identification and Preservation of the Deep Inferior Epigastric Pedicle

Harvest of the rectus muscle flap is achieved using Hot Shears/Monopolar Curved Scissors (Intuitive Surgical) in the dominant working arm and a Cadiere or ProGrasp forceps (Intuitive Surgical) in the non-dominant arm. A 30° camera is placed in the central port to allow for improved visualization of the posterior abdominal wall. Before proceeding with dissection of the rectus muscle, the deep inferior epigastric pedicle is identified in the ipsilateral lower quadrant through the peritoneum (Video 14.1). The peritoneum is then sharply divided at this level, and dissection is performed from the lateral edge of the rectus muscle to several centimeters laterally to allow ease of transposition of the muscle flap. Although usually unnecessary, the pedicle may be dissected to its origin at the external iliac vessels if there is concern for any tension, kinking, or twisting of the pedicle.

Dissection of the Posterior Rectus Sheath

After the pedicle has been identified and preserved, dissection of the posterior rectus sheath is performed (Videos 14.2, 14.3, and 14.4). A transverse incision in the peritoneum is made from lateral to medial along the width of the rectus muscle at the level of the deep inferior epigastric pedicle. This step allows for identification of the medial and lateral borders of the rectus muscle and allows the rectus muscle to be reflected down into the pelvis. The medial dissection is performed first by creating a vertical incision just lateral to the medial border of the rectus muscle and continuing superiorly to the costal margin. The costal margin can be identified by having an assistant externally palpate its border; otherwise it is difficult to distinguish from the intraperitoneal surface. This is often the most difficult portion of the dissection given the steep camera and instrument angle. It is important to dissect to this level to allow the muscle to reach the perineum.

Next attention is turned to the lateral border of the muscle with dissection proceeding at the inferior portion of the rectus muscle at the level of the transverse peritoneal incision.

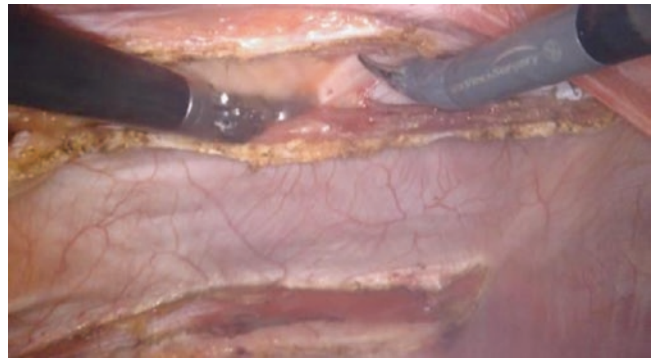

Fig. 14.3 Intraperitoneal view of medial and lateral borders (superior and inferior aspects of the figure, respectively) of the rectus muscle dissected

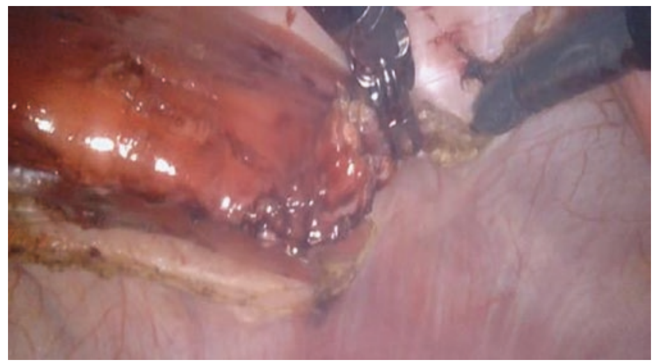

Fig. 14.4 Intraperitoneal view of the superior rectus muscle (distal flap) being divided with electrocautery

The vertical incision should be made at least 1 cm medial to the lateral border of the rectus muscle to ensure that the insertion of the transversalis and oblique muscles is not violated. The dissection is continued superiorly in the same manner as the medial dissection. Care should be taken to ensure that the intercostal neurovascular pedicles entering laterally into the rectus muscle are identified and cauterized (Fig. 14.3).

Division of the Rectus Muscle and Mesh Placement

Once the costal margin has been reached on both the medial and lateral aspects of the muscle, these dissections are joined by dividing the peritoneum, posterior rectus fascia, and rectus muscle transversely (Fig. 14.4, Video 14.5). The superior epigastric vessels should be identified and controlled, and hemostasis of the muscle should be ensured. The rectus muscle can now be freed from the overlying anterior rectus sheath from distal to proximal (Video 14.6). Perforators should be identified and controlled with electrocautery or Weck Hem-o-lok clips (Intuitive Surgical). Care should be

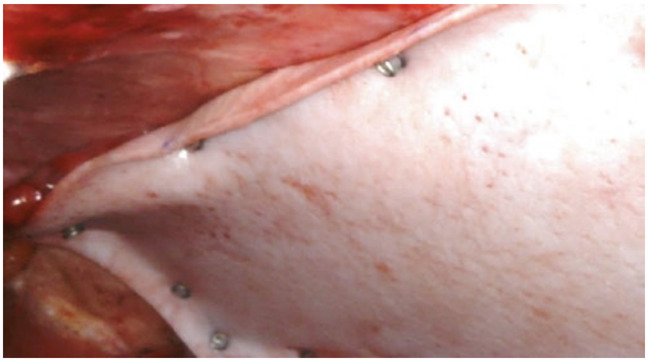

Fig. 14.5 Intraperitoneal view of biologic mesh closure of posterior sheath

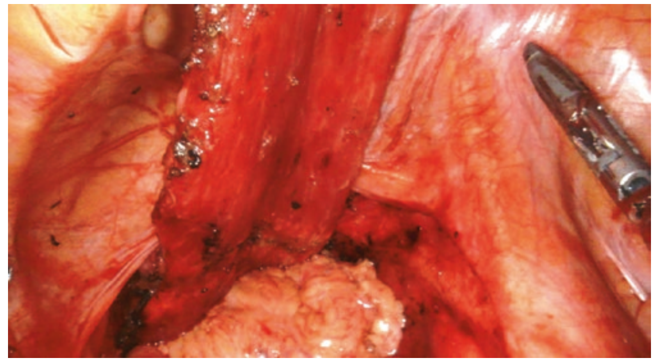

Fig. 14.6 Intraperitoneal view of the rectus muscle transposed through the rectal vault with buttressing omental flap

taken at the level of the tendinous inscriptions to prevent damage to the rectus muscle and overlying anterior sheath. Damage to the anterior sheath can lead to defects causing weakness of the abdominal wall and increased risk of bulge and hernia. Dissection of the anterior sheath is continued down to the level of the deep inferior epigastric pedicle. The rectus muscle insertion to the pubis should be left intact so as to prevent excessive tension on the vascular pedicle.

The described technique leaves a strip of posterior rectus sheath and peritoneum attached to the posterior surface of the muscle allowing the flap to be secured into place. Without this strip of fascia, it can be difficult to secure the flap as suturing directly through the muscle often leads to tearing of the muscle itself. Furthermore, the peritoneum on the posterior rectus sheath is ideal for resurfacing posterior vaginal wall defects as it quickly mucosalizes. When the posterior sheath is harvested with the muscle, we recommend reinforcing the abdominal wall with biologic or synthetic mesh to help decrease the incidence abdominal bulge or hernia (Fig. 14.5).

Inset of the Rectus Muscle

Upon completion of the flap harvest and closure of the posterior abdominal wall, the rectus flap is inset into the pelvic or perineal defect (Video 14.7). In post-APR reconstruction, the rectus muscle is secured through the perineal defect (Fig. 14.6). Laparoscopic visualization is used to ensure appropriate internal lie of the muscle and pedicle without any twisting or undue tension. The muscle is then secured just under the skin and the overlying perineal incision is closed. In the case of fistula repair, the robot is re-docked in the standard pelvic position, and the muscle can be interposed between the areas of repair. A drain is placed through the buttock and positioned near the flap after APR reconstruction. A drain is not required if the flap is being used to buttress a fistula repair.

Postoperative Care

Patients must refrain from sitting directly on the perineal incision for at least 4 weeks in the cases of post-APR reconstruction. However, patients are encouraged to walk and are allowed to lie supine or sit on a donut cushion. When the flap is inset deep in the pelvis, there are no pressure restrictions.

Special Considerations and Complications

The learning curve for implementation of this surgical innovation into one's surgical repertoire is steep, and, with experience, the flap harvest itself can be performed in less than an hour. Additionally, recent literature supports the safety and feasibility of this technique for a wide spectrum of applications [36–38].

As with any manner of harvest, complications of robotic rectus muscle harvest include bleeding, hernia, and/or bulge in the donor site. Our experience has demonstrated that significant donor site bulge does occur, in certain instances, if the posterior sheath is not reconstructed. This challenges previously held beliefs regarding the anterior sheath's capacity to solely maintain the integrity of the abdominal wall. We have noted increased risk of bulge in patients with higher BMI and a large intra-abdominal fat component, as the pressure from the intra-abdominal contents produces significant tension on the single anterior rectus sheath. It is therefore recommended to reinforce and/or repair the posterior rectus sheath with biologic mesh [40].

Summary

The robotic rectus muscle flap is a novel approach to harvest a vascularized tissue flap from an intraperitoneal, minimally invasive approach. The increasing utilizaiton of robotic surgery by other surgical specialties has necessitated compensatory innovation by plastic surgeons to retain referral patterns. The morbidity of open pelvic reconstruction is difficult to justify given the decreased morbidity seen with minimally invasive tumor extripation and fistula takedown.

With the advent of continually advancing minimally invasive robotic techniques for abdominopelvic surgery, the necessity of developing and adopting robotic methods of pelvic reconstruction have become apparent. We have presented our institution's preferred technique for the use of the robotically harvested rectus abdominis muscle flap as a workhorse for minimally invasive pelvic reconstruction. In the setting of minimally invasive tumor extirpation, pelvic exenteration, and fistula repair the use of the surgical robot provides patients with improved outcomes and minimal morbidity.

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History and Future of Transanal Minimally Invasive Surgery

15

Elliot G. Arsoniadis and Dana Sands

Foundations: Transanal Endoscopic Microsurgery

The beginning of transanal minimally invasive surgery has generally been ascribed to Buess in 1985. In their landmark paper, Buess and colleagues describe their experience resecting 12 rectal neoplasms utilizing a rigid proctoscope. In addition to the rigid proctoscope, the procedure described use of a port for gas insufflation, a stiff oblique-angle stereoscopic optical system, and ports for up to four surgical instruments. Utilizing this platform, the authors were able to successfully resect ten adenomas and two adenocarcinomas that would have otherwise required the more invasive “open” anal approaches [1]. This landmark publication was the first to utilize minimally invasive surgical instruments via natural orifice access for local resection of rectal neoplasm and thus can be considered the first report of transanal endoscopic microsurgery (TEM).

Although expertise in the TEM platform would continue to grow at certain specialized centers over the next decades, it failed to gain widespread adoption throughout the colorectal surgical community. This has been attributed to a lack of access on the part of the majority of the colorectal surgical community to formal training utilizing this platform as well as the cost of the device [2]. One cost-analysis study from Great Britain from the previous decade showed that the initial capital investment of £40,000 would be made up for after 12 TEM procedures were performed. This takes into consideration the cost of inpatient hospitalization for what would otherwise be a rectal resection using open abdominal access. Despite this, prohibitive cost continued to remain a leading argument against widespread adoption of TEM [3].

E. G. Arsoniadis · D. Sands (✉)
Department of Colorectal Surgery, Cleveland Clinic Florida, Weston, FL, USA
e-mail: sandss@ccf.org

Transanal Minimally Invasive Surgery

In 2010 Atallah and colleagues introduced the world to transanal minimally invasive surgery (TAMIS). Recognizing the benefits of the TEM platform and dismayed by the lack of adoption, the group offered the colorectal surgical community a platform for transanal surgery that was relatively inexpensive and utilized equipment with which they were familiar and would require much less specialized training [4]. Single-port laparoscopy was already being performed for colorectal resections via the abdominal approach for some time [5]. This utilized the single-incision laparoscopic surgery SILS Port (Covidien, USA) for minimally invasive access to the abdominal cavity. Atallah and his group published the first series of six patients to undergo transanal resection of rectal neoplasms using the SILS Port placed in the anus and the resection being performed with standard laparoscopic equipment, rather than the rigid proctoscope and instrumentation of the TEM platform. The authors noted technical success, with negative margins in all but one of the pathological specimens, and cited a relatively faster operative time of 86 minutes compared to average 120–140 minute TEM [4]. In addition, the SILS Port caused no damage to the anal sphincter, another concern that had been raised regarding the TEM platform [6].

In the ensuing 4 years following the introduction of TAMIS, 33 manuscripts and 3 abstracts were published detailing the worldwide experience with the platform in 390 patients. Experience with TAMIS centered predominately in the USA and Western Europe, but published reports from these early years can also be found from Japan, Australia, and Brazil. In a 2014 systematic review, Martin-Perez and colleagues describe the worldwide experience with TAMIS. The majority (>50%) of TAMIS procedures were performed for early-stage adenocarcinoma (Tis or T1), with a sizeable minority being performed for benign neoplasms (39%). The largest studies included in the review contained 62 and 50 patients. Overall resection quality was excellent,

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with 4.36% margin positivity, and only 2.36% requiring conversion to an alternative modality of resection (open transanal, laparoscopic transabdominal). Mean operative time was 76 minutes. Over two-thirds of cases were performed using the SILS Port utilized in the original report by Atallah. However, eight different transanal ports were described. One of these, GelPOINT path transanal access platform (Applied Medical, Rancho Santa Margarita, CA, USA), was designed specifically for TAMIS [7]. At this time, both the SILS Port and the GelPOINT platforms are FDA approved in the United States. Further improvements in the TAMIS technique came in 2014 when Bislenghi and colleagues published their experience using the AirSeal system insufflator (SurgiQuest, Inc., Milford, CT, USA) to provide stable pneumorectum during the procedure. The device, working through a dedicated AirSeal Access Port, provided continuous CO_2 insufflation, pressure monitoring, and smoke evacuation. This allowed for a more stable working space and eliminated the previous problem of 'flapping' bowel [8].

Experience with TAMIS continues to grow. Familiar laparoscopic equipment and little to no capital investment requirement have made uptake increase at a greater pace than was seen with TEM. Resolution of the challenge of stable pneumodistension of the rectum has also contributed to adoption of the technique. In addition, the experience required to perform adequate excisions with reasonable operative times has been cited as 14–24 cases [9], a feasible number for practicing colorectal surgeons.

One of the first reports of a robotic approach to TAMIS utilizing the benefits of wristed instruments of the DaVinci platform was by Bardakcioglu et al. in 2013 [10]. This eventually led to the development of the DaVinci SP system introduced by Intuitive Surgical in 2018, a 2.5 cm single-port device with a camera and three-wristed instruments. As of this writing, the SP platform is FDA approved for urology with the plan to seek approval for transanal application in the near future.

Transanal Total Mesorectal Excision

Although the use of the TAMIS platform for local resection of rectal neoplasms is important, the most impressive development in the history of TAMIS has been in its use in performing total mesorectal excision (TME). Transanal total mesorectal excision (taTME) was developed from the prior experience in TEM and TAMIS and blended with the principles of TME. In the words of one recent editorial, "(taTME) takes the most important developments in rectal cancer surgery to emerge over the last 30 years and unifies them into one operation" [2].

The concept of using the transanal approach to perform proctectomy was not a new one. Marks and colleagues had described and performed the transanal-transabdominal (TATA) approach for accomplishing TME since the 1980s [11]. TATA utilized specialized retractors to gain transanal access, and many found the visualization poor and could not complete the transanal portion of the case [2]. Minimally invasive transanal colorectal resection without abdominal access was described in 2007 in a cadaveric model by Whiteford and Swanström. This occurred during a period of enthusiasm for natural orifice transluminal surgery (NOTES), a concept where endoscopic instrumentation was placed through "natural orifices" (mouth, anus, or vagina) and then a gastrotomy/proctectomy/vaginotomy was made endoscopically to enter the peritoneal cavity. Whiteford and Swanström utilized the TEM platform to gain access to the rectum, perform a proctotomy, and then following entrance into the peritoneal cavity proceeded to perform a sigmoid colectomy, lymphadenectomy, and primary anastomosis [12].

The first report of taTME performed on a human was by Sylla and Lacey in 2010 at the Hospital Clinic of Barcelona, Spain. The authors utilized the Karl Storz TEO proctoscope to gain transanal access to the presacral plane and then continued the dissection medially, laterally, and inferiorly to mobilize the rectum. Transabdominal support was provided via laparoscopic access with a single 5 mm port and two 2 mm ports. The vast majority of the dissection, including ligation of the inferior mesenteric vasculature, was performed transanally, with the laparoscopic ports being utilized mostly for visualization and retraction. The specimen was extracted transanally, and a hand-sewn coloanal anastomosis was performed. The procedure lasted 4.5 hours and produced an intact mesorectal specimen with negative proximal, distal, and radial margins and 23 lymph nodes [13].

These same authors later reported their experience in a single-arm study of 20 patients undergoing "transanal minilaparoscopy-assisted natural orifice transluminal endoscopic surgery." They reported intact mesorectum, negative distal and circumferential margins in all patients, and an average of 15 harvested lymph nodes, with few Clavien-Dindo Grade I and II complications. Interestingly, for this study the authors utilized the GelPOINT multiport rectal device (Applied Medical, USA) rather than the TEO rigid proctoscope utilized in the initial case report. Increased laparoscopic access was gained in the abdomen. More colonic mobilization, including splenic flexure mobilization, as well as inferior mesenteric vascular ligation, was performed laparoscopically, in contrast to the initial report where laparoscopic assistance was mainly utilized for retraction [14].

In the years that followed Sylla and Lacy's initial report on taTME, there was increased interest in performing and reporting the technique. A 2015 review by Araujo and colleagues counted 150 performances of taTME in the literature. The majority of these publications were either case reports or small case series. Most cases were performed for rectal adenocarcinoma, although there were some reports including benign indications as well. Nearly all cases utilized some form of abdominal access, either via single-port laparoscopy, traditional laparoscopy, or even robotic assistance. The TAMIS platform was used in 111 cases for transanal access, while the TEM platform was used in 37 cases and a flexible endoscope in 2 cases [15].

The largest series in this review included 30 taTME procedures. Inclusion in this study by Rouanet and colleagues included a narrow pelvis (inter-tuberosity distance under 10 cm and inter-ischiatic distance under 12 cm), unfavorable tumor features, and concern for possible CRM involvement based on pelvic MRI [15, 16]. This is in contrast to the earlier study by Lacy and colleagues where T4 tumors were a contraindication to performance of taTME.

In 2014 Velthuis published the first study comparing taTME with laparoscopic TME (without a transanal approach). Although there were no differences in the rate of CRM or distal margin positivity, there was a statistically significant difference in the rate of mesorectum completeness. Only 72% of specimens were graded as "complete" in the laparoscopic arm, while 96% were graded as complete in the taTME arm ($p < 0.05$) [17]. As experience with taTME increased, its value in obtaining a full oncologic resection under conditions where resection quality was compromised was being realized. Among these conditions, obesity, males with the inherently narrow pelvis, distal lesions, and locally advanced lesions are factors that have been associated with difficulty in obtaining negative margins and complete TME via an abdominal approach. These various factors have been cited as appropriate criteria for taTME, with the ideal candidate being an obese male with a distant, advanced lesion [18].

taTME uptake has been aided by the development of a formalized training program for surgeons interested in utilizing the technique. The program is comprised of both didactic learning elements and cadaver-based hands-on training. The course directors reported 81 successful course completions by colorectal surgeons between November 2014 and October 2015. Following course completion, the course directors cite the need for continued mentorship for those surgeons performing taTME. The authors of the study describing this course also advocate for the development of formal guidelines for the appropriate use of taTME by the Americans Society of Colon and Rectal Surgeons [19].

Future Directions

The development of taTME continues to this day, and various reports exist of modifications to the procedure to increase its safety and efficacy in obtaining excellent oncologic outcomes. Verheijen and colleagues were the first to report using robotic assistance to accomplish the transanal portion of taTME in 2014 [20]. This was followed that same year by a small series of robotic-assisted taTME by Atallah and his group, who coined the term "RATS-TME" [21]. The perceived benefit of robotic assistance would be increased maneuverability within the confined space of the single-port used for transanal access.

Stereotactic navigation for use in performing taTME has also been described. Atallah and colleagues published their first report using stereotactic navigation to perform TME for a rectal adenocarcinoma that was abutting the prostate. The procedure was performed successfully with an accuracy level of ±4 mm [22]. Through social media in 2018, both Atallah et al. announced that they had performed the first successful robotic taTME with stereotactic navigation, and Bardakcioglu et al. reported a successful case of a dual robotic approach to a taTME utilizing the Flex, a flexible transanal robotic platform (Medrobotics, Raynham, MA).

Most important in the future of taTME is the need for a randomized clinical trial comparing taTME to traditional abdominal approaches to TME. In 2015 the COLOR III Trial was announced and began patient recruitment. This international, randomized trial's goal is to compare oncologic outcomes for low and mid-rectal tumors undergoing resection by taTME or laparoscopic TME. The primary endpoint is CRM involvement, and secondary endpoints are disease-free and overall survival, recurrence, completeness of mesorectum, morbidity/mortality, percentage of sphincter-saving procedures, and quality of life. The study continues to accrue patients, with a goal of 1098 patients over 4 years. Initial results are eagerly anticipated, as this will be the first randomized trial comparing taTME to any other modality for TME [23].

Conclusion

taTME combines Heald's concept of TME and Marks' TATA procedure with the advances in minimal access surgery brought to us first with Buess's TEM and later TAMIS, as well as the many advances in laparoscopic surgery that preceded it. taTME continue to gain acceptance across the colorectal surgical community. As it does, its young history continues to be written. It is predicted that it will become more and more a part of formal colorectal training, with one editorial touting that "Transanal TME will become an 'index case' with a level of importance to rival the highly coveted ileoanal anastomosis" [2]. The highly anticipated results of COLOR III and other trials comparing taTME to transabdominal TME will certainly be an important addition to the history of transanal minimally invasive surgery. As with any new modality in surgical history, taTME is not without its opponents. However, both opponents and enthusiasts must agree that transanal minimally invasive surgery, and most especially taTME, represents a novel way to approach the pelvis and achieve an excellent oncologic specimen while maintaining the principles of minimally invasive surgery to ameliorate the trauma of access while enhancing the visualization, and thereby safety and effectiveness, of surgery.

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Robotic Transanal Minimally Invasive Surgery (TAMIS)

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Shanglei Liu and Samuel Eisenstein

Introduction

In this chapter, we will discuss the techniques for robotic transanal minimally invasive surgery (R-TAMIS) for the purpose of excising rectal lesions. This procedure is the newest evolution from a variety of natural orifice operations described in the past including transanal endoscopic microsurgery (TEM) and laparoscopic transanal minimally invasive surgery (TAMIS). R-TAMIS is considered a natural orifice approach to full-thickness resection of anorectal diseases that are locally contained. It is great option for patients with small to moderate sized lesions of low malignant potential. The robotic platform adapts very well to the limited operative space in the anus and rectum without significantly compromising operative dexterity. Many investigators are expanding the utilization of R-TAMIS beyond simple excision (such as transanal total mesorectal excision). But as these procedures remain largely investigational, this chapter will limit itself to the simple excision and closure technique.

Background

In the early 1980s, Buess et al. first reported on TEM as a minimally invasive procedure to remove rectal polyps and early rectal cancers through the anus [1–3]. This approach achieved full-thickness resections with acceptable margins for lesions from 5 to 20 cm from the anal verge [3]. In long-term follow-up, TEM had favorable oncologic outcome as well as low morbidity and mortality [4–8]. However, general adoption of TEM has been limited in clinical practice. One of the biggest reasons for this was the difficult learning curve associated with the technical challenges of this operation. Training was often only available at selective centers across the nation. Additionally, the operation required specialized instruments not widely available. And finally, the TEM approach may be unsuitable for lesions closer to the anal verge [8–10].

To solve these problems, transanal minimally invasive surgery (TAMIS) was introduced in 2009. This approach used traditionally laparoscopic instruments placed through the anus to perform local excision. Previous studies have shown that TAMIS provides high-quality local excision, comparable to TEM [11–14]. TAMIS has the additional benefit of utilizing conventional laparoscopic instruments that are nearly ubiquitously available in all hospitals. Yet, using laparoscopic tools in TAMIS to replace TEM equipment was not without its shortcomings. While the original TEM instruments were angled to facilitate rotational maneuvers within the rectum, laparoscopic instruments were limited by their rigid design and inability to fully articulate their working tip. This loss of degree of freedom was a great drawback to operating with laparoscopic instruments, especially in small spaces or through single port techniques [15]. This decreased range of motion became very pronounced during TAMIS due to the small working space inside the rectum.

In 2010, the da Vinci Robotic Surgical System (Intuitive Surgical, Inc., Sunnyvale, CA) caught the interest of many clinical investigators as a possible platform for TAMIS. Prior to this, robotic surgery had been adopted in surgeries where operative space is limited, such as the mediastinum and pelvis. Investigators initially demonstrated the feasibility of R-TAMIS in cadaver models [16, 17]. Since then, several published case reports and small series have described the R-TAMIS technique with encouraging early results [18–21].

S. Liu
Department of General Surgery, University of California San Diego, San Diego, CA, USA
e-mail: s5liu@ucsd.edu

S. Eisenstein (✉)
Department of Surgery, UC San Diego, La Jolla, CA, USA
e-mail: seisenstein@ucsd.edu

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R-TAMIS is still a novel procedure only performed in specialized centers. Because of this, operative standards and limitations have not been well defined. To make matters even more complicated, since the introduction of this technique, the makers of the da Vinci Robotics introduced the newest iteration of its technology, the da Vinci Xi™, in 2014. With increased ease of docking capabilities and decreased external arm collision, the Xi™ platform integrated well into the previously developed robotic technique. The general techniques described in the following sections are done using the Xi™ system but should be generalizable to previous robotic platforms as well.

Preoperative Planning

Patients with benign or low malignant potential anorectal lesions are considered for R-TAMIS. These are very similar to the selection criteria for TEM including patients with incompletely resected or endoscopically unresectable polyps, early-stage rectal neoplasm (uTis or uT1N0M0) with low-risk histology (no lymphovascular invasion, moderately to well differentiated), carcinoid or other neuroendocrine tumors <2 cm, and selective locally advanced tumors needing palliative debulking, and repairs of high rectovaginal fistulae [22–27]. Because robotics is a relative new surgical approach to transanal surgery, many investigators continue to push the boundaries of this technique to include surgeries where meticulous endoluminal dissection of the anus and rectum is needed.

Anatomically, the limitations of R-TAMIS are also similar to TEM. However, the potential for feasible resection is still an area of active investigation. In our experience, R-TAMIS should be able to be safely resected within following criteria:

- 2–20 cm proximally from the dentate line
- Up to 5.5 cm in longest dimension
- Up to 50% of the luminal circumference

Although it may be possible to resect a lesion beyond these measurements, a backup surgical excision plan should be planned in case the case proves too technically challenging.

Absolute contraindications to R-TAMIS mainly pertain to cases where extensive resection of perirectal fat and lymphatics are required. In its current form, RT does not provide adequate sampling of perirectal lymph nodes and has not been shown to be adequate for locally advanced tumors. A conventional oncologic resection with lymph node excision should be used for these cases.

All patients undergoing evaluation for RT should undergo a colonoscopy by either the operating surgeon or a gastroenterologist. The goal is to assess the anatomic measurements, obtain tissue biopsies, and locate any synchronous lesions. For early-stage malignant tumors of the rectum, either endorectal ultrasound (EUS) or pelvic magnetic resonance imaging (MRI) should be performed to determine preoperative staging.

Preoperative physiologic testing for patients is not universally required and should be determined on a case-by-case basis. Although general anesthesia with endotracheal intubation is preferred, chemical paralysis is not required. It would be feasible to perform the operation under laryngeal mask airway (LMA). Additionally, it is theoretically possible to do this technique under a spinal block under monitored anesthesia care (MAC).

Similarly, there are no established guidelines on withholding anticoagulation or antiplatelet agents preoperatively. R-TAMIS allows the usage of monopolar and bipolar electrocautery, local suturing, and the application of the full spectrum of intraoperative chemical hemostasis agents. We do not recommend routinely withholding all anticoagulation preoperatively. The risk factors for each case needs to be evaluated by the surgeon on an individual basis between cardiovascular risks and the size of resection.

It is recommended that all patients undergo a routine mechanical bowel preparation prior to surgery. A full bowel preparation is often unnecessary for operating in the rectum. Because of this, a sodium phosphate-based enema (such as Fleet® Enema) the morning of the surgery is recommended. The goal of this is to simply empty the rectal vault in order to create adequate space for surgery. Since there is a relatively small area undergoing the surgical procedure, even if the rectum is not completely evacuated at the time of the procedure, simple table irrigation and suction can be employed to empty the rectal vault.

Perioperative antibiotics are given within 1 hour of the start of surgery. These antibiotics include cefazolin and metronidazole, or an equivalent antibiotic regiment to provide similar broad coverage of enteric pathogens. No postoperative antibiotics are routinely given.

Room Setup and Positioning

A variety of patient positioning is possible for robotic TAMIS including prone jack-knife, lateral recumbent fetal position, or lithotomy with moderate Trendelenburg. The decision of which position to use should be decided based on patient safety, tumor position, and the surgeon's comfort.

Prone jack-knife positioning offers the most amount of free space above the patient for the robotic arms (Fig. 16.1). This serves to minimize external arm collision during the case. Theoretically, this is also the most natural position for operating on tumors located on the anterior wall of the rec-

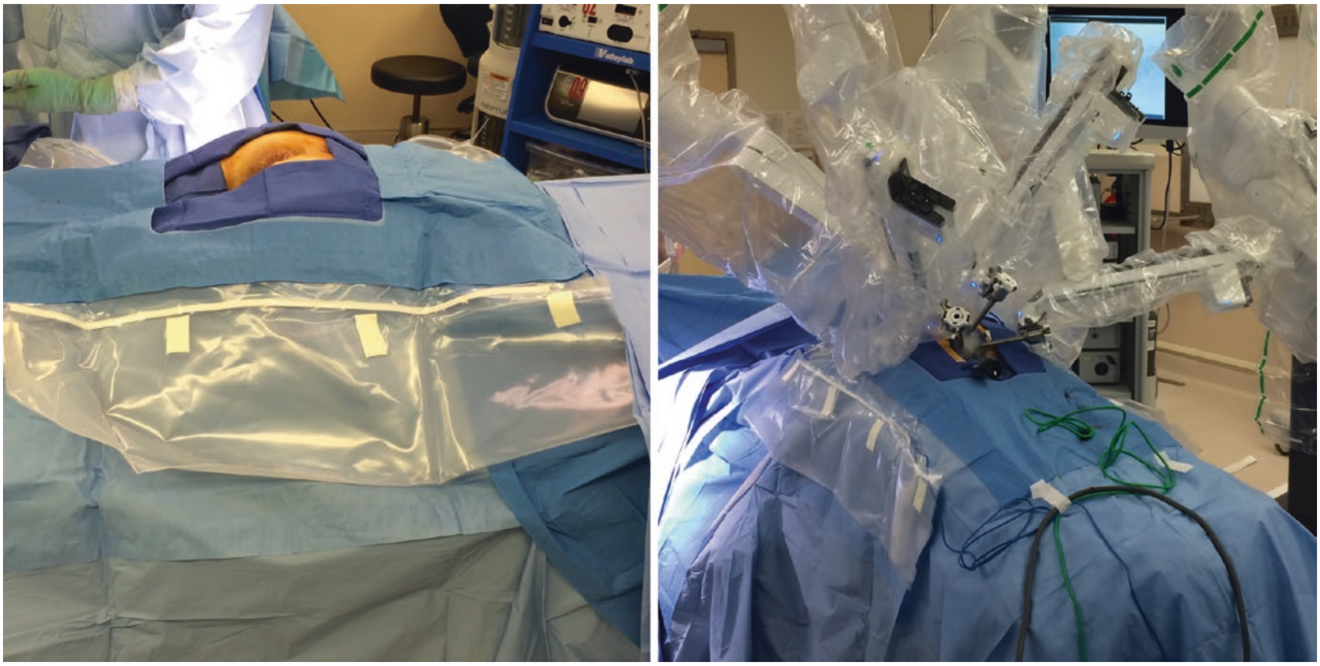

Fig. 16.1 Patient positioning in prone position (left) and docking of robot arms (right)

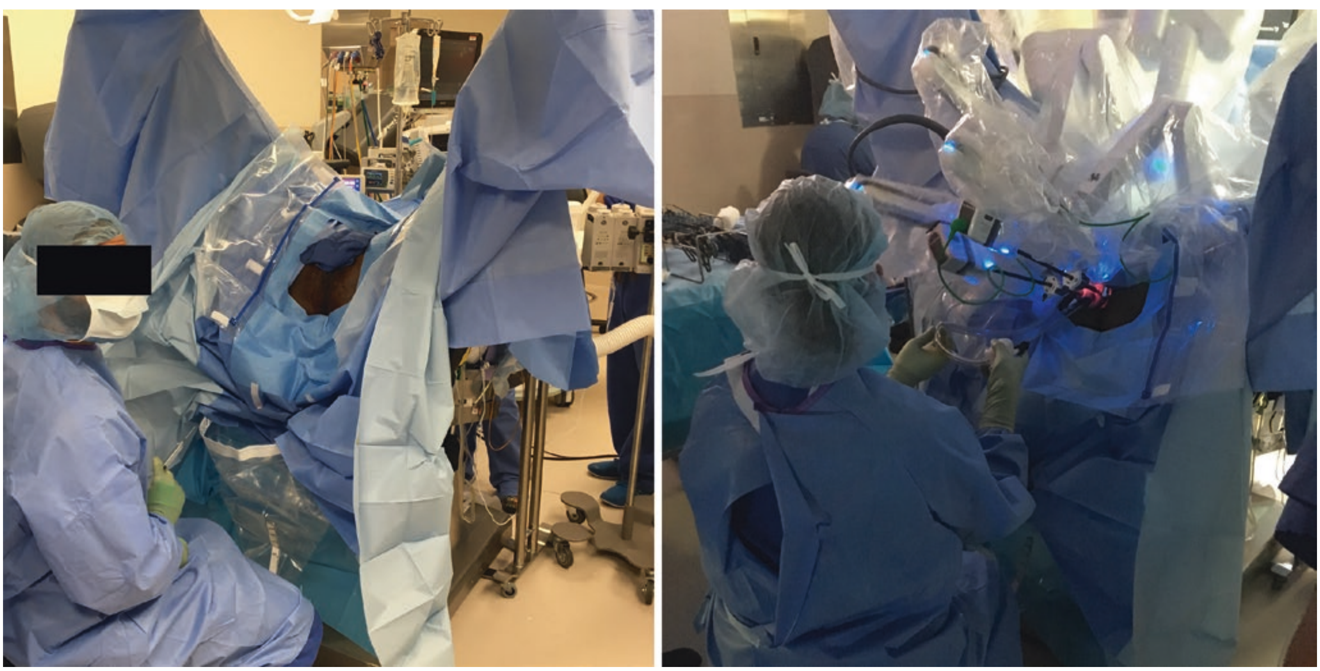

Fig. 16.2 Patient positioning in lithotomy position (left) and position of assistant to arms (right)

tum. The biggest drawback to this technique is difficult airway access for the anesthesiologist during the case and the limited space for a second surgeon assistance if needed.

A reasonable alternative is the lateral recumbent fetal position. This allows better anesthesiology access to the patient airway. When utilizing this positioning, the side of the patient that is down should be the side of the rectal wall on which the lesion is located. The patient should also be positioned in a way as to align the predicted path of the rectum in parallel with the direction of the bed.

Lithotomy with moderate Trendelenburg and tucking of both arms is also a popular position (Fig. 16.2). This is typically the easiest position to place the patient and gives the anesthesiologist full access to the patient's airway during the case as well as simple abdominal access which may be useful for higher lesions if there is concern for violating the peritoneal cavity. The surgical assistant could also sit between the patient's raised legs during the case. The biggest challenge of this positioning is that the patient's legs become physical boundaries for the external arms of the robot. It may take an experienced operator to adjust the robotic arms correctly as to minimize external collision between the robotic arms with themselves as well as the patient's legs.

Operative Tools/Supplies

There are two main robotic platforms available for R-TAMIS (either the da Vinci Xi™ or the Si™). While both have been used for R-TAMIS, there are some differences between the two, which will be addressed in a later section. There are also a variety of robotic graspers and dissectors that can be used depending on surgeon preference. The basic equipment needed are:

- Robotic surgical platform (either Xi™ or Si™)
- GelPOINT® Path Transanal Access Platform (Applied Medical, Rancho Santa Margarita, CA)
- Robotic 30° (or 0°) scope
- Robotic monopolar energy module
- Robotic dissector (we recommend robotic scissors)
- Robotic grasper (we recommend a low-force grasper such as a cadiere)
- 3-0 absorbable suture (either conventional suture or barbed suture)
- Laparoscopic suction
- Laparoscopic grasper

Trocar Placement and Robotic Docking

Once positioned, the operation should begin with a digital rectal examination. The tumor should be >2 cm from the dentate line or be proximal enough that it will not be covered by the protective GelPOINT™ trocar, which serves as a projective cuff for the anus and typically sits at the top of the anorectal ring (Fig. 16.3). Usually if the tip of one's finger will fit between the top of the anorectal ring and the lesion, then there is adequate space to fit the trocar. It is possible that very low lesions may become amendable to transanal excision without the need of robotic surgery when the patient is more relaxed under general anesthesia.

Once the decision is made to proceed with R-TAMIS, the anus is gently dilated with several fingers, and a GelPOINT™ silicone cuff is placed into the anal canal and suture anchored to the surrounding skin. Three 8-mm robotic trocars and one

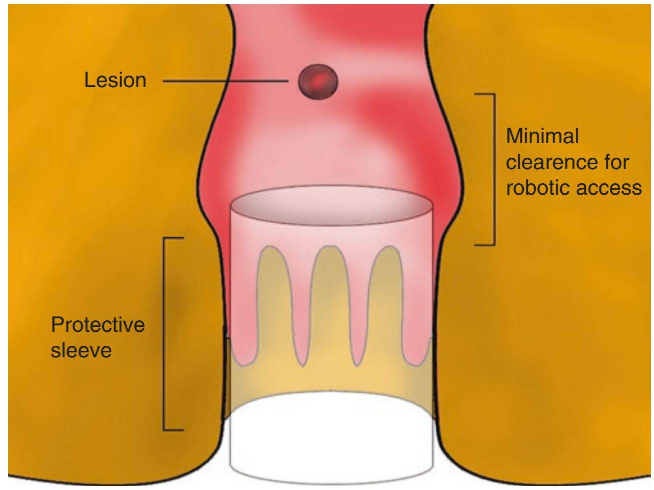

Fig. 16.3 Location of protective sleeve may cover the lesion to be excised if too close to the dentate line

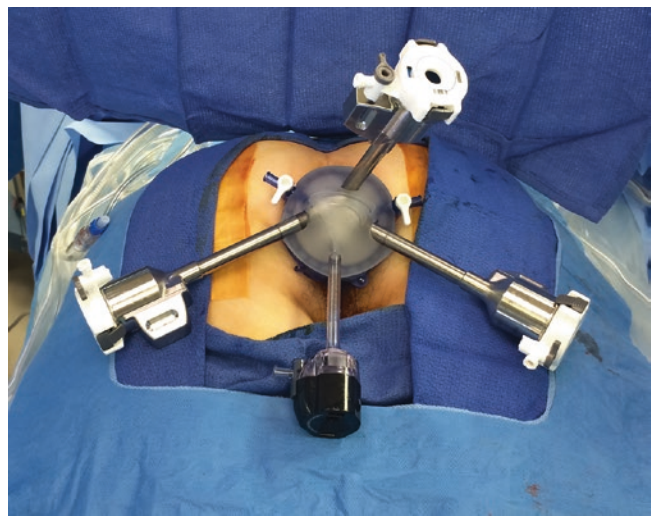

Fig. 16.4 Placement of robotic trocars and assistant port trocar

5-mm laparoscopic trocar are placed into the gel interface (Fig. 16.4). Care is taken to place the fulcrum of the robotic trocars (marked by the black line on the trocar) at the level of the anal sphincter to protect the muscles from stretch injury. When properly placed, there should be minimal radial displacement of instruments onto the sphincter muscles (Fig. 16.5).

The rectum is insufflated with CO_2 with pressure setting of 15 mm Hg. This can be most easily facilitated by an integrated suction/insufflation system such as the AirSeal (ConMed, Utica, NY). This allows for easy evacuation of smoke in a tight space and can also potentially regulate insufflation should the peritoneal cavity become violated. The robotic system is docked from either side of the patient. An 8-mm, 30° robotic camera is placed in the middle and two articulated robotic instruments on either side. The assistant will be placed on the

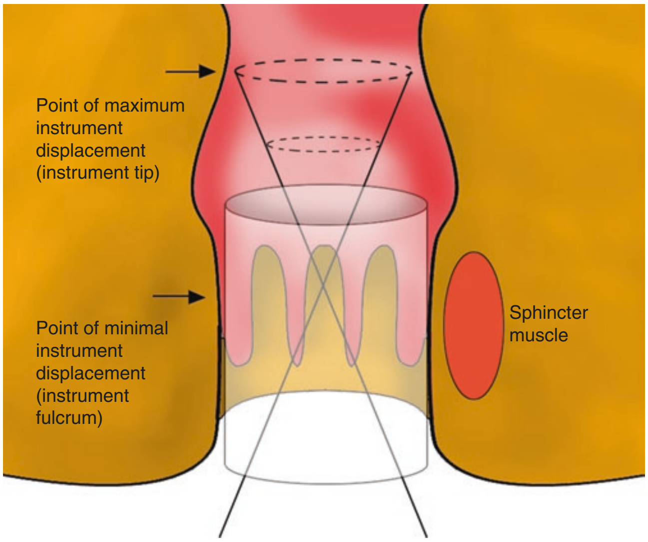

Fig. 16.5 Positioning of fulcrum point of robotic trocars should be at the level of the sphincter muscles

opposite site of the robot body and use the laparoscopic assist port to provide suctioning and tissue extraction.

Operative Steps

Operative steps	Degree of technical difficulty (1–10)
Exploratory anoproctoscopy	1–2
Full-thickness excision of lesion	4
Closure of defect	5

Exploratory Anoproctoscopy

The tumor is first examined visually using the robotic camera. Although it is technically possible to resect tumors located superiorly in the visual field, the most ideal location for resection is when the tumor is located in the inferior to inferior-lateral aspect (Fig. 16.6). This allows one to keep the 30° scope high in the field and make space below for the two arms to operate. Tumor size and percentage of luminal involvement is once again assessed. Instruments are inserted under direct visualization and tested by seeing if they are able to move past the lesion by 1–2 cm. The monopolar electrocautery is connected to the robotic scissors. Although a number of robotic dissectors may be used, we recommend an energized robotic scissor to provide both sharp and cautery dissection.

Full-Thickness Excision of Lesion

Resection begins by marking the boundaries of resection by the energized dissector prior to tissue manipulation

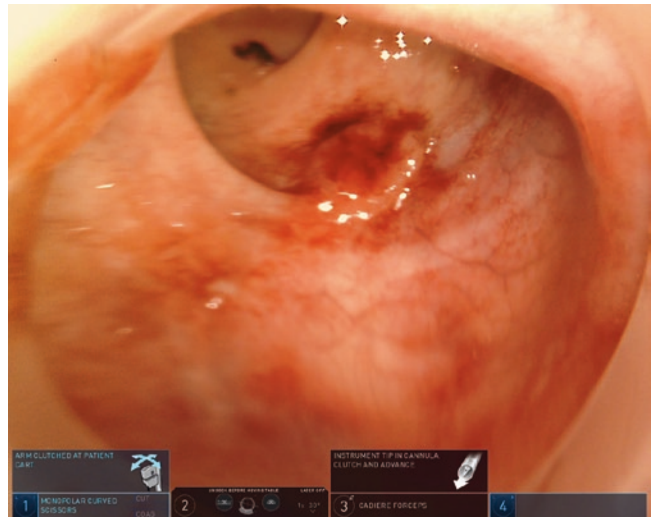

Fig. 16.6 Exploratory anoproctoscopy

Fig. 16.7 Marking the perimeter of the lesion with monopolar scissor tips

(Fig. 16.7). This is usually done 1–2 mm peripheral to the lesion's borders. Next the grasper is used to elevate the lesion while the base of the lesion is dissected. A low-force, small-profile grasper, such as a cadiere, is best used here. This will limit the damage to the healthy remaining rectum and also allows space to articulate the grasper at a right angle. The judicious use of electrocautery helps to reduce tissue contraction at the resection margins and make it easier to identify when full-thickness dissection is achieved (Fig. 16.8). A laparoscopic suction catheter can be used for defog during the case if you are not employing an integrated suction/insufflation platform and is operated by the surgical assistant through the 5-mm laparoscopic trocar. Full-thickness excision is confirmed with visualization of the perirectal fat, and dissection should be carried down to this level (Fig. 16.9).

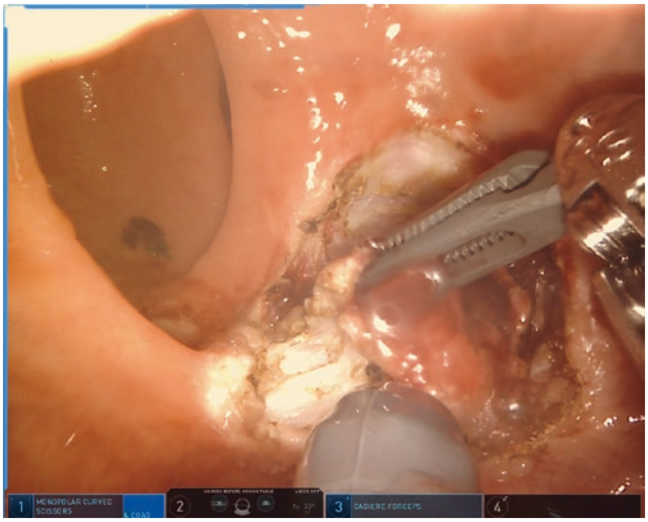

Fig. 16.8 Full-thickness excision of lesion using monopolar scissors

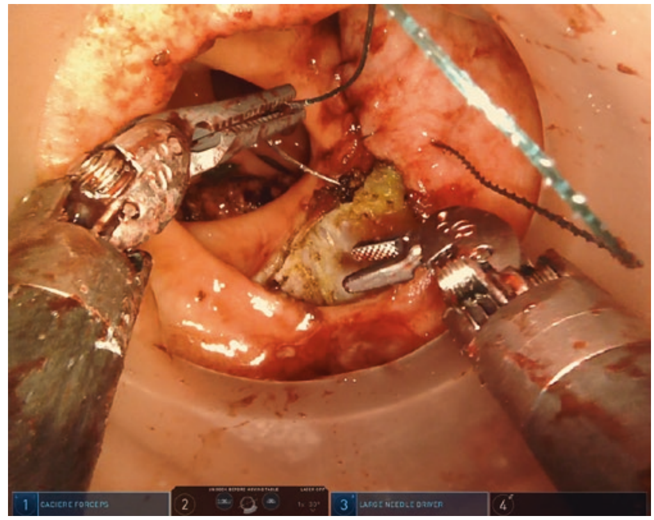

Fig. 16.10 Transverse primary closure of defect through robotic suturing

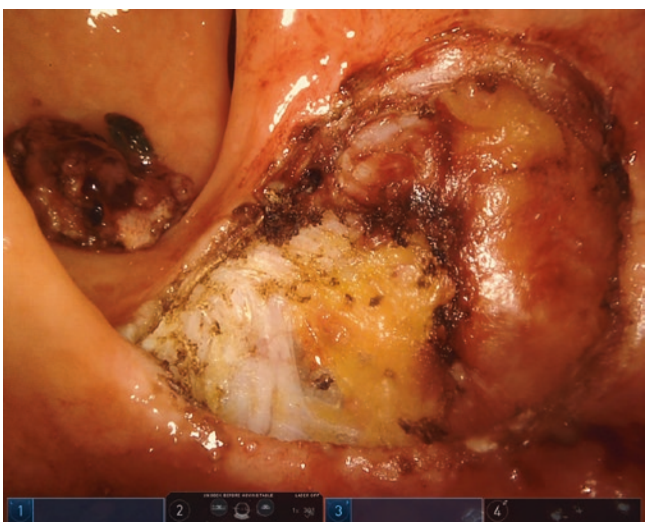

Fig. 16.9 Full-thickness defect after resection showing perirectal fat

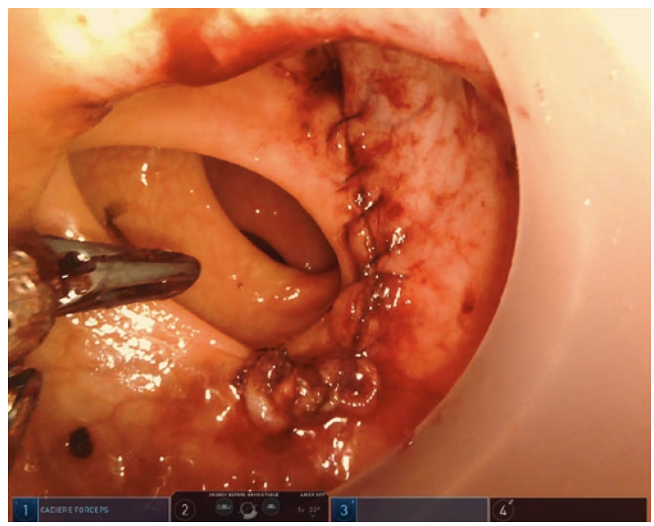

Fig. 16.11 Completion of suturing of defect

Closure of Defect

The closure of the rectal defect in TAMIS is an area of ongoing debate; however, there are emerging studies suggesting decreased rates of bleeding and other wound complications if the defect was able to be closed primarily [28, 29]. The rectal wall defect is closed with absorbable suture in a transverse direction to avoid narrowing of the rectum. Either running suture or interrupted suture may be used. We find that the simplest closure is performed with a 6-in. 3-0 V-lock barbed suture (Medtronic, Minneapolis, MN) as this avoids the need to tie knots within the narrow space of the rectum (Fig. 16.10). Care should be taken to avoid narrowing the lumen to the point of obstructing the passage of stool. Successful resection is defined as the absence of visible tumor in the surgical bed and pathologically negative margins (Fig. 16.11).

While it is not preferable to violate the peritoneum for these procedures, that does not necessarily mean the procedure needs to be converted in well-prepared bowel when the procedure continues to be technically simple. Anterior lesions and lesions in the upper rectum tend to be higher risk for this violation. When this occurs, the pneumoperitoneum tends to equalize with the pneumorectum, and the insufflation within the rectum can be lost entirely. This can be relieved by releasing the pneumoperitoneum through placement of a Veress needle. The use of an integrated suction/insufflation system also helps maintain insufflation within the rectum when venting through the abdomen.

In these cases successful closure of the rectal defect is crucial to minimizing complications. Once complete closure of the excision site is achieved, it can be tested by removing the Veress needle and testing for ongoing rectal insufflation. If there is any concern, abdominal laparoscopic (or robotic) trocars can be placed to evaluate the closure as well as to sew in a second layer. If the procedure is too technically challenging to perform after violating the peritoneum, the procedure can often be completed abdominally, completing the disk excision and closing the defect.

Postoperative Follow-Up

Patients may be observed in the hospital for one night prior to discharging home. They should be started on their normal diet postoperatively.

Patients should receive regular follow-up with the surgeon at 1–3 months postoperatively. All patients are expected to follow up with their primary care provider, their gastroenterologist, or the operating surgeon at 1 year. MRI or colonoscopy should be performed 1 year post-op or earlier as indicated. There is a possibility of upstaging the tumor on final pathology. In such cases, formal resection with or without chemotherapy and radiation are recommend. Having had R-TAMIS should not exclude the patient from having a curative oncologic resection.

Some patients may experience a transient incontinence postoperatively. This is almost always transient and generally resolves with the first 3–6 months. Depending on the size of the lesion, some patients will also experience clustering of bowel movements postoperatively, similar to a low anterior resection syndrome. This is more common for larger lesions and tends to be related to shortening the length of the rectum. Again this will resolve in the majority of patients within the first year after their procedure.

Technical Feasibility

The robotic approach to TAMIS is the most recent evolution of natural orifice surgery for the treatment of low-risk rectal tumors. This technique may be ideal for the treatment of low-risk rectal neoplasms not amendable to conventional transanal excision. These include early-stage (T1N0M0) rectal cancers without high-risk pathological characteristics and inadequately resected rectal polyps.

Feasibility of resection also needs to be considered with consideration to the size and location from the dentate line. Lesions that are too large (>5.5 cm), too distal (<2 cm from the dentate line), or too proximal (>20 cm from the dentate line) may not be feasible for this technique using currently available robotic platforms (Fig. 16.10). The reason for this is severalfold. First, larger lesions may become visually obstructive when operating in the tight space of the rectum, resulting in incomplete or piecemeal resection of tumor. Lesions that are too close to the dentate line may be amendable to transanal excision without the need for the robotic surgical platform. Lesions too far from the dentate line may severely limit the operative range of the robotic arms since their fulcrum needs to be at the level of the dentate line. These more proximal lesions also run the risk of violating the peritoneal cavity, which may not increase the risk of postoperative complications but almost always makes the procedure more technically challenging. We would advise caution when resecting near or outside the range of these anatomical measurement and be prepared for a secondary surgical approach in case R-TAMIS cannot be performed.

Variations in Patient Positioning

The current literature has not agreed on the most optimal positioning for patients undergoing R-TAMIS. When it was first developed, investigators favored prone or left lateral decubitus positioning [19]. However, lithotomy positioning has been also described in detail [30]. In practice, either position should be technically feasible. The robotic camera is capable of 360° articulation and can be easily inverted if the lesion is not in the normal top-down view, especially if the surgeon chooses a 30° scope. As a result, whether the tumor is above or below the field of view should not negatively impact the surgery.

There are however patient-sided limitations that affect positioning. For example, it is feasible that a patient with a history of hip surgery or other orthopedic limitations may not be able to abduct his or her legs for lithotomy positioning. On the other hand, a high-risk airway patient may be better managed by anesthesia in the face up position. Ultimately, positioning will be determined by a combination of physician preference and physical limitations of the patient. Similarly, as we discussed before, lesions are more amenable to removal in a dependent position, and therefore it may be advisable to position your patient accordingly.

Older Versus Newer Robotic Platform

As the evolution of technology phases out older generations, it is expected that with time the da Vinci Xi™ and X™ platform will overtake Si platform in popularity and availability in the future. Several advantages of the newer platform had been observed in literature, the most common of which relates to shorter console times attributed to improved ease of use with less clashing of the robotic arms in a tight space [31].

This chapter describes R-TAMIS as it most applies for the da Vinci Xi™ robotic platform. However, the considerations for the da Vinci Si™ platform should be the same or very similar. Anecdotally, the da Vinci Xi™ provides more customizable external arm positioning, which allows for reduction of external collision during the case. This is important in ensuring the maximal range of motion available during surgery.

Summary

R-TAMIS is a simplified approach to a transanal excision of rectal lesions and other transanal procedures and is utilizing all benefits of the da Vinci Xi™ robotic platform including flexible instrumentation. Expected further development of robotic platforms designed for a transanal approach will likely further validate the technique.

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17 Transanal Total Mesorectal Excision: Single-Surgeon Approach

Cristina R. Harnsberger and Justin A Maykel

Introduction

Total mesorectal excision (TME) is the standard of care for rectal cancer surgery as it has been shown to dramatically impact local recurrence and sphincter preservation [1–4]. It is a technically challenging procedure, particularly in obese patients, those with a narrow pelvis, or presence of a bulky tumor. Significant morbidity can result in the form of anastomotic complications and genitourinary and bowel dysfunction [5–6]. Comparison of laparoscopic to open TME has produced conflicting results in multiple large randomized clinical trials [7–10]. There are technical challenges to the laparoscopic approach as exposure requires an experienced assistant. Laparoscopic retraction to adequately expose the anterior plane can be challenging as the uterus and a floppy cul-de-sac can obscure visualization. Smoke tends to accumulate deep in the pelvis, limiting visualization further. In addition, laparoscopic and robotic staplers are not optimally designed for perpendicular division of the rectum low in the pelvis, and often multiple staple firings are required, which can increase risk of anastomotic leak [11]. Furthermore, lack of tactile sensation and tumor visualization may limit an adequate distal negative margin. As such, there remains room for optimization of the minimally invasive TME technique.

Transanal TME (taTME) has emerged as an alternative minimally invasive technique to traditional open or laparoscopic proctectomy and provides a solution to many of the aforementioned challenges [12–15]. The laparoscopic caudal to cranial TME dissection technique allows the surgeon to directly visualize the tumor and precisely choose the distal resection margin, use pneumoinflation to facilitate rectal dissection, optimally visualize the mesorectal dissection plane, and avoid injury to surrounding neurovascular structures and the prostate/vagina, without having to retract intra-abdominal structures that envelop the pelvis. Early outcomes have been promising, with improved histologic outcomes and fewer positive circumferential and distal margins compared with other minimally invasive surgical options [16–19]. Although long-term data is still emerging, the ongoing international, randomized, controlled COLOR III trial will compare laparoscopic and transanal TME, adding to the data on the latter.

Background

A single-surgeon approach has some advantages compared to a dual-surgeon team. Patient positioning can be optimized for the surgeon in both the abdominal and perineal portions of the procedure. During the laparoscopic abdominal dissection, steep Trendelenburg and right lateral decubitus positions facilitate visualization of the deep aspects of the pelvis and gravitational distraction of the small bowel out of the operative field. However, in the perineal portion of the dissection, moderate Trendelenburg with a level horizon is ideal to maintain true anterior and posterior landmarks, while dissection proceeds cephalad. When the single-surgeon team starts from the abdominal field, the colon remains decompressed, whereas an inadequate distal purse string in the perineal field allows colonic dilation and thereby limits abdominal visualization in the case of a dual-surgeon approach [20]. Additionally, during the perineal dissection, it can be essential to have the benefit of full pneumopelvis without competition from abdominal insufflation, the latter of which can collapse the pelvis and limit working space. This can be particularly important in a narrow male pelvis, with a bulky mesorectum in an obese patient, or in the presence of a heavy, bulky tumor.

C. R. Harnsberger · J. A Maykel (✉)
Department of Colon and Rectal Surgery, University of Massachusetts Medical School, Worcester, MA, USA
e-mail: Cristina.Harnsberger@umassmemorial.org; justin.maykel@umassmemorial.org

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There are limitations to the single-surgeon approach. The duration of the operation and subjugation of the patient to general anesthesia is longer than with a dual-surgeon approach. However, the two-team approach may actually be more costly as two surgeons and two scrub teams are employed. In the case of a difficult dissection, a dual-surgeon approach can afford better visualization, as the two surgeons can assist each other in exposure and identification of tissue planes. The St. Gallen consensus on safe implementation of taTME advises to operate with two teams simultaneously whenever possible [20]. Depending on practice patterns and resources, many surgeons do not have the ability to employ the assistance of a second surgeon for a particular operation. Accordingly, one must be prepared to complete all steps of this operation with accompaniment of a single assistant. Ultimately, the single-surgeon approach has been demonstrated to be oncologically adequate, safe, and feasible [21].

Preoperative Planning

Extensive surgeon preparation is essential for successful adoption of the transanal TME technique as the dissection plane and retrograde approach are novel even for the most experienced open or laparoscopic surgeon. A comprehensive understanding of the anatomic relationships between the rectum, mesorectum, and surrounding pelvic structures from this vantage point will serve as a foundation. Preoperative didactic and cadaveric training are critical, as are experienced surgeon mentors and proctors. It is additionally important to have significant experience with transanal endoscopic surgery. For the initial cases, patient selection is key; women and those with benign disease or small tumors of the mid rectum are excellent candidates. It is worth nothing that the anterior dissection in women tends to be more straightforward as correct identification of the plane between the rectum and vagina is much easier than that between the rectum and prostate.

Preparation of the operating room staff is paramount to successful introduction of the technique. Familiarity with the equipment, setup, and steps of the procedure are vital. Even with a single-surgeon approach, abdominal and perineal fields require duplicate instrument sets, laparoscopy towers, suction machines, and energy generators. As such, additional scrub and circulating manpower can be extremely helpful for maintaining efficiency.

Equipment

An insufflation system that utilizes continuous carbon dioxide (CO_2) insufflation and rapid smoke evacuation is critical to success. With a standard CO_2 insufflation system, the perineal operative field is subject to "bellowing" and collapse with any amount of suctioning or standard smoke evacuation device. Investment in a commercially available insufflation system, such as the AirSeal (CONMED, NY, USA), is critical to the success of a transanal TME program.

An access device that maintains pneumopelvis is another necessity for this approach. Rigid platforms such as those used for transanal endoscopic microsurgery (TEM, Richard Wolf Medical Instruments Corp, IL, USA) and transanal endoscopic operations (TEO, KARL STORZ Tuttlingen, Germany) can be utilized. The advantage of the rigid platforms is the ability to secure the device and camera in a manner that allows complete control by the operating surgeon, without the need of an assistant camera holder. Flexible platforms such as the single incision laparoscopic surgery (SILS) port (Covidien, CT, USA) is an additional option that provides ability to maneuver through a narrowed anal canal. We prefer the two-part GelPOINT Path Transanal Access Platform (Applied Medical, Inc., Rancho Santa Margarita, CA, USA) due to its versatility. With the cap removed, its semirigid access channel provides ability for lumen visualization, transanal suture placement, specimen extraction, and creation of a hand-sewn coloanal anastomosis if necessary.

Instruments with angled tips facilitate the transanal mesorectal dissection in a relatively narrow field. Bovie electrocautery with the extender and angulated tip is an option, in addition to the bent laparoscopic L hook and angled needle tip TEM cautery; the latter is our preference due to its precision and maneuverability.

Visualization in the perineal field is best accomplished with an angled scope. Options include the bariatric length 5-mm 30-degree scope or the 5-mm Endoeye flex camera (Olympus, Center Valley, PA, USA). The long length of these scopes minimizes interaction with the operating surgeon's hands and instruments. Our preference is the former with optional angled light cord given its familiarity and ease of use.

Room Setup and Positioning

Two sterile tables are prepared for the abdominal and perineal portions of the dissection, each with separate laparoscopic and instrument setups, one on the patient's right and the other at the feet (Fig. 17.1). We prefer to have both laparoscopy towers and energy generators on the patient's left as we perform the abdominal portion with surgeon and assistant standing on the patient's right (Fig. 17.2).

The patient is placed in modified lithotomy with the right arm tucked. Chest straps and shoulder support are instituted to prevent the patient from sliding during changes in positioning. Prior to prepping and draping the patient, the rectum is irrigated with diluted iodine solution through a rigid proctoscope to remove any excess liquid stool (Fig. 17.3). The patient is then prepped and draped using an alcohol-based preparation for the abdominal field and an iodine solution for the perineal field. The vagina is prepped in females to allow for examination during the case.

Fig. 17.1 Dual sterile tables

Operative Steps

Operative steps	Degree of technical difficulty (scale 1–10)
Abdominal	
1. Port placement and exploratory laparoscopy	1
2. Abdominal dissection	3 to 5
Perineal	
3. Initial dissection open	2
4. Initial dissection laparoscopic	5
5. Laparoscopic transanal total mesorectal dissection	6
6. Connection of abdominal and perineal dissection fields	6
7. Specimen extraction	2
8. Anastomosis	4

Abdominal Field

The goals of the abdominal portion of the operation are to (1) mobilize the left colon and upper rectum, (2) divide the superior hemorrhoidal vessels, (3) facilitate the anastomosis, and (4) create a loop ileostomy.

Port Placement and Exploratory Laparoscopy

Port placement is performed as in a laparoscopic low anterior resection. After establishment of pneumoperitoneum,

Fig. 17.2 OR layout

Fig. 17.3 Rectal irrigation

we prefer 5-mm ports in the periumbilical region (camera), right mid-abdomen, epigastrium, and suprapubic regions.

Abdominal Dissection

This part of the dissection follows the steps in other chapter for sigmoid and upper rectal resection. The abdomen is scanned for any evidence of occult metastatic disease. Mobilization of the left colon is then performed, in addition to the splenic flexure when necessary to facilitate a tension-free anastomosis. Identification of the ureters and hypogastric nerves are critical, which will additionally be necessary to avoid injury during connection of the abdominal and perineal dissection planes and completion of the dissection. The superior hemorrhoidal vessels are divided, and dissection of the upper rectum is performed. Care should be taken to limit rectal dissection to the upper rectum, so inadvertent connection of the abdominal and perineal fields does not occur prematurely, as this can limit perineal visualization.

Advantages of the Single-Surgeon Approach During the Abdominal Dissection

One advantage of the single-surgeon approach is that the patient can be placed in steep Trendelenburg and right lateral decubitus during the abdominal portion of the dissection. Additionally, insufflation pressure set at 15 can be continued throughout the abdominal dissection as it does not compete with the pneumorectum established in the perineal dissection. Furthermore, in the two-surgeon approach, pneumorectum can make abdominal dissection difficult as the colon can fill with CO_2 and dilate and limit visualization.

Perineal Field

The goals of the perineal dissection are (1) closure of the distal rectum; (2) full-thickness, circumferential transection of the rectum; (3) dissection in the TME plane; (4) connection of the two operative fields; and (5) colorectal/anal anastomosis. The laparoscopic transanal TME approach is ideal in patients with low rectal tumors in which sphincter preservation is possible.

Initial Dissection

The initial mode of dissection depends on tumor location. For low-lying tumors that abut the internal sphincter, an intersphincteric dissection plane can be established using a standard open approach facilitated by placement of a LoneStar Retractor System (Cooper Surgical Inc., Stafford, TX, USA). Electrocautery is used to divide the rectal wall distal to the tumor, and dissection is advanced as far proximally as possible with standard open instruments. Once a working space has been created for placement of the laparoscopic access device, the mobilized rectum is sutured closed. This isolates the tumor from the operative field, prevents stool spillage, and allows establishment of pneumopelvis to facilitate dissection in the TME plane. The GelPOINT Path access sleeve is placed at this time.

In mid to low rectal tumors that are above the sphincter complex, placement of the laparoscopic access channel initially is preferred. It can be challenging to obtain adequate effacement of the anus to facilitate placement of the relatively stiff laparoscopic access device, so we have found use of the LoneStar helpful. We then use the GelPOINT Path access sleeve and insert it into the anal canal such that its deep aspect sits just above the anorectal ring. The superficial external ridge is secured to the perianal skin with two sutures. The LoneStar retractor can then be removed (Fig. 17.4a, b). Closure of the rectum using 0 Prolene suture and distal transection are accomplished laparoscopically.

In a pure laparoscopic approach where the distal transection has not yet been performed and following placement of the access channel, the cap is connected, and pneumorectum is established. We prefer to use four ports so that suction can be used by the assistant when necessary (Fig. 17.5). Pressure can be set at 15 mm Hg, and we prefer to use the AirSeal for reasons previously described. Using the angled TEM cautery, marks are placed circumferentially 1 cm distal to the lowest extent of the tumor (Fig. 17.6). A 0 Prolene purse string is used to close the rectal lumen. This step can be performed in one of two ways: directly through the open access channel using a standard needle driver or laparoscopically particularly when the purse-string site is not easily visualized transanally (Fig. 17.7a, b). Once the lumen is closed, a second set of circumferential marks are placed 1 cm distal to the purse string at the level of the intended transection site (Fig. 17.8). This maneuver helps prevent tangential or uneven division of the rectum in relation to the tumor and the sphincter complex.

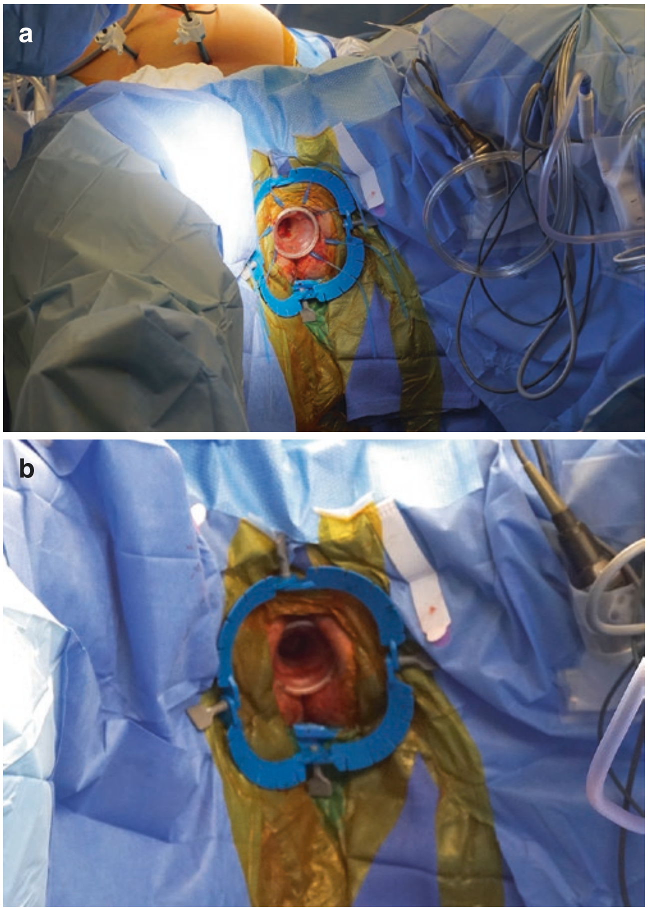

Fig. 17.4 (**a**, **b**) Access sleeve placement

Fig. 17.5 Transanal port placement

Fig. 17.6 Demarcation of intended purse-string site

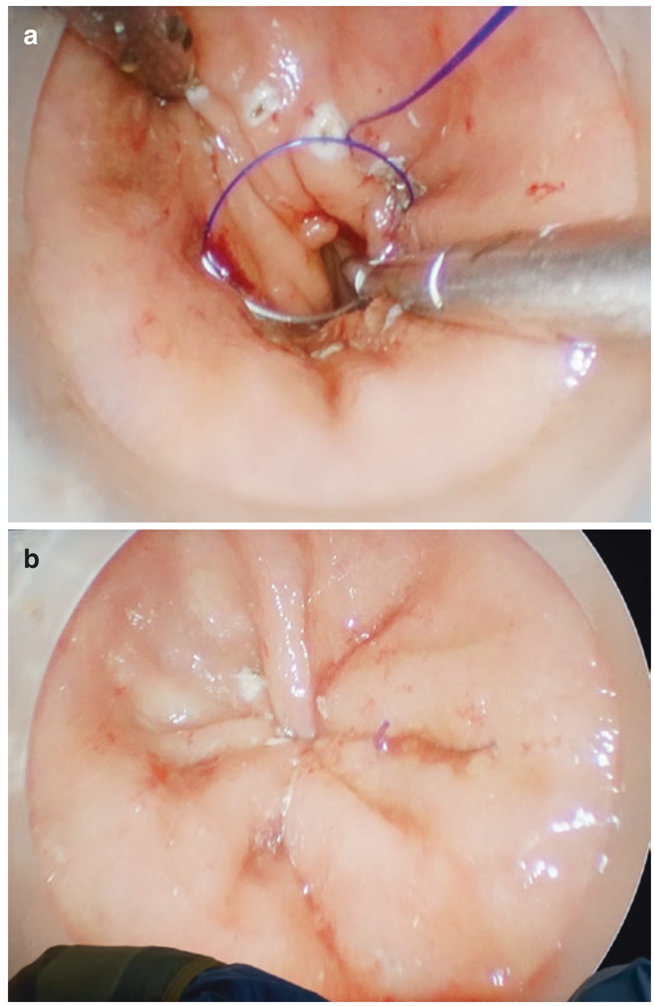

Fig. 17.7 (**a**) Purse-string placement. (**b**) Closed distal rectum

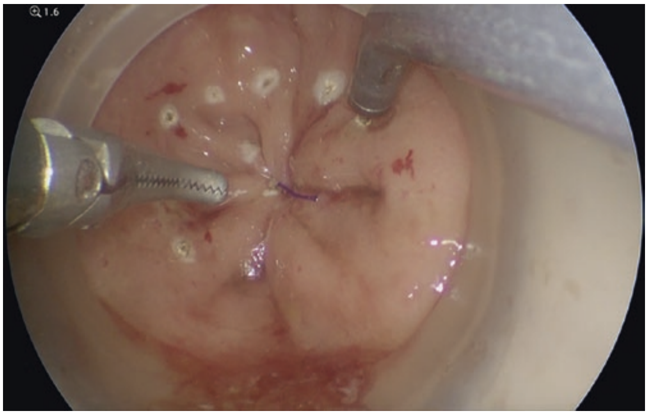

Fig. 17.8 Demarcation of intended distal rectal transection

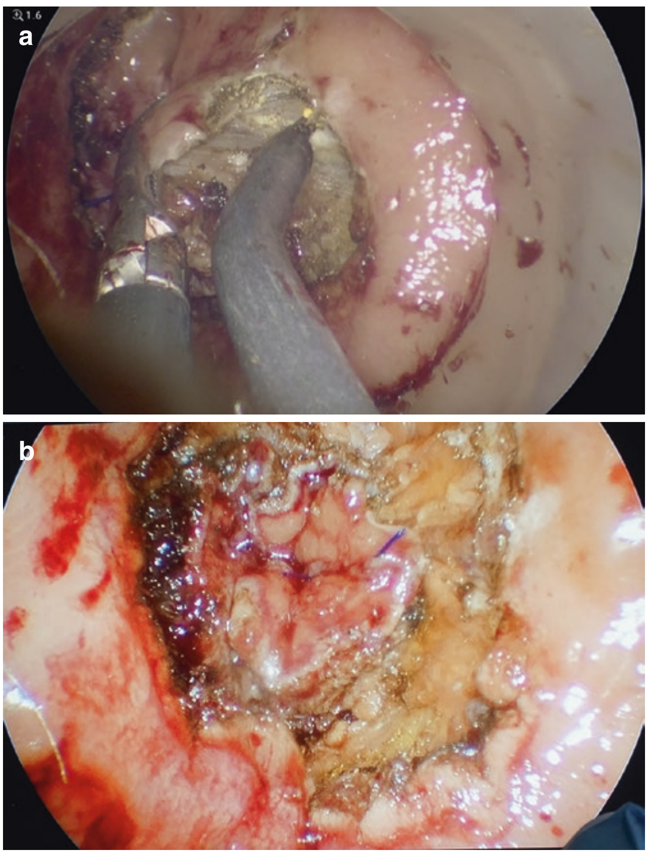

Fig. 17.9 (**a**, **b**) Perpendicular division of rectal wall

Laparoscopic Transanal Total Mesorectal Dissection

Division of the distal rectum and entrance into the proper TME plane is a critical step in the operation. Patients who have had neoadjuvant therapy may have a very thickened rectum, and care should be taken to continue transection perpendicular to the rectal wall rather than tangentially (Fig. 17.9a, b). For low-lying tumors, the dissection begins

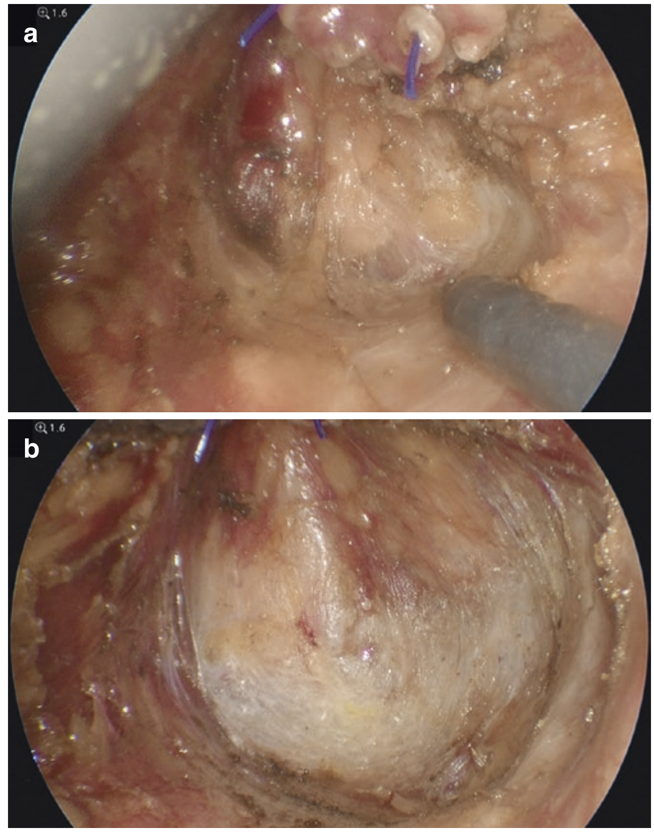

Fig. 17.10 (**a**, **b**) Posterior presacral plane

distal to the end of the mesorectum, and entrance into the plane between the muscular wall of the rectum and the pelvic floor musculature and eventually the presacral plane is best performed posteriorly (Fig. 17.10a, b). It is imperative to stay outside of the fascia propria of the mesorectum and avoid entering the intramesorectal plane around the rectum. Pneumopelvis facilitates tissue retraction and dissection within the avascular TME plane, and further tissue retraction can be performed with a laparoscopic grasper such as a Maryland. We always perform the posterior and anterior dissections first, as the correct planes are more readily identified. Then, continue by connecting the dissections laterally taking care to avoid lateral sympathetic nerves. In the transanal TME approach, the anterior dissection is well visualized, and one can readily see the prostate (Fig. 17.11), which is often one of the most difficult portions of the dissection from an abdominal approach.

There are a few pitfalls one should be aware of during the transanal TME approach. During the anterior portion of the dissection in the lowest aspect of the rectum distal to the prostate, the rectourethral muscle must be divided to prevent entering the plane anterior to the prostate, rendering the urethra susceptible to injury [22]. By developing and following the posterior TME plane, one can then continue this plane laterally and anteriorly, which should prevent the aforemen-

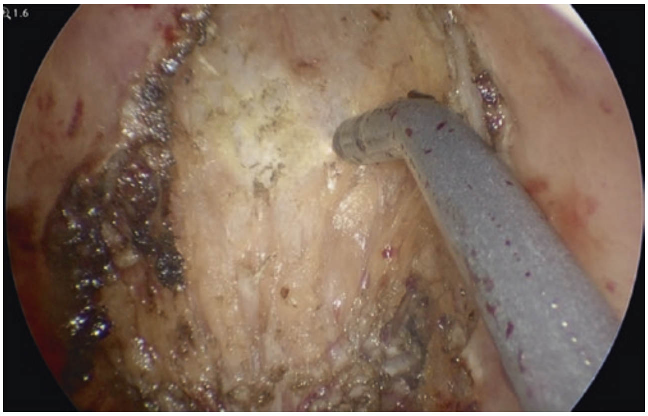

Fig. 17.11 Anterior plane with prostate visualized

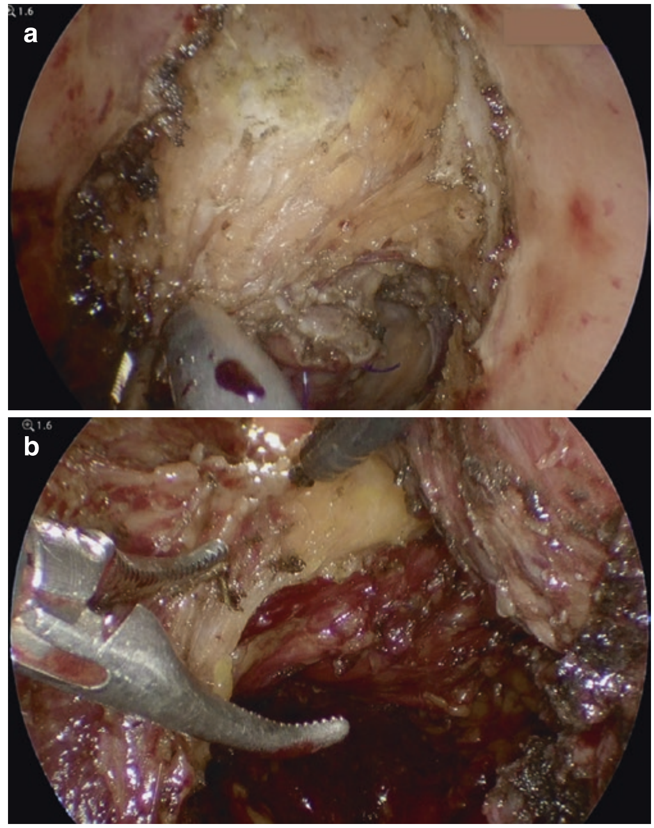

Fig. 17.12 (**a**, **b**) Transanal visualization of the lateral stalks

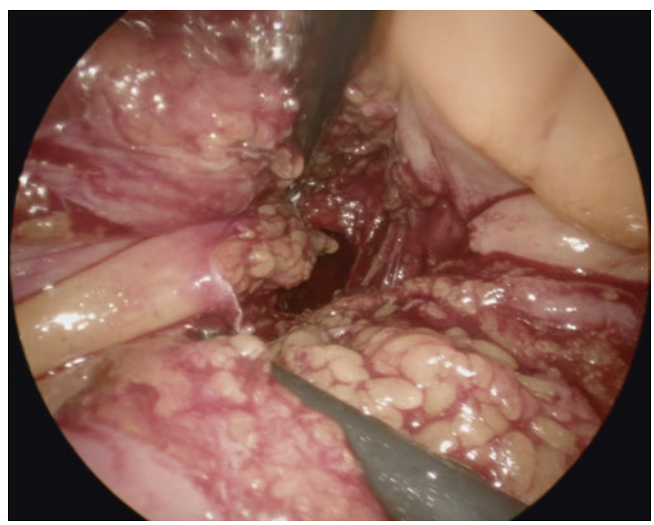

Fig. 17.13 Abdominal visualization of the lateral stalks

tioned wrong-plane surgery. Furthermore, the lack of an avascular plane and pesky bleeding during the anterior dissection can indicate incorrect dissection along the periprostatic vascular sinuses and capsule. If there is ongoing concern regarding the location of the prostate and urethra, the cap can be removed allowing the surgeon to palpate anteriorly and identify the location of the prostate and urinary catheter. In females, the vagina is routinely prepped so that examination can be performed if further clarification of the anterior dissection plane is necessary.

The correct plane during the lateral aspects of dissection can be inconspicuous. As such, initially proceeding in the posterior and anterior planes can make the location for division of the lateral stalks better defined and prevent a natural tendency to "cone out" and dissect too laterally (Fig. 17.12a, b). Close attention to sympathetic nerve fibers will prevent injury, as visualization of these fibers is excellent in the transanal TME approach. In the final stages of the lateral dissection, the corresponding abdominal view will confirm the correct plane of dissection (Fig. 17.13).

Connection of Abdominal and Perineal Dissection Fields

The perineal plane is connected to the abdominal plane either posteriorly along the presacral plane or anteriorly in the cul-de-sac (Fig. 17.14). Once connected, pneumoperitoneum will be re-established, and that tends to limit exposure and further dissection from the perineal field. This particular step is clearly aided with a two-team approach but can be safely performed alone. When performing a single team approach, two options are available depending on the experience and ability of the assistant. The perineal team can move to the abdominal field and complete the dissection by dividing the peritoneum and circumferentially connecting of the two fields. Alternatively, and when pelvic exposure from above is challenging, the perineal assistant can move to the abdominal field independently and help provide retraction and exposure for the perineal surgeon as the two fields are connected from below. We prefer to perform this part of the surgery from the abdominal field to assure proper exposure and dissection along tissue planes that spare the ureters and pelvic nerves. Once the TME is completed, the specimen is ready for proximal division and extraction.

Specimen Extraction

Choice of extraction site is dependent of surgeon preference and patient anatomy. Transanal specimen extraction can be possible if the mesorectum is not bulky and the mobility of the colon is sufficient for division and placement of the EEA anvil externally. Pulling a bulky mesorectum out transanally can cause tearing of the specimen and apparent defects in the mesorectum, so caution should be exercised. Additionally, the mesentery can be torn creating a mesenteric hematoma and/or devascularized conduit. This risk can be minimized by dividing the colon mesentery all the way to the wall of the colon to prevent tearing prior to extraction. However, in the appropriate patient with a lean mesorectum and sufficient mesenteric length, transanal specimen extraction avoids an abdominal extraction site. Alternatively, the specimen can be extracted via a Pfannenstiel incision, extended periumbilical port site, or expanded ileostomy site and the EEA anvil placed via that location (Fig. 17.15). If the specimen is extracted through the abdomen, this site must be covered/closed in order to re-establish pneumoperitoneum for the remaining steps of the operation.

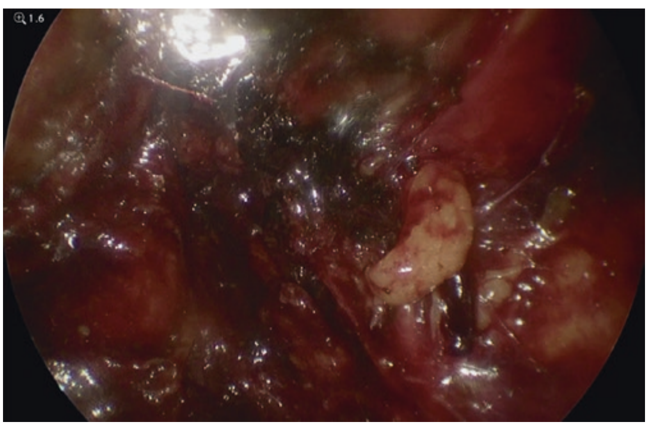

Fig. 17.14 Connection of the perineal and abdominal planes

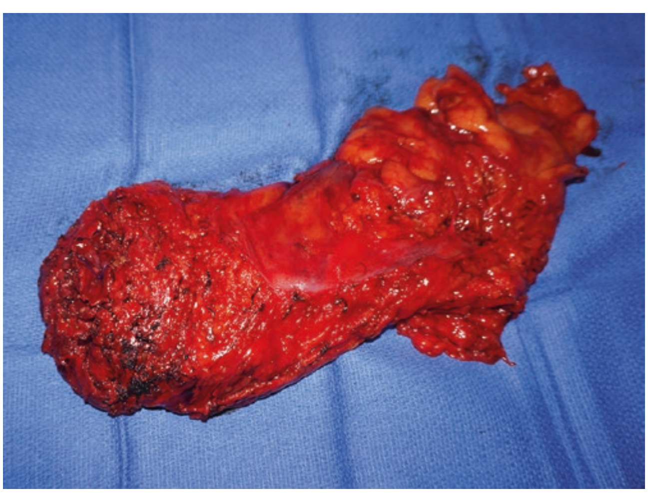

Fig. 17.15 Specimen following extraction via Pfannenstiel incision

Anastomosis

A variety of anastomotic techniques have been described [23]. The rectal cuff should be mobilized circumferentially from the levators and vagina or prostate such that a purse-string suture can be placed and the distal rectum can be pulled into the stapler head. A 2-0 Prolene purse string is then placed under the direct exposure provided by the GelPOINT Path access channel. A drain of the surgeon's preference can be placed transanally and the purse string tied securely around the end of the drain. We have found that the extended EEA stapler post can be inserted into the end of a 19-round Blake drain, which is used to guide the head of the stapler through the nearly closed center of the rectal cuff (Fig. 17.16a, b). From the abdominal field, the drain is detached from the stapler post, and the anvil is mated to the stapler post. The anterior (particularly the vagina) and lateral tissues are retracted and visualized laparoscopically (Fig. 17.17). Routine vaginal

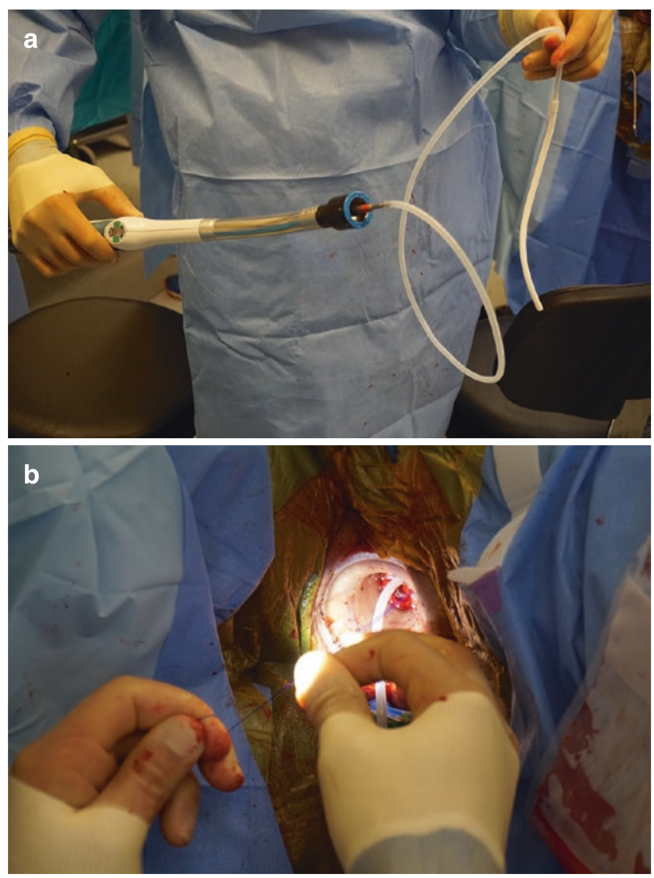

Fig. 17.16 (**a**) 19-round Blake drain on EEA stapler post. (**b**) Distal rectal purse string tied around drain

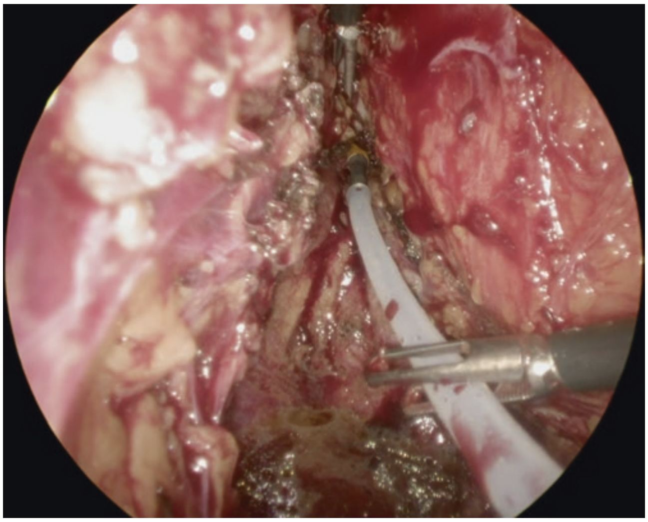

Fig. 17.17 Transabdominal tissue retraction and exposure of the EEA stapler post

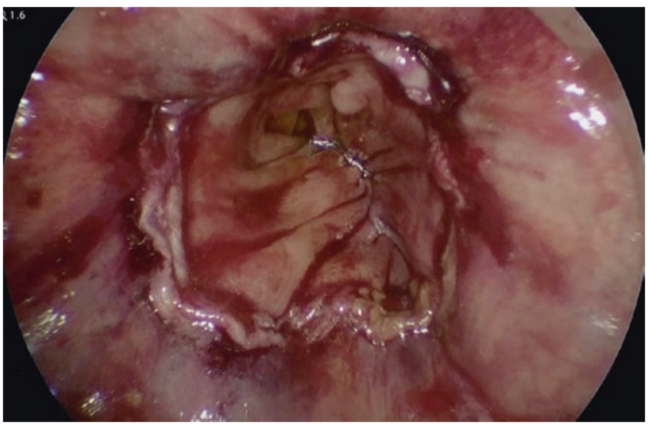

Fig. 17.18 Transanal visualization of the anastomosis

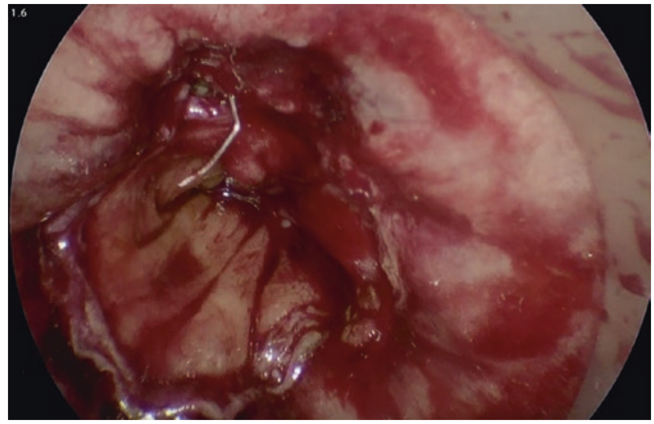

Fig. 17.19 Anterior anastomotic defect

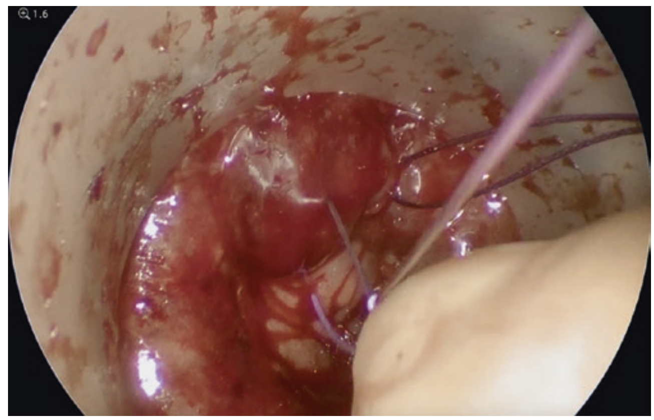

Fig. 17.20 Transanal repair of anastomotic defect

examination prior to firing of the stapler will confirm adequate separation of the rectovaginal septum. The anastomosis can then be clearly visualized from the transanal field (Fig. 17.18). After the stapler is fired, a "reverse air leak test" is performed, as pneumoperitoneum will cause bubbling into the rectal lumen if a defect is present (Fig. 17.19). If so, this can be readily oversewn by the surgeon transanally through the perineal access channel (Fig. 17.20).

Alternatively, when pelvic exposure cannot be obtained or maintained sufficiently from the abdominal field, the mating of the two ends of the stapler can be performed from the perineal field. By using the Covidien 33-mm hemorrhoid stapler with the long anvil post, the proximal colon can be manipulated into place transanally, and following stapler mating, the device can be closed and fired.

If the anastomosis is too low to be accomplished in a stapled fashion, the transected end of the colon can be delivered to the anal canal for a hand-sewn coloanal anastomosis. When performed at this level, the access channel must be removed and replaced with a LoneStar retractor for exposure.

Conclusion of the Case

Following completion of the anastomosis, the surgical team will move to the abdominal field to place the drain in the appropriate position and perform a diverting loop ileostomy.

Advantages to the Single-Surgeon Approach During the Perineal Dissection

As with the abdominal portion of the operation, there are advantages to a single-surgeon approach in the perineal portion of the dissection. Patient positioning can be optimized, which is typically moderate Trendelenburg with a level horizon. As such, orientation of anterior and posterior planes during the transanal TME is kept straight. In addition, pneumopelvis can be maintained at 15-mm Hg without competition from pneumoperitoneum that threatens to collapse the field of view. In addition, the "luxury" of having two surgeons available to operate simultaneously for a single operation can be impractical depending on practice environment and resource availability.

Summary

Laparoscopic transanal TME has emerged as a safe minimally invasive approach for the treatment of benign and malignant diseases of the mid and low rectum. Initial functional and oncologic outcomes of transanal TME are comparable to the open approach, while offering solutions to the current limitations of both open and laparoscopic techniques. Investment in the necessary equipment and training of the operating room team will facilitate team efficiency. The single-surgeon transanal TME approach has unique advantages. Although the learning curve can be steep, a thorough understanding of pelvic anatomy, solid foundation in laparoscopic and transanal endoscopic surgery, deliberate training, and experienced mentors will provide the framework for success [24–25].

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Transanal Total Mesorectal Excision for Inflammatory Bowel Disease: Cecil Approach

18

Karen Zaghiyan, Aimee Gough, and Phillip Fleshner

Introduction

In this chapter we describe our technique of transanal total mesorectal excision for inflammatory bowel disease, specifically the technique for total proctocolectomy with transanal ileal pouch-anal anastomosis (taIPAA) for ulcerative colitis. The technique can be modified if performing 3-stage vs. 2-stage taIPAA.

Background

Ileal pouch-anal anastomosis is the standard operation for patients with ulcerative colitis (UC) and inflammatory bowel disease-unclassified (IBDu) [1, 2]. Transanal total mesorectal excision is a viable minimally invasive option in patients with rectal cancer [3]. There is also emerging evidence for the value of this technique in benign disease [4–7].

Equipment, Room Setup, and Positioning

The procedure is accomplished with two teams working simultaneously. Necessary equipment for successful completion of taIPAA is shown in Table 18.1. Positioning of video monitors and back table setup for laparoscopic and transanal surgery are shown in Fig. 18.1. The operating table is positioned for modified lithotomy with anesthesia setup at the patient's head. The back table for the abdominal dissection is positioned just lateral and beyond the patient's right leg. The abdominal team utilizes conventional laparoscopy with both the surgeon and assistant generally standing on the patient's right side during laparoscopic portions of the case with their video and insufflation tower directly across from them near the patient's left hip (Fig. 18.1).

The transanal team is seated between the patient's legs, and their video tower is placed near the patient's left shoulder to allow the anesthesiologist access to the patient. The 3D video screen arm is extended to allow the screen to be placed in the midline and parallel to the transanal team's line of sight (Fig. 18.2). The 3D camera cord is run parallel to the left and through the pocket of the abdominal drape to reach the transanal team. The transanal back table is placed beyond the patient's left leg. A Mayo stand is placed near the left foot to rest the 3D camera and other laparoscopic equipment (Fig. 18.3). We place the Airseal® iFS insufflation management system (CONMED Inc., Utica, NY) lateral to the patient's leg between the transanal back table and the abdominal team's laparoscopic tower. Our transanal back table has a bottom shelf where the electrocautery unit is placed to help reduce the footprint of the transanal equipment as the operating room quickly becomes very congested.

After induction of general endotracheal anesthesia and placement of an orogastric tube to suction, the patient is repositioned from supine to low lithotomy position with supplemental padding to protect from peroneal nerve injury. A foam underpadding is used to prevent patient slippage or falls during extreme Trendelenburg positioning (Fig. 18.4). A sacral "bump" consisting of a rolled towel is critical to lift the perineum off the operating table. The arms are tucked. Intravenous antibiotic is adminis-

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K. Zaghiyan
Division of Colon and Rectal Surgery, Cedars Sinai Medical Center, Los Angeles, CA, USA

A. Gough
Department of Surgery, Wyoming Medical Center, Casper, WY, USA

P. Fleshner (✉)
Division of Colon and Rectal Surgery, Cedars-Sinai Medical Center, Los Angeles, CA, USA

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Table 18.1 Equipment setup for transanal TME for inflammatory bowel disease

Equipment	Transanal dissection	Abdominal dissection
Instrument tray	1. Minor instrument tray 2. Single laparoscopic grasper	Standard laparoscopic tray
Laparoscope	3D 10 mm scope with articulating tip[a]	Standard 30-degree 10 mm scope[b]
Insufflation	Continuous insufflation platform[c]	Standard insufflation
Trocars/retractors	1. Lone Star® disposable retractor ring (14.1 cm × 14.1 cm) and eight 5 mm sharp stay hooks[d] 2. Soft disposable transanal access platform with 2 self-retaining sleeves[e] and additional 12 mm access port[c]	Option 1: 3 trocars: 12 mm, 10 mm, 5 mm, 2nd 5 mm optional[f] Option 2: single incision platform[g] + 5 mm trocar
Energy device	Energy device with suction and hook cautery[h]	Advanced energy device[i]
Staplers/sutures	Option 1 (hand-sewn anastomosis) Seven 2-0 chromic sutures Option 2 (stapled anastomosis) 29 mm EEA stapler[j] 0 polypropylene suture[k]	1. Terminal ileal transection: (laparoscopic 60 mm linear cutting stapler[l]) 2. J-pouch creation Linear cutting stapler (2 loads)[m] Laparoscopic 60 mm linear cutting stapler (1 load) 2-0 polypropylene suture

[a]ENDOEYE FLEX 10 mm articulating tip video laparoscope, Olympus, Center Valley, PA, USA
[b]ENDOEYE II 10 mm, 30°, rigid video laparoscope, Olympus, Center Valley, PA, USA
[c]Airseal® iFS, TriLumen Filtered Tube Set and Airseal® 12 mm access port, CONMED Inc., Utica, NY, USA
[d]Lone Star® Retractor System, CooperSurgical, Inc., Trumbull, CT, USA
[e]GelPOINT® Path Transanal Access Platform (4 × 5.5 cm), Applied Medical Inc., Rancho Santa Margarita, CA, USA
[f]Laparoscopic trocars rounded tip with balloon, Applied Medical Inc., Rancho Santa Margarita, CA, USA
[g]GelPOINT® Mini Advanced Access Platform, Applied Medical Inc., Rancho Santa Margarita, CA, USA
[h]Endopath® Probe Plus II, Ethicon Inc., Somerville, NJ, USA
[i]LigaSure™, Medtronic Inc., Minneapolis, MN, USA
[j]CDH29A 29 mm circular stapler, Ethicon Inc., Somerville, NJ, USA
[k]Prolene® suture, Ethicon Inc., Somerville, NJ, USA
[l]Echelon Flex™ Powered Plus 60 mm, Ethicon Inc., Somerville, NJ, USA
[m]DTS Series™ GIA™100–3.8 mm single use reloadable stapler, Covidien LP, Mansfield, Massachusetts, USA

tered. A urinary catheter is placed and draped over the left leg so that is not in the way of the transanal team. The abdomen and perineum are prepped and draped, and an underbuttock drape with a pocket is placed. The energy device and suction for the abdominal dissection are passed off the patient's right and the laparoscopic equipment

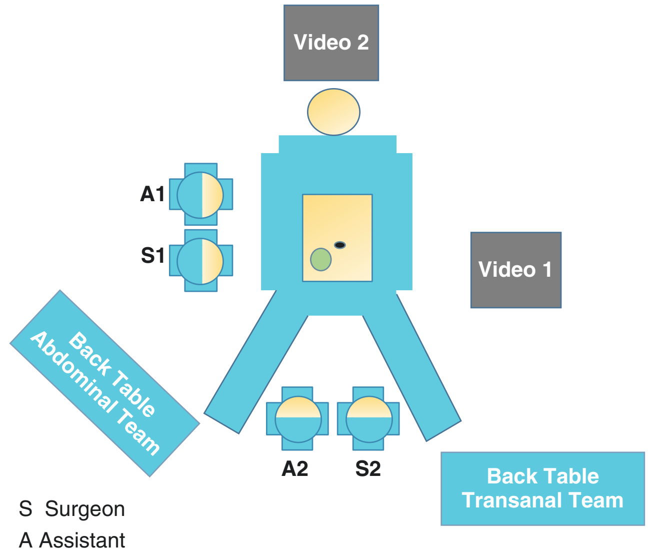

Fig. 18.1 Setup of video towers and back table for abdominal and transanal team

Fig. 18.2 Video tower and screen for abdominal team placed directly across from them near the patient's left hip. Video tower for transanal team placed near the patient's left shoulder to allow anesthesia access to the patient and video screen arm extended to allow the screen to be placed in the midline and parallel to the transanal team's line of sight

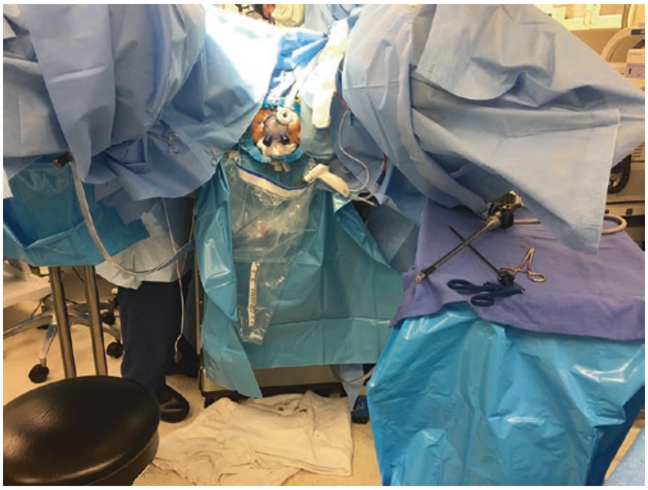

Fig. 18.3 A Mayo stand positioned near the patient's left leg can be used to rest transanal equipment including the 3D camera. The cords for the transanal equipment are run over the patient's left leg and secured with a towel clamp

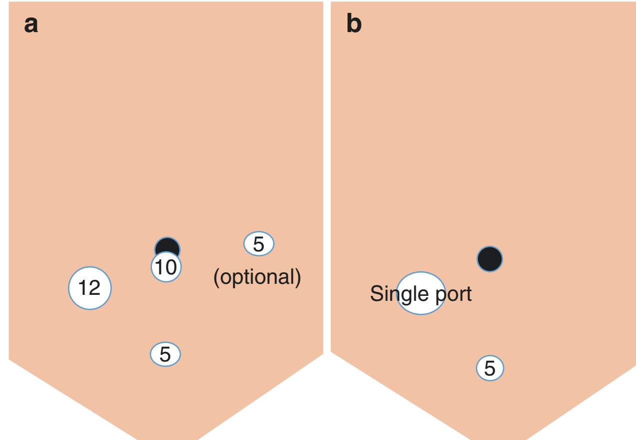

Fig. 18.5 (**a**) Laparoscopic ports for laparoscopic portions of the procedure including abdominal colectomy. (**b**) Alternatively, single-port platform can be placed at the future ileostomy site with single 5 mm additional trocar at the suprapubic position to help with retraction of pelvic organs during proctectomy

Fig. 18.4 Operating table is padded to prevent patient falls during steep Trendelenburg position

toward the patient's left. The transanal setup consists of passing all tubing and power cords over the patient's left leg secured with a towel clamp (Fig. 18.3). The cord for the 3D laparoscopic camera used in the transanal dissection is passed up through the abdominal drape pocket to the tower setup by the patient's left shoulder.

Port Placement

Trocars are placed in only three positions utilizing the future ileostomy site for one of the ports (Fig. 18.5). This allows adequate visualization while at the same time maximizing cosmesis in these often young patients. Some surgeons use an additional 5 mm trocar in the LLQ to facilitate flexure mobilization and rectal dissection. Alternatively, single-port surgery can be performed through the future ileostomy site (Fig. 18.6) with an additional 5 mm trocar placed in the suprapubic position to aid in lifting up the pelvic structures during the pelvic dissection.

Operative Steps

Operative steps	Degree of technical difficulty (scale 1–10)
Abdominal team	
1. Port placement and exploratory laparoscopy	1
2. Abdominal dissection	3–5
Perineal team	
3. Initial dissection open	2
4. Initial disssection laparoscopic	5
5. Laparoscopic transanal total mesorectal dissection	6
6. Connection of abdominal and perineal dissection fields	5
7. Specimen extraction	4
8. Anastomosis	6

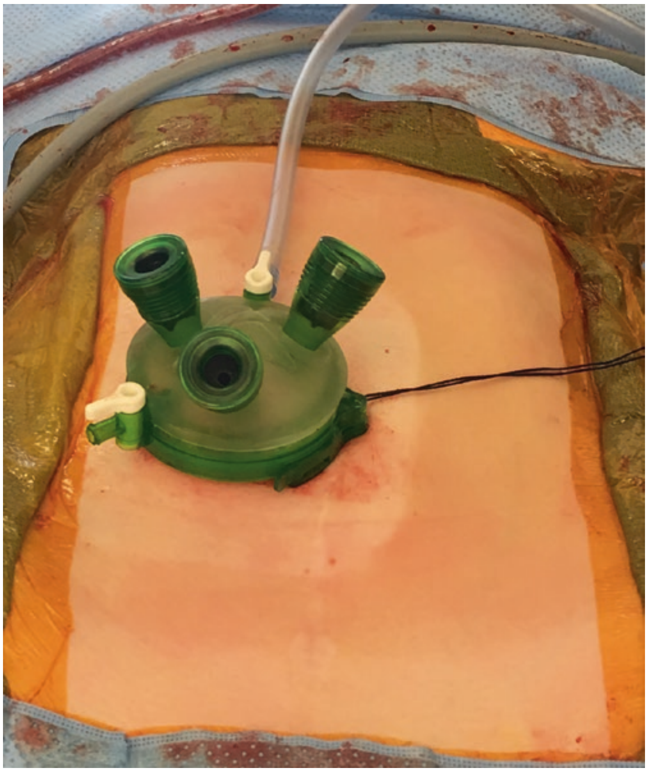

Fig. 18.6 GelPOINT® Mini used in the future ileostomy site to achieve single site abdominal access for colectomy and later for creation of the ileal pouch

Abdominal Team

After creation of pneumoperitoneum, the small bowel is evaluated for Crohn's disease and the abdomen explored for any evidence of bowel perforation (purulent drainage or abscess). Abdominal colectomy is performed in a standard fashion, with close to bowel mesenteric dissection, preservation of the ileocolic artery, and avoiding injury to the duodenum, stomach, small bowel loops, spleen, and pancreas. Assessment of small bowel mesenteric length for pouch reach at this point is critical. If the mesentery is foreshortened or thick due to fat infiltration, the upper rectum should be cleared of its mesentery with superior rectal artery preservation, stapled closed, and the ileal pouch aborted.

Should there be adequate length, the transanal team can begin the transanal dissection.

Abdominally, the terminal ileum is then transected flush with the cecum (Echelon Flex™ Powered Plus 60, Ethicon Inc., Somerville, NJ, USA). The terminal ileal mesentery is dissected off the duodenal sweep both laterally and medially. The abdominal team should then create the ileal pouch while the perineal team is performing the low rectal dissection. The RLQ trocar site is enlarged and GelPOINT® Mini (Applied Medical Inc., Rancho Santa Margarita, CA, USA) placed through this incision and ileal pouch mesentery exteriorized. Selective mesenteric vessel division to create a 15–20 cm ileal J-pouch or S-pouch that reaches beyond the symphysis pubis is then accomplished in the standard fashion (Video 18.1). The pouch enterotomy is closed with a 2-0 Prolene suture around a betadine-soaked gauze placed at the apex to further occlude the enterotomy and prevent pouch fluid seepage, and the pouch is reintroduced into the peritoneal cavity and GelPOINT® Mini capped to re-establish pneumoperitoneum.

The proctectomy is then started by division of the superior rectal artery close to the rectal wall. This allows for safe entry into the presacral space while avoiding injury to the hypogastric plexus. Rectal dissection along the TME plane is begun. The amount of top-down rectal dissection is dependent on the patient's anatomy and ease of dissection but generally continues circumferentially until it is hindered by exposure or the transanal dissection is met.

Perineal Team

Initial Dissection

A Lone Star® retractor (CooperSurgical, Inc., Trumbull, CT, USA) is placed for exposure. The GelPOINT® path (4.5 × 5.5 cm) transanal access platform is opened and the dilator used to gently stretch the anal canal. The access channel is inserted into the rectum with the beveled edge typically sitting just above the anorectal ring. Under direct visualization, a purse-string suture of 0 Prolene is placed 2 cm above the dentate line or just proximal to the access channel (Video 18.2). Care is taken to in the anterior plane to avoid incorporation of the vagina or prostatic urethra. Approximately 20 knots are created which are used as a handle during the taTME dissection.

The cap of the GelPOINT® path is prepared as follows: a 12 mm Airseal® trocar and two additional GelPOINT® path trocars are triangulated along the cap as far from the center of the cap as possible (Fig. 18.7). Once the purse-string is performed, the cap is placed and pneumorectum achieved at 12 mm Hg. At this point it is important to ask the abdominal operators to also turn insufflation to 12 mm Hg or lower to prevent competing pressures. We typically place the Airseal® trocar anteriorly with working ports inferiorly (Fig. 18.8).

Laparoscopic Transanal Total Mesorectal Excision

The rectum is marked circumferentially two thirds of the way between the purse-string suture and the access channel (Video 18.3) and transected full thickness at a 90° angle with the bowel wall circumferentially using the Endopath® Probe Plus II hook (Ethicon Inc., Somerville, NJ, USA). A sharp 90° turn is often necessary posteriorly to gain entry into the TME plane recognized by the loose alveolar tissue (Video 18.4). During this portion of the dis-

Fig. 18.7 GelPOINT® path transanal access platform setup with Airseal® trocar and 2 self-retaining GelPOINT® sleeves triangulated laterally

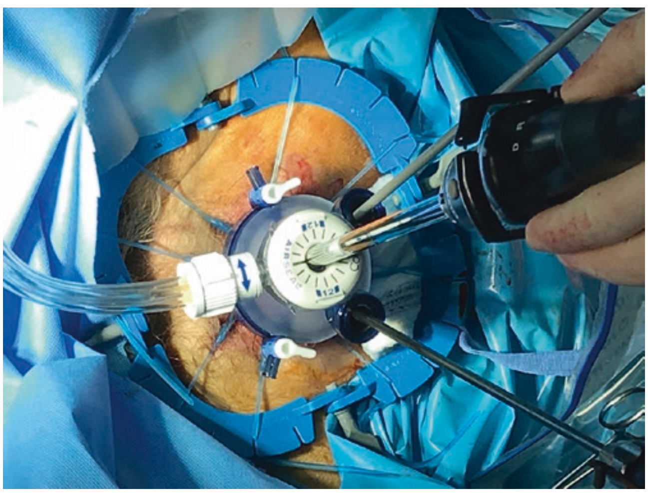

Fig. 18.8 12 mm Airseal® trocar placed anteriorly and used for 3D camera port and working ports placed laterally

section, care should be taken to avoid entry into the intramesorectal plane between the rectum and mesorectum unless intending to perform close rectal dissection (Video 18.5). The anterior dissection should be performed cautiously to avoid deep dissection and injury to the prostatic urethra in a male (Video 18.6). The dissection is easier in women because the vagina can be identified by digital manipulation (Video 18.7). The anterior and posterior planes are connected laterally close to the mesorectum to avoid injury to the nervi erigentes (Video 18.8). In the anterolateral dissection, the paired prostatic arterial branches contained in the neurovascular bundles of Walsh may be identified and preserved at the 2 and 10 o'clock position. Bleeding in this location may be a first sign of wrong plane dissection, and the transanal operator must be aware of this important landmark to avoid prostatic and neurovascular injury.

Connection of Abdominal and Perineal Dissection Fields

The anterior plane is typically an easier point to break into the peritoneal cavity; however sometimes if the posterior dissection is further ahead, this can be helpful also. After rendezvous, the abdominal and transanal teams work together to dismount the rectum. Circumferential mobilization of the rectum is accomplished with the assistance of the abdominal team who can retract up the rectum or help in the dissection at this time (Video 18.9).

Specimen Extraction

When the entire rectum is dismounted, the transanal cap is removed, the distal purse-string grasped, and the rectum and colon eviscerated through the anus. The pelvis is then irrigated, and the abdominal team orients and places the pouch at the pelvic brim. The ileal pouch can then be grasped by the transanal team and delivered down to the anus. The GelPOINT® path access channel is removed, pouch is grasped with ring forceps, and pouch reach is assessed for anastomosis (Video 18.10).

Anastomosis

After the ileal pouch is brought down to the anus, a decision is made regarding the need for and feasibility of a mucosectomy. In this approach, the amount of rectal cuff maintained can be tailored to patient factors and tension on the pouch. We have been concerned about using a stapled anastomosis in this setting due to almost universally observed tension on the anastomosis which may increase the risk of subsequent leak. Rather, the pouch is hand-sewn directly to either the remaining rectal cuff or after a partial or complete mucosectomy (Video 18.11) to the remaining cuff or dentate line using 2-0 Chromic or Vicryl suture (Video 18.12). If a double purse-string stapled anastomosis is chosen, the pouch purse-string is placed by the abdominal team through the future ileostomy site, and the transanal team performs the distal purse-string. A drain can be secured to the proximal anvil to help deliver the pouch down. After the EEA stapler is mated, the distal purse-string is secured, the stapler closed and fired (Video 18.13).

Abdominal Team

A few final steps are carried while the anastomosis is being completed transanally. First, a closed suction drain is placed through the suprapubic port and positioned dorsally into the deep pelvis. Next, bilateral laparoscopic TAP (transversus abdominis plane) blocks are performed as previously described [8]. Finally, the diverting ileostomy is created by following the afferent limb backward from the pouch inlet for about 40 cm and exteriorizing the bowel through the RLQ port after ensuring adequate orientation of the proximal and distal bowel.

Summary

The use of a taTME approach for patients undergoing ileal pouch-anal anastomosis is feasible. Further studies on the short-term and long-term benefits, especially functional outcomes, are eagerly awaited.

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