Updates in Surgery

Graziano Ceccarelli
Andrea Coratti *Editors*

Robotic Surgery of Colon and Rectum

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The aim of this series is to provide informative updates on hot topics in the areas of breast, endocrine, and abdominal surgery, surgical oncology, and coloproctology, and on new surgical techniques such as robotic surgery, laparoscopy, and minimally invasive surgery. Readers will find detailed guidance on patient selection, performance of surgical procedures, and avoidance of complications. In addition, a range of other important aspects are covered, from the role of new imaging tools to the use of combined treatments and postoperative care.

The topics addressed by volumes in the series Updates in Surgery have been selected for their broad significance in collaboration with the Italian Society of Surgery. Each volume will assist surgical residents and fellows and practicing surgeons in reaching appropriate treatment decisions and achieving optimal outcomes. The series will also be highly relevant for surgical researchers.

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Robotic Surgery of Colon and Rectum

Springer

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Foreword

The first Italian Society of Surgery's Biennial Report on the general aspects and applications of robotics in general surgery was published in 2014. Over this period of almost 10 years, important surgical steps forward have been made in all fields of thoracic, abdominal, and pelvic surgery, as a result of the improvement of the robots and the robotic surgical procedures, with a fine-tuning of the relative technical steps. This is especially true for robotic colorectal surgery and the reason why the publication of a new book on this subject appeared necessary. I sincerely thank Graziano Ceccarelli and Andrea Coratti, leading experts of robotic surgery, for editing this excellent monograph bringing us up to date on this topic.

In the 25 chapters of the volume, the editors and authors deal with all aspects of robotic colorectal surgery, from the evolution of the technology to the development of colorectal resections, with particular attention to the training, learning curves, costs, and cost-effectiveness of the procedures. Every step of robotic right colectomy, transverse and left flexure resections, left colectomy and sigmoidectomy, both for cancer and for diverticular disease, rectum resection, Miles' procedure, Hartmann's reversal, and total colectomy are described in detail. A special chapter is dedicated to robotic transanal surgery. Finally, a wide overview on the new robotic platforms is provided.

The authors are to be congratulated on the high quality of the work, and I am sure this book will become a reference and will captivate all its readers, whether novices or experts.

Rome, Italy
September 2023

Massimo Carlini
President
Italian Society of Surgery

Preface

Colorectal diseases represent one of the most important chapters of abdominal pathology, generating a very high volume of surgical procedures in colorectal and general surgery units around the world. In the last two decades, the minimally invasive laparoscopic approach has achieved widespread diffusion everywhere, demonstrating excellent functional and oncological results, arousing great interest among patients and in some cases becoming the standard of care.

Technology is rapidly advancing, offering revolutionary innovations in particular with the advent of robotic surgery, with wide application in different fields including colorectal surgery. Robotic technology was introduced in the early 2000s and gained progressive momentum in surgical community over following decades, providing surgeons with an advanced platform to approach advanced and complex minimally invasive operations.

Although several books on the subject have already been published, the great interest and diffusion of robotics in colorectal surgery have made it necessary, in our opinion, to produce a general update focused above all on the latest technical innovations and on the results of the most relevant and recent literature.

The book is organized into “anatomical” chapters that deal with the different colorectal segments with the related surgical procedures (from right colectomy to ultra-low anterior rectal resection and transanal surgery) and specific technical variants (complete mesocolic excision, bottom-to-up approach, indocyanine green use, total mesorectal excision, lateral pelvic lymph node dissection). Robotic technology offers important advantages over laparoscopy for both the surgeon and patient, including improved ergonomics, endo-wristed instruments, and better vision. These benefits may be particularly useful for more complex and challenging situations (such as the CME technique, low rectal cancer, one-stage treatment of colorectal and liver metastases), translating into potentially improved perioperative and oncological outcomes.

The new frontiers of benign and emergency colorectal diseases (inflammatory bowel disease, diverticulitis, rectal prolapse, and other non-oncological colorectal diseases) have also been considered, as well as the new robotic platforms recently introduced into the healthcare market. Some of these, such as the single-port platforms, may represent a revolutionary approach to this surgery. Finally, aspects of cost are also discussed.

For this book, a group of expert colorectal surgeons with extensive experience in minimally invasive and robotic surgery was involved. Many chapters are accompanied by short videos made by the authors.

Foligno, Italy Graziano Ceccarelli
Grosseto, Italy Andrea Coratti
September 2023

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Part I

General Features

1 The Evolution of Minimally Invasive Robotic Surgery in the Last 20 Years

Michele De Rosa, Walter Bugiantella, Federica Arteritano, Lorenzo Mariani, Fabio Ermili, and Graziano Ceccarelli

1.1 Introduction

About a century and a half after the introduction of the first endoscope prototypes [1], the first laparoscopic appendectomy in 1980 [2] marked the beginning of the era of modern minimally invasive surgery [3].

After the full integration of laparoscopy into the surgical armamentarium, supported by several compelling results, at the dawn of the new millennium the robotic approach represented the next step in this revolutionary process, specifically conceived to address most of the technical limitations of conventional laparoscopy, with enhanced visualization, superior dexterity and precision.

Although its application in surgery dates back to 35 years ago, the last two decades have witnessed how this system has slowly, but constantly, gained the approval of the surgical community, becoming a new standard of care. From the first robotic systems to the new emerging platforms, a brief but intense technological development has been observed and implementation of virtual reality, computer assistance and artificial intelligence will introduce a significantly different method of operating (Table 1.1).

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Table 1.1 A timeline of the modern era of minimally invasive surgery

1983	First laparoscopic appendectomy	Semm [2]
1983	Transanal endoscopic microsurgery	Buess et al. [4]
1985	First laparoscopic cholecystectomy	Mühe [5]
1985	PUMA 560 brain biopsy	Kwoh et al. [6]
1991	First laparoscopic colectomy	Jacobs et al. [7]; Fowler et al. [8]
1991	Probot	Imperial College of London
1992	Robodoc	Integrated Surgical Systems
1994	AESOP 1000	Computer Motion
1995	Intuitive Surgical foundation	
1997	Robotic cholecystectomy – Intuitive Mona	Himpens et al. [9]
1998	ZEUS	Computer Motion
1999	da Vinci first generation	Intuitive Surgical
2001	Lindbergh operation – First telesurgery	Marescaux et al. [10]
2002	First robotic colectomy	Weber et al. [11]
2003	Computer Motion & Intuitive Surgical merge	
2006	da Vinci S	Intuitive Surgical
2009	da Vinci Si	Intuitive Surgical
2014	da Vinci Xi	Intuitive Surgical
2015	Flex Robotic System	Medrobotics Corporation
2017	da Vinci X	Intuitive Surgical
2017	Senhance Robotic System	TransEnterix Surgical
2018	da Vinci SP	Intuitive Surgical

1.2 Background

The Czech word “robota” describes forced labor or activity and appeared almost a century ago in the science-fiction play *R.U.R. Rossumovi univerzální roboti* (R.U.R. Rossum’s Universal Robots) by the novelist Karel Čapek. Since then, the term has been used to define a machine-orientated ultraprecise, repetitive, and pre-programmed procedure.

The application of robotics in surgery is relatively recent and is directly derived from military projects aiming to develop a technology to be used in hostile environments where the expert surgeon is away from the patient. The concept of telesurgery or remote surgery entails wireless networking and robotic technology to connect surgeons and patients who are geographically distant, and has become one of the main driving forces behind the development of surgical robots. The “space race” with the launch of the Sputnik and the creation of the NASA (National Aeronautics and Space Administration) were additional factors concurring to the evolution of robotics and telepresence. By 1980 an intense period of discovery and research started with the DARPA (Defense Advanced Research Projects Agency) funding several institutions to expand telepresence surgical systems featuring remote articulating arms and stereoscopic imaging. Although not fully developed, all the tools and systems characterizing the robots we use today originated from those intuitions, which allowed robotic-assisted surgery to make its appearance in the operating room in the mid 1980s [12, 13].

1.3 Robotic Platforms

In 1985, a standard industrial robotic system, the PUMA 560, was used to orient a needle for a computed tomography-guided brain biopsy, providing automatic positioning and greater accuracy compared to a human hand [14]. Shortly afterwards, the same technology was used by Davies to perform a transurethral resection of the prostate (TURP) [15]. The London Imperial College later developed a computer-integrated system for prostatectomy named PROBOT and in 1992 the ROBODOC system (Integrated Surgical Systems, Sacramento, CA, USA) was designed to improve the precision of total hip arthroplasties [16].

In 1994 the AESOP 1000 (Automated Endoscopic System for Optimal Positioning 1000 – Computer Motion, Santa Barbara, CA, USA), a table-mounted robotic arm controlled by the surgeon's voice commands to manipulate a laparoscopic camera, was approved by the FDA and marketed [14]. In 1998 the Zeus robotic platform (Computer Motion, Santa Barbara, CA, USA) was introduced and the concept of telerobotics was finally realized with the surgeon seated at a console distant from the operating field. The system was equipped with a console, a 3D imaging system and three independent arms, one AESOP arm and two surgical arms with four degrees of freedom, manipulated by two handles. Cardiac surgery was the most relevant field of application, and in 2001 a transatlantic cholecystectomy, the so-called Lindbergh operation, was performed with the surgeon operating in New York while the patient was in Strasbourg, France.

1.4 The da Vinci Era

Years earlier, when the ZEUS system was already in use, Intuitive's first robotic surgical prototype was developed. This platform presents three main components: a master console where the operating surgeon sits, a vision cart holding a dual light source and dual cameras, and a patient-side moveable cart where the robotic arms are mounted. The master console consists of an image-processing computer generating a true three-dimensional image with depth of field; a stereoscopic viewer port where both eyes are accommodated allowing a binocular visualization with greater focus and comfort; foot pedals to control electric devices, instrument/camera arm clutches and master control handles controlled by the surgeon to drive the servant robotic arms. The instruments are cable-driven and provide seven degrees of freedom and two degrees of axial rotation, imitating the human wrist. Motion scaling and tremor elimination enhance accuracy and precision. The camera arm contains two 5-mm scopes and the image projected onto two screens is truly three-dimensional and is displayed above the hands of the surgeon giving the illusion that the tips of the instruments are an extension of the control grips and the impression of being at the surgical site [17].

Early experiences included a cholecystectomy performed with the second-generation prototype Mona by Himpens operating from Saint-Blasium General

Hospital in Dendermonde, Belgium [9], and a mitral valve replacement by Carpentier [18].

In 2000 the da Vinci robot obtained FDA approval for general laparoscopic procedures and became the first operative surgical robot in the United States.

In 2003, after three years of legal battle, Computer Motion merged with Intuitive Surgical discontinuing the development of the ZEUS system and combining innovations and improvements on the da Vinci platform.

The first da Vinci robot had three arms, of which one for the endoscope, but a four-arm robotic version was approved for clinical use two years later.

The first-generation da Vinci robot featured 3D vision and their patented EndoWrist technology with “7 degrees of freedom” and 90-degree articulation, mimicking the human wrist. Seven years later the da Vinci S was released with 3D high-definition camera vision, a simplified set-up and an interactive touch-screen display.

Several new features became available in 2009, when the da Vinci Si was released, including a dual console for training purposes, Firefly fluorescent imaging, TilePro software showing on screen up to three different images, the surgical field and two other video sources like ultrasound or EKG simultaneously, along with an upgraded 1080i camera.

In 2014, a more advanced and versatile version of the da Vinci, the fourth-generation Xi platform, was released. Access of the robotic arms to all abdominal quadrants without the need for re-docking and moving the operating table while the robotic arms are docked, offer the opportunity to perform multiquadrant single-docking procedures with more ease and consequently decreased operative time. Visualization is improved with a 1080p camera and simplified trocar placement decreases instrument and arm clashing. Furthermore augmented-reality software allows the assessment of intestinal perfusion or real-time 3D anatomical simulation of abdominal structures [19, 20].

The da Vinci X, a smaller version of the Xi, has been available since 2017 and without the table motion technology it is designed for single-quadrant applications.

The game-changing SP da Vinci robotic platform has been recently introduced and approved by the FDA for urological procedures, anticipating what is expected to happen soon for colorectal surgery, where preliminary studies have already demonstrated its feasibility and usefulness mainly in transanal and endoscopic procedures. This is a single-port system, consisting of a 2.5-cm cannula with three fully elbowed EndoWrist instruments and a fully articulating 3D HD endoscope, including a 360-degree boom with 360-degree instrument rotation.

1.5 Robotic Colorectal Surgery Landmarks

The year 2002 marks the publication of the first case series of robotic-assisted colon resections for benign disease [11], as well as the first cases of patients with colon cancer [21].

In 2003, Delaney described the first case of robot-assisted rectopexy and Giulianotti reported six cases of robot-assisted rectal anterior resection for rectal cancer [22, 23], while in 2006 a case series of robotic low anterior resections with total mesorectal excision (TME) for cancer was published, showing no significant differences in perioperative clinical outcomes compared to the conventional laparoscopic approach [24].

Soon thereafter, several groups began publishing data comparing robotic and laparoscopic colorectal surgery [25]. Robotic systems seem to provide major advantages mostly in rectal surgery, where the operation in a narrow and deep space such as the pelvis may benefit from 3D views and accurate manipulations with wristed microinstruments. Therefore, although most of the studies published so far, such as the ROLARR (Robotic vs. Laparoscopic Resection for Rectal Cancer) trial [26], did not demonstrate significant benefits of robotics compared to laparoscopy, a growing number of robotic rectal resections has been reported and is expected to increase further.

1.6 Emerging New Robotic Platforms

Although the da Vinci platform has dominated the world of robotics for more than a decade, the technological advancement in this field of research is constantly progressing, with each day bringing new devices.

The Senhance Surgical System (TransEnterix, Morrisville, NC) entered the market after being cleared by the FDA in October 2017. It consists of a surgeon console unit provided with a HD-3D monitor, requiring special 3D glasses, and two master controllers moving four robotic arms, endowed with non-wristed laparoscopic 5-mm instruments. The system also includes haptic force feedback and an advanced eye-tracking technology which allows the surgeon to control the camera with eye movements [27].

The CMR Versius Surgical Robot (Cambridge Medical Robotics, Cambridge, UK) is a lightweight, modular platform with a surgeon's console and three or four independent robotic units approved in Europe, Australia, India, Brazil and Honk Hong for urology, gynecology, and general surgery [28].

The Flex robotic system (Medrobotics Corp., Raynham, MA, USA) is the first platform provided with a flexible robotic arm, housing at the tip a miniaturized 3D-HD camera flanked by two working channels accommodating flexible dedicated instruments. The system is completed by two main units, the Flex Control Console to move the flexible endoscope through a joystick and the Flex Cart and Base which carries the base and is point of communication between the console and the robotic arm.

Despite being initially conceived for transoral applications, the system received FDA and European Union clearance for transanal applications. Indeed, the special design suitable for endoluminal navigation makes it useful for minimally invasive transanal excisions, but also for more complex operations, as proved by the feasibility study of transanal TME [29, 30].

The Revo-i surgical robot (Meere Company, Seoul, South Korea), the MiroSurge (Medtronic, Minneapolis, USA), the Hinotori Surgical Robot System (Medicaroid, Japan), the Single Port Orifice Robotic Technology – SPORT (Titan Medical Company, Toronto, Canada) are other robotic systems already available on the market or pending regulatory approval.

The very next phase of this evolution is the application of artificial intelligence to surgical robotic systems, with the aim of performing increasingly challenging procedures with safety and efficiency, while enhancing their ability to interact with complex environments and assist in the decision-making process. Completely automated surgical systems are at the moment, and will probably remain, only a theoretical perspective, but a new phase of robotic-guided, rather than robot-assisted surgery, has already started.

1.7 Conclusions

In recent decades, an exponential advancement in minimally invasive techniques has been observed, with the introduction of robotics representing one of the most remarkable events.

Despite the initial widespread criticism and rejection, robotic surgery's power to overcome the limitations of laparoscopy and offer a higher quality of surgery has made the approach a fully accepted surgical option. Its application to colorectal surgery showed safety and feasibility, as well as some operative advantages for surgeons, but clear benefits for patients are still far from being proven, partly because the speed of technology development often exceeds the ability of high-evidence studies to validate the results.

Longer operative times and expensive equipment leave some questions unanswered, but what yesterday was difficult to foresee has become a reality today, and it is not difficult to imagine that, as already happened with laparoscopy, the surgeons of tomorrow might not be able to perform certain procedures other than robotically.

The da Vinci system by Intuitive Surgical, which carries in its name the genius of Leonardo, represents the first and prominent actor of this revolutionary history but, with the progressive expiration of many patents, several potential competitors are starting to appear, pushing forward the boundaries of innovation.

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Survey: Italian Robotic Colorectal Surgery

2

Maria Michela Di Nuzzo, Roberto Peltrini, Michele D'Ambra, Graziano Ceccarelli, Umberto Bracale, and Francesco Corcione

2.1 Introduction

Robotic platforms are currently the latest step in the development of technological innovations applied to surgery. They allow natural wristed movements within a narrow space and provide a surgeon-controlled three-dimensional field, reducing tremor and integrating fluorescence optical outputs [1]. The use of robotic platforms was introduced in the early 2000s, when Weber [2] performed the first robotic colectomy. Ten years later, the use of robotic technologies had become frequent in colorectal surgery, especially among Korean and Italian surgeons.

Despite the initial learning curve, the complete lack of tactile sensation and the prolonged operative time due to the robot docking time, the majority of colorectal surgeons stated they prefer this robotic approach owing to its maneuverability in narrow confined spaces and superior advantages in nerve visibility and preservation [3]. To date, robotic technologies have been applied for both malignant and benign colorectal diseases, such as inflammatory bowel disease, colonic diverticulum or pelvic organ prolapse. The international ROLARR trial (ISRCTN80500123) [4, 5] and the South Korean COLRAR trial (NCT01423214) reported the superiority of robotic over laparoscopic surgery for rectal cancer especially in terms of conversion

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to open surgery, quality of pathological specimens and some short-term postoperative outcomes. However, the spread of the robotic approach in colorectal surgery is still inadequate in Italy. For this reason, we decided to perform a survey in order to have a picture of the current national situation.

2.2 Methods

The study steering committee used remote brainstorming to develop the questionnaire, which was shared on Google Form (Google LLC, Mountain View, California US). It includes 41 questions, mostly closed-ended. All questions were set as mandatory fields and concern the type of institution (public hospital, university hospital, private center, other), general information about the institution and specific questions for each type of robotic colorectal procedure. The estimated mean time to complete the survey was about 15 min.

The link (https://forms.gle/DbfVDYCEztXGPrCv9) was circulated as an email invitation to the chiefs of all Italian colorectal surgery departments equipped with a robotic platform. Baseline information on the respondents and the names and locations of the surgical units were stored through the questionnaire. Three members of the steering committee (U.B., R.P., and M.M.D.N.) downloaded the survey results and shared them with the other members.

Categorical variables were reported using counts and percentages for the preliminary results.

2.3 Preliminary Results

A total of 27 Italian centers took part in the survey. Characteristics of the departments are: 66.7% public hospitals, 25.9% university hospitals and 7.4% other types of medical facility (Fig. 2.1). A total of 88.9% of the surgeons work in institutions with more than 200 beds and in general surgery units with more than 20 beds.

In 23.1% of the included centers, the robotic platform has been present for at least 15 years, so all surgeons are experienced in robotic surgery. About 40.7% of centers have more than three surgeons using the robot for colorectal disease. About

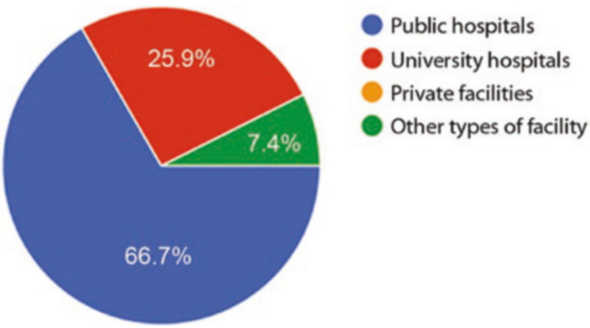

Fig. 2.1 Types of facility included in the survey

70.4% of the survey participants had performed laparoscopic colorectal resections before approaching robotics.

Moreover, the analysis showed that survey respondents proposed robotic surgery as follows:

– to all patients with colorectal diseases in 22.2% of cases;
– only to patients selected by well-defined criteria in 44.4% of cases;
– only to patients selected at the discretion of first surgeon in 33.3% of cases.

Specifically, the selection criteria were:

– 48.1% patient's disease + BMI + surgeon expertise
– 29.6% patient's disease + surgeon expertise
– 22.2% patient's disease.

The surgeons were asked to rate the usefulness of the robotic approach in colorectal surgery in relation to the disease to be treated. The results, reported in Fig. 2.2, show that most of the "remarkably useful" responses were related to diseases of the rectum and right colon.

Robotic surgeons were asked what was the least complex procedure to be performed in the early stages of the learning curve. More than 50% reported right hemicolectomy as the easiest intervention to be performed during the learning process. By contrast, 74.5% of surgeons stated that rectal resection surgery with total mesocolic excision is the most complex procedure and therefore to be avoided in the early stages of the learning curve. A total of 81.5% of respondents reported agreement to shorten the learning curve by means of dedicated robotics courses, tutoring activities and attending dedicated high-volume robotic colorectal surgical units.

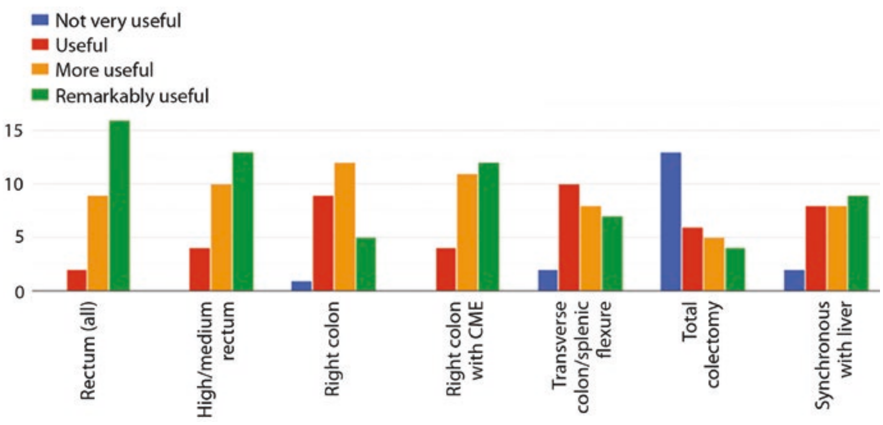

Fig. 2.2 Importance of robotic approach in relation to the colorectal disease

Fewer than 33.3% of surgeons have direct experience of robotic platforms other than the da Vinci system (e.g., CRM Versius or Hinotori). Currently, 96.2% of respondents believe that 3D-robotic vision is better than laparoscopic vision, and 77.4% of them also consider 4K laparoscopic vision inferior to robotic vision.

Analysis of the rate of robotic colorectal procedures performed over one year yielded the following results:

- in 8 centers the robotic approach is less than 20%
- in 13 centers the robotic approach is between 20% and 50%
- in 3 centers the robotic approach is between 50% and 80%
- in 3 centers the robotic approach is used in more than 80% of cases.

About 50% of the responding centers propose robotic surgery as the first approach for both right and left hemicolectomy and for anterior rectal resection in 10% to 50% of cases. For over 50% of respondents the main advantages of the robotic approach are evident during right hemicolectomy. In over 80% of centers, the anastomosis is performed intracorporeally during right robotic hemicolectomy.

The rate of conversion to open or laparoscopic surgery is:

- less than 5% in 19 centers (70.4%)
- between 5% and 20% in 7 centers (25.9%)
- between 20% to 50% in 1 center (3.7%).

The main causes for surgical conversion include different conditions, such as visceral adhesions, obesity, incorrect patient selection, or inadequate surgeon experience. The conversion rate is shown in Fig. 2.3.

In 20 centers, intraoperative use of indocyanine green (ICG) fluorescence imaging was reported both for right hemicolectomy and left colon or rectum surgery, while in 6 centers its use was limited to left colectomy and rectal anterior resection (74.1% vs. 22.2%) (Fig. 2.4).

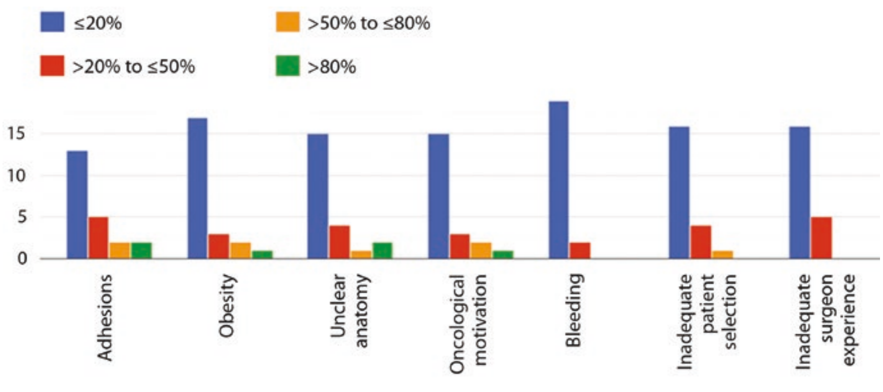

Fig. 2.3 Main causes of conversion of colorectal robotic surgery to open or laparoscopic surgery

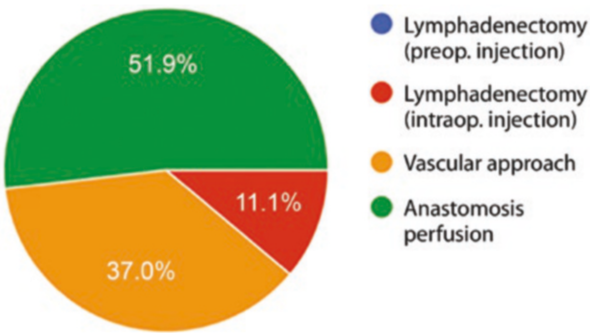

Fig. 2.4 Indocyanine green fluorescence uses in colorectal robotic surgery

Lastly, in about 60% of the centers included in the survey the use of robotic surgery decreased during the Covid-19 pandemic, as happened for most elective surgeries.

2.4 Discussion

Analysis of the preliminary data shows that the majority of respondents work in high-volume laparoscopic colorectal centers using a robotic approach for more than 15 years.

They reported that right hemicolectomy could be the easiest procedure to be done during the early learning process. In the same way, for over 80% of the surgeons right colectomy could be the most suitable for a robotic approach because of the advantages of the robotic platform during intracorporeal anastomosis. This finding is consistent with the results of a recent Italian systematic review and meta-analysis, which reported a higher rate of intracorporeal anastomosis in robotic right colectomy than in the laparoscopic group [6, 7].

Despite the common opinion that the robotic platform is very useful for rectal surgery [3], over 50% of respondents reported that the benefits of robotics are also evident in right hemicolectomy. This finding is consistent with the results that only 8/27 centers (29.6%) propose robotic rectal resection as a first approach.

The intraoperative use of ICG fluorescence imaging optimizes intraoperative vision of anatomical structures by improving blood and lymphatic flow [8]. In accordance with the spread of this technology, all centers included in this survey use ICG fluorescence and apply it during robotic colorectal surgery to detect lymph nodes and to test perfusion of the anastomosis.

As is well known, the Covid-19 pandemic had a negative impact on colorectal surgery, increasing the time to diagnosis and treatment [9]. Also the use of robotic platforms has been negatively affected. This is in line with other experiences in Italy, as reported in a recent national survey [10], which found that the use of the robotic approach decreased during the pandemic as well as all minimally invasive approaches.

Another important finding of our survey is the unanimous agreement that the robotic platform needs to be implemented through a standardized training program. So, similarly to the Fundamentals of Robotic Surgery (FRS) in the USA and the European Academy of Robotic Colorectal Surgery (EARCS) in Europe, we hope that also in Italy an academy of robotic surgery will be set up in order to standardize education and training programs.

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3 Training in Robotic Colorectal Surgery

Sofia Esposito, Alice Francescato, and Micaela Piccoli

3.1 Introduction

Robotic surgery represents the greatest revolution in general surgery of the last twenty years, and when a new technology is introduced in surgical practice standardized training becomes of utmost importance. Some of the challenges to young surgeons' training in this field are represented by elevated costs, duty hours, and the presence of senior surgeons still going through their learning curve, which may limit teaching to residents and junior surgeons [1]. However, in the light of the current dissemination of robotic surgery, there will likely be fundamental robotic skills requirements to complete general surgery residency, and the need for a structured robotic training curriculum has been supported by several associations and program directors [2, 3].

Training a robotic colorectal surgeon has two different aspects to be considered: learning how to use the platform, and learning procedural skills strictly related to colorectal surgery. Considering the trainee's previous practice is of paramount importance to differentiate educational pathways, but institutional experience with the platform and case volume should also be weighed, given that the absence of an expert surgeon and low program operative volumes could negatively impact on a robotics curriculum. Moreover, when assessing the overall costs of training, the acquisition of a virtual simulator and robotic dual console should be included. All these angles need to be considered prior to creating a structured training program, which should present realistic and achievable goals, in order to avoid frustration and loss of credibility towards hospital management [4]. Additionally, the ideal robotic colorectal surgery training program should provide an objective assessment of acquired skills with well-established requirements to proceed from one step to the

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next, and non-operative robotics skills should also be implemented and evaluated [5]. We are training not only console surgeons, but also bedside assistants since correct trocar positioning and reliable feedback from the operating table are essential to the effective and safe completion of a robotic colorectal procedure. Finally, training should not be limited to robotic novice surgeons, but also extended to trainers, as mentors need to adapt to new teaching technologies such as telementoring and the use of the robotic dual console [6]. Whether or not specific robotic colorectal training should be started during residency or reserved for post-residency fellowships is still debated. In our opinion, surgical residents should be familiar with the fundamentals of robotic surgery and should be able to act as table assistants by the end of residency, and during the last year of residency they should be able to perform low-complexity robotic procedures.

3.2 Learning Curves in Robotic Colorectal Surgery

Establishing learning curves for robotic colorectal procedures has implications on training planning and consequently on credentialing [7]. The most reported variables used to assess learning curves are time-related, but the learning process in robotic surgery involves multiple aspects, so a multidimensional analysis could be more reliable and should include evaluation of the trainee's surgical background, surgery type, postoperative morbidity, oncological outcomes, and a risk score stratification of cases, since patient selection can heavily impact operative times [8].

There are three phases to the common robotics learning curve: an initial learning stage with a rapid decrease in operative time, a second phase with stabilization of operative time (plateau or competence phase) and a third phase of mastery, with a decrease in operative time [4]. However, some studies reported an increase in console time during the mastery phase, which was attributed to the fact that the surgeons performed more complex cases as they progressed through the learning curve [9, 10]. The number of cases required to achieve competence in colorectal surgery is extremely variable in the literature. Recently, Nasseri et al. evaluated the learning curve of an expert laparoscopic colorectal surgeon by reviewing 111 consecutive colorectal procedures and found that the surgeon gained competence after 13 surgeries and mastery after 70 [7]. Park et al., in their multidimensional analysis of the learning curve for robotic low anterior rectal resection found that competence was achieved after 44 cases and mastery after 78 [11]. De Angelis et al. described a 16-case learning curve for robotic right colectomy for a surgical fellow with little experience in laparoscopic colorectal surgery. The learning curve for laparoscopic right colectomy was reported to be 25 cases [12]. Interestingly, a recently published systematic review questions the common perception of a shorter learning curve for robotic colorectal surgery compared to laparoscopy, claiming that the advantages of the robotic platform may result in a better baseline performance in early practice rather than a shorter learning curve. The authors found that conversion rates are significantly reduced in the early robotic learning curve when they are more common in laparoscopy. Moreover, all the studies taken under consideration in the review showed at some point a shorter robotic operating time, with a greater time advantage in complex tasks such as knot tying in simulation environments or total mesorectal excision in clinical practice [13]. When evaluating a trainee's acquisition of a specific surgical technique, experience gained in other types of surgery is often neglected, as is operating room staff experience, despite the fact that these aspects can also impact learning. Guend et al. analyzed both individual and institutional learning curves and reported that the first surgeon who started practice achieved competence after 74 cases, but once the program was established other surgeons required only 25 to 30 cases to reach proficiency [14].

Another controversial topic is whether previous laparoscopic experience impacts the learning curve in a significant way. While many authors agree that limited laparoscopic experience should not discourage from approaching robotic colorectal surgery, especially in high volume centers [15, 16], others support the fact that experienced laparoscopic colorectal surgeons may have advantages in terms of learning curve. Wong et al., in their analysis of the learning curve of an experienced colorectal surgeon (1500 colorectal cases) during his transitioning to robotics, found that performance of complex cases early in the learning curve did not impact negatively postoperative outcomes. The authors suggested the adoption of audits on patient outcomes to assess the progression of the learning curve. The first audit was held with the hospital direction after the first 10 cases, and full accreditation was provided only after full review of the results [17].

As can be easily inferred from this quick overview, the published data are often difficult to replicate and to compare. Patient selection remains essential, and the training pathway should start with less complex cases to optimize outcomes. Operative volume, the application of a structured training curriculum, and the presence of an experienced mentor surgeon inside the institution are all factors with the power of shortening the learning curve, along with the choice of a fixed dedicated operating room team to improve workflow and communication.

3.3 Current Colorectal Training Programs, Educational Tools, and Assessment of Outcomes

A recent systematic review reported broad consensus on the fact that a structured robotic colorectal training program should have a modular approach including theoretical knowledge, case observation, simulation, and proctored training. All training programs reported in the study were designed for the da Vinci platform (Intuitive Surgical, Sunnyvale, CA) [18]. Several generic curricula have been developed by single institutions and residency programs. The Fundamentals of Robotic Surgery (FRS) is a proficiency-based curriculum created by surgery experts from multiple specialties that uses basic technical skills to train and assess robotic surgeons [19]. If we consider more specifically robotic colorectal training, four structured training programs can be identified in the literature: the European Academy of Robotic and Colorectal Surgery (EARCS) program, the National Colon and Rectal Surgery Robotic training program (CRSRTP) sponsored by the association of Program

Directors for Colon and Rectal Surgery, the da Vinci Robotic System Intuitive Surgical program, and the Colorectal Robotic Surgery Training curriculum established by the European Society of Coloproctology (ESCP) [18, 20]. Moreover, a recent survey administered to American colorectal surgery program directors revealed that most programs have a robotic curriculum [21].

All programs include a theoretical phase along with a simulation phase. The CRSRTP mandates scores of >90% for key simulator exercises, and other programs have simulator time requirements ranging from 8 to 50 hours [20]. Recently, Intuitive is offering the possibility of practicing at the virtual simulator not only basic technical skills, but also steps of surgical procedures which include, amongst others, right colectomy [22].

Relevant features of colorectal training pathways are proctored cases and the component-based approach, which consists of deconstructing the procedure in defined and measurable components that could be evaluated more objectively. During proctored cases, the presence of the robotic dual console allows the proctor to take control of the robotic instruments when needed and to point resection planes without interrupting surgical workflow. The ESCP proposed a component-based approach for robotic low anterior resection, identifying for each step of the procedure errors and critical errors to help objective assessment. In this way the evaluation is not limited to a volume-outcome correlation, since performing a certain procedure an established number of times, does not always guarantee competency [23].

Objective assessment of outcomes outside the virtual simulation setting remains challenging. During the sixth Clinical Robotic Surgery Association (CRSA) congress an expert round table proposed a competence assessment scale for each specific colorectal procedure [2]; the EARCS too created a Global Assessment Score (GAS) form to objectify competence assessment [18, 24]. Lately, there is emerging interest in the use of automated performance metrics including kinematic and event data, such as instrument vibration, to evaluate robotics competency. The recently developed My Intuitive App (Intuitive Surgical, Sunnyvale, CA) gives the surgeon the possibility to see minute-by-minute use of instruments per arm, console time, operative and non-operative time, and compare the data with national trends; this could favorably impact competency evaluation [25]. Moreover, in the near future the development of the Internet of Surgical Things and the use of Artificial Intelligence could further improve objective assessment of robotic skills.

In 2020 a robotic surgery training curriculum was established in our institution. Junior surgeons experienced as table assistants and autonomous in the performance of robotic low-complexity procedures, but with limited experience in laparoscopic colorectal surgery started their robotic colorectal training from robotic right colectomy, leaving anterior resection as the final step. Senior surgeons, expert in laparoscopic colorectal surgery, started their transition to robotics from right colectomy as well, but rapidly proceeded to anterior resection. Since the introduction of the robotic colorectal program there has been a rapid shift in indications, and currently the majority of low anterior resections for rectal cancer in our institution are performed robotically. This – along with the growing evidence of the advantages of the robotic platform in rectal resection [26] – makes robotic training essential for colorectal surgeons. The future generation of colorectal surgeons might have learned how to perform rectal anterior resection directly with the robot, without going through laparoscopy, as already happened with prostatectomy.

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4 Costs in Robotic Colorectal Surgery

Alessandra Marano and Felice Borghi

4.1 Introduction

Robotic surgery (RS) has gained popularity since the introduction of da Vinci surgical system (Intuitive Surgical Inc., Sunnyvale, USA) in the year 2000, representing a revolution for surgical practice and minimally invasive surgery. Thanks to their well-known technological improvements [1], robotic systems are being used in a wide variety of procedures including colorectal (CR) surgery. Several studies have been published to describe the safety and efficacy of RS in CR surgery and promising benefits of robotics over other alternative conventional approaches (i.e., laparoscopic or open) have been reported [2–4]. Hence, the technical advantages of robotic systems should theoretically allow expansion of the minimally invasive approach in the field of CR surgery. However, some concerns have been raised about the use of this new technology, in particular about its real clinical benefits [2, 5] in comparison with its supposed higher costs.

The aim of this chapter is to analyze the current state of costs in robotic CR surgery using da Vinci surgical system.

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4.2 Preliminary Considerations

Because Intuitive Surgical supplies most robotic technology, current costs in robotic CR surgery are evaluated considering da Vinci system on the market. However, before going into the subject, a few general aspects should be considered.

- In 2000, the US Food and Drug Administration cleared the da Vinci for general laparoscopic surgery. Currently, the da Vinci surgical system is, with 7135 installed systems worldwide, the most used platform [6]. Intuitive Surgical markets its products through a direct sales force in the United States, Europe (excluding Spain, Portugal, Italy, Greece, and most Eastern European countries), China, Japan, South Korea, India, and Taiwan [7].
  The different mode of distribution of the robotic system among countries (direct vs. indirect) represents itself the first limitation when analyzing RS costs.
- When a hospital is considering the acquisition of robotic system, an accurate assessment of the total cost of ownership (CoO) should be an integral part of the technology acquisition equation. The CoO assessment should include all relevant fixed and variable cost components:
  - Fixed costs include implementation and maintenance costs. Currently, there are five available versions of the da Vinci, with an average sales price of \$1.47 million and a yearly average service contract cost of \$154,000 [7]. Moreover, there are different purchasing methods, such as installment and leasing.
  - Variable costs include da Vinci and non-da Vinci supplies; operating room time based on surgical case time, divided into cut-to-close time and patient-in-room time; operating room personnel costs; hospital stay costs, which include length of stay (LoS) in both the intensive care unit and the general ward, costs of reoperation, and postoperative procedures. The impact of surgeon learning curves is another variable cost that should be called out, given that learning curves can lead to a cost per case being overstated together with case mix by service line and annual robotic case volume. Moreover, instrument use and surgeon instrument preferences are another contributor to cost and associated variability.

  Hospitals use a variety of approaches to robotic cost accounting, making it difficult to determine accurate CoO assessments across hospitals [8].
- Health technology assessment is used when a new technology is being introduced into clinical practice. Economic evaluation should not only consider fixed and variable costs, but also the benefits from the different aspects related to patient treatment, such as LoS, complications, readmission or oncological outcomes. To date, cost-effectiveness analysis (CEA) and cost-utility analysis (CUA) are the most commonly used economic evaluation frameworks for international health technology institutions [9].
  Currently, few studies have performed a complete economic evaluation of robotic CR surgery [10–16]. There is a role for methodologically sound observational studies that should focus on the development, exploration and assessment [17] of

robotic CR procedures to examine clinically relevant patient-important outcomes rather than surrogate measures [5].

- Reimbursement to the hospital for utilization of the robot and hospitalization expenses are also in straight correlation with the health care system. Since 1978 Italy has a universalistic national health system (NHS). The 1992 reform of the NHS introduced a system of remuneration of prospective hospitals, based on the classification of the Diagnosis-Related Groups (DRG). In 2011 the new It-DRG that includes the Italian Classification of Procedures and Interventions (CIPI) was introduced with the aim of reducing the costs for the NHS [18]. However, to date there are no differences for laparoscopic or RS, although in the proposed new CIPI at least 30 procedures will be classified as robotic-assisted [19]. Currently, only Lombardy, Tuscany and Veneto have approved an additional compensation dedicated to RS with substantial differences.

  Differences between countries, private or public sectors render any approach to evaluate cost data complex. The use of the laparoscopic or robotic approach generates an increase in variable costs mostly without changing revenues.

On this basis, the current evidence of the costs of the application of robotics in CR surgery is reported as follows.

4.3 Costs in Robotic Colon Surgery

In agreement with another previous publication [20], a recent study evaluating the cost-effectiveness of open, laparoscopic, and robotic colectomy based on modeled analysis of the published literature found that laparoscopic and robotic colectomy result in more quality-adjusted life years (QALY) and lower cost than the open approach [13]. The authors underline that, with more than 50% of colectomies still being performed using an open approach in the U.S.A., this finding represents an important opportunity for improving the value of colectomy delivered across the country. This consideration might be translated also to Italy's system where, according to the National Outcomes Programme (Programma Nazionale Esiti, PNE), 46.6% of all colectomies were performed laparoscopically in the period 2015–2020, with a median LoS of 7 days [21].

Robotic colectomy is not currently cost-effective by any of the conventional standards used in cost-effectiveness studies, but it can surpass laparoscopy by achieving better quality of life (QoL) after surgery and lowering disposables costs, LoS, time off work, and hernia rates. However, it remains unclear whether RS can achieve improvements of this magnitude [13].

Focusing on right colectomy, in all [16, 22, 23] but one [24] of the most recent cost analyses comparing robotic and laparoscopic right colectomy, operating time (OT), total operating room and hospital costs were higher for the robotic cases compared with laparoscopy, although the difference was not significant in any of the series. These outcomes are in agreement with those reported by a previous meta-analysis [25].

Currently, robotic right colectomy does not provide any significant clinical advantage likely to justify the additional costs, and should probably be used with appropriate clinical justification in high-volume centers with a standardized surgical protocol [26].

4.4 Cost in Robotic Rectal Surgery

Robotic rectal surgery is more expensive than laparoscopic surgery especially in terms of its high capital, amortization, recurrent costs and longer OT [11, 12, 27–30].

Interesting findings have been reported by two recently published papers. A monocentric cost-effectiveness analysis of robotic versus laparoscopic rectal resection showed for the first time an apparent improvement in the QoL of the patients in favor of the robotic group [14]. Simianu et al. have recently examined the cost-effectiveness of open, laparoscopic, and robotic approaches to proctectomy from a societal and healthcare system perspective [15]. One important finding of this study is that an open approach is less cost-effective than both minimally invasive techniques. Since approximately 50% of surgery for rectal cancer continues to be open in Italy [31], the proportion of operations carried out with a minimally invasive approach should be increased.

Robotic proctectomy can be cost-effective if modest differences in costs of the operation (such as OT and use of disposables), LoS and time off work can be achieved [15]. In the societal model, reducing the cost of disposables for RS by as little as $400 or achieving a shorter mean duration of robotic cases (by as little as 20 min) could make robotic proctectomy cost-effective.

Recently, a Chinese trial has reported for the first time advantages of RS in improving the oncological quality of resection for middle and low rectal cancer compared with laparoscopy [4]. The robotic group had significantly higher total hospitalization costs but significantly lower postoperative costs which might be associated with lower postoperative morbidity.

Future studies should be conducted for accurate assessment of the already promising functional outcomes provided by RS. However, in rectal cancer surgery, it is particularly important to put surgery-related costs into perspective considering that the most significant cost drivers are oncological and outpatient workup/follow-up treatments irrespective of surgical approach [32].

4.5 How Can Robotic Colorectal Surgery Become Cost-Effective?

Several efforts can be made to decrease variable costs:

- use of the robotic platform in a multidisciplinary high-volume center can reduce the extra costs per procedure [33] and may also help to obtain discounts on the purchase costs of robotic instruments [34];

– surgeon's experience and programmatic standardization (technique, case time, team performance metrics) can contribute to reduce the number of disposables used in each operation and the OT [8, 11, 12, 15]. Moreover, since the beginning of 2021 there has been an evolution of robotic instruments that allowed the number of uses to be extended to eighteen times while keeping the price of each instrument unchanged [34];
– especially for robotic rectal cancer surgery, a decreased conversion rate to open surgery and related morbidity and LoS (linked to an enhanced recovery program) can therefore reduce hospital charges [3, 33, 35].

Since RS has considerable potential to improve and advance surgical care, institutions with the ability to prioritize research over pure cost containment may promptly adopt robotics to improve patient outcomes [36].

Finally, the robotic surgical procedure market is expanding. Outside of the current monopoly system, there are several robotic platforms [37] that are entering the marketplace. Exactly what effect this competition will have on the cost-effectiveness of robotics remains to be determined.

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Part II

Colon Cancer

5 Robotic Right Hemicolectomy, Medial-to-Lateral Approach

Francesco Guerra, Giuseppe Giuliani, Lorenzo De Franco, Michele Di Marino, and Andrea Coratti

5.1 Background

There is growing evidence in favor of robotic assistance in performing minimally invasive right colectomy [1]. Despite the lack of robust, high-level data on the topic, potential benefits in terms of conversion rate, proportion of reconstruction with intracorporeal anastomosis, and postoperative length of hospital stay have been reported in association with robotic surgery as compared to the more widespread technique of the "conventional" laparoscopic procedure [1–3]. Herein we report the details of our technique of a fully robotic radical right colectomy with intracorporeal anastomosis using a fourth-generation four-arm surgical robot (da Vinci Xi, Intuitive Surgical, Sunnyvale, CA).

5.2 Equipment, Patient Positioning and Operating Room Setup

Recommended main equipment:

- 30° endoscope
- fenestrated bipolar forceps

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– monopolar scissors
– large needle-driver
– VesselSealer (optional)
– robot-integrated (SureForm) or laparoscopic linear stapler.

The patient is placed in the supine position. A 10–15° Trendelenburg position is given, with a left lateral tilt (10–15°). The bedside surgeon(s) is on the left of the patient. Pneumoperitoneum is obtained using the Veress needle in the left hypochondrium. A standard laparoscopic 10–12-mm port (L1), and four robotic 8-mm ports (R1–R4) are placed as illustrated in Fig. 5.1. Robotic accesses are generally placed along an oblique line, which may vary according to the conformation of the abdomen, as well as to intra-abdominal anatomy. A general laparoscopic inspection of the peritoneal cavity is undertaken to confirm the preoperative diagnosis (i.e., identification of tumor location) and rule out signs of extra-organ disease. The terminal ileum and the ascending colon are exposed, while the small bowel is moved away from the mesenteric root and placed towards the left quadrants. The greater omentum and transverse colon are lifted cranially and to the left, so that the junction of the descending and horizontal segments of the duodenum becomes visible in most patients through the thin anterior visceral peritoneum of the pancreaticoduodenal bloc.

The robot is docked from the right side of the patient. Typically, R4 is used for monopolar scissors, which we favor for all dissections. The bipolar fenestrated forceps and the tip-up grasper are employed on R2 and R1, respectively. The 30° endoscope is installed in R3 throughout the surgery. The bedside surgeon utilizes the laparoscopic access to introduce gauzes and threads, and deliver irrigation and suction, as needed.

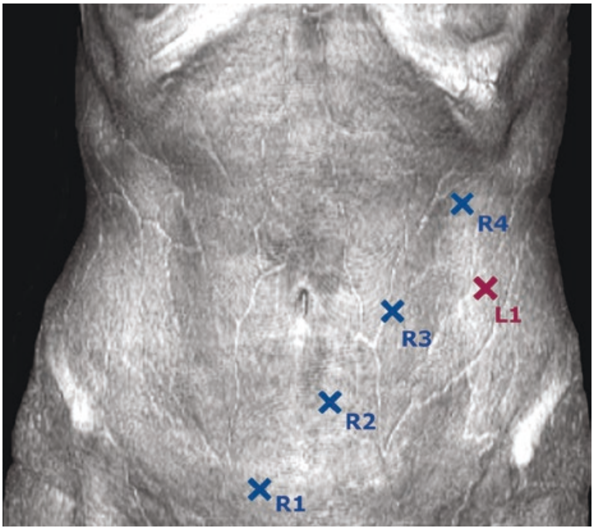

Fig. 5.1 Port setting. When a robot-integrated endostapler is used, a dedicated 15-mm robotic port is installed in R4

5.3 Technique/Procedure

By using the tip-up grasper the ileocecal junction is put under traction to place the ileocecal vascular pedicle on tension. An inframesocolic window is next opened by dividing the medial peritoneal fold. The genitourinary Gerota's fascia should be carefully preserved inferiorly, and the plane of dissection along the Toldt's fascia developed from medially to laterally. Identifying these embryological planes allows for a neat and precise mobilization of the right colon and mesocolon off the retroperitoneal structures. This dissection continues until the duodenum is revealed and care should be taken to maintain the dissection plane anteriorly. The ileocecal pedicle is thus prepared and the superior mesenteric venous axis is exposed. The ileocecal artery is divided proximally between hem-o-lok clips. The ileocecal vein as well as the superior mesenteric vein are thus dissected free to allow for a complete mesocolic excision. The ileocecal vein is then divided at its origin between hem-o-lok clips (Video 5.1).

The medial-to-lateral dissection is advanced to the lateral attachments of the paracolic gutter, while the mesocolic window is lifted superiorly by gentle and progressive traction by the tip-up grasper. Proceeding caudally, the ileal mesentery is divided and the terminal ileum transected using the 60-mm endostapler with white cartridge. During the dissection of the ileal mesentery, a small ileal branch of the ileocolic vascular pedicle is generally encountered and divided between hem-o-lok clips.

The dissection continues cranially through the fusion fascia of Fredet, exposing and preserving the inferior duodenal flexure and the head of the pancreas. This dissection is typically blunt, or accomplished sharply with minimal energy, to avoid thermal injury. When present, the right colic pedicle is thus prepared, doubly clipped, and divided. While the right colic artery is often found crossing anteriorly, the right colic vein is generally encountered as the only structure branching at a right angle from the lateral aspect of the superior mesenteric vein axis or emerging obliquely from the gastrocolic trunk of Henle (Video 5.1). At this point the medial-to-lateral dissection can be continued to take down the hepatic flexure. However, in most cases this is most easily accomplished from cranially. The transverse mesocolon is now tractioned caudally and the gastrocolic ligament is divided in its right portion to enter the lesser sac. Typically, the bedside surgeon aids with grasping the transverse colon while the tip-up grasper provides countertraction by retracting the greater epiploon cephalad. Once the right gastroepiploic arcade is identified to be preserved, R2 grasps the proximal transverse colon caudally and R4 dissects the transverse mesocolon from the mesogastrium from medial to lateral. Proceeding laterally, the hepatocolic ligament is similarly divided, conjoining the previous inframesocolic dissection plane and releasing the hepatic flexure. Once the mesocolic mobilization is achieved, the right branch of the middle colic vascular pedicle is identified and prepared. For this purpose, both an inframesocolic and supramesocolic approach can be employed, depending on the case. Our preference is to identify the middle colic axis from the lesser sac and divide its right branch with better visualization of the entire mesocolon and inferior border of the pancreas. The artery and vein are typically clipped and divided selectively. The remainder of the transverse mesocolon is divided and the relative greater omentum is partitioned to include its right portion in the resection. The transverse mesocolon is next transected using the 60-mm endostapler with blue cartridge.

Lateral mobilization follows releasing the lateral attachments of the ileocecal junction and the right paracolic gutter, until the specimen is completely detached. The specimen is thus placed above the liver for later retrieval.

Our standard technique of reconstruction entails an isoperistaltic semi-mechanical side-to-side anastomosis accomplished using a 60-mm stapler and manual closure of the common enterotomy. To do so, the ileal and colonic ends are first approximated by placing a 3–0 stay suture in the lateral aspect of the anastomosis, with care taken to ensure that no torsions exist. This suture is then put under gentle traction by the third arm to aid in alignment of the two anastomotic ends, as illustrated in Video 5.2. A small enterotomy is thus created on the antimesenteric aspect of both bowel ends, using the monopolar scissors. An endostapler with a 60-mm blue cartridge is introduced through the enterotomies and fired. The stapler is gently removed and the anastomotic line is checked for hemostasis. The common enterotomy is now closed with an inner layer of a continuous Lembert suture, typically using a 3–0 barbed thread (Video 5.2). The final step includes an outer layer of some 3–0 interrupted Lembert sutures, which approximate the serosal layer and bolster the anastomotic line. The greater omentum is placed over the anastomosis and through the mesenteric defect, to provide protection against internal hernias and anastomotic leakage. The specimen is thus extracted through a mini-Pfannenstiel incision using a plastic wound retractor. Finally, the abdominal cavity is checked for adequate hemostasis, and generously irrigated with saline. We do not routinely use drains, which are placed only in the case of infection or abscess. The abdomen is carefully desufflated and the port accesses are closed.

With reference to the standard course of patients receiving a robotic right colectomy, ambulation is solicited immediately after surgery. On the first postoperative day the bladder catheter is removed and a semi-solid diet is started and advanced as tolerated. Typically, the patient is discharged home on postoperative day 3 or 4.

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Robotic Right Colectomy: The Bottom-Up Approach

6

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6.1 Introduction

The benefits of minimally invasive surgery in terms of 30-day postoperative outcomes for the treatment of colonic cancer are well known, with equivalent long-term oncological results [1–3].

Technological advances in surgery in recent decades have been mostly driven by the development and introduction of robotic surgical platforms that could potentially overcome the limitations of conventional laparoscopy, increase the uptake of minimally invasive colorectal resection and shorten the learning curve [4–8].

The most debated and controversial issues in right colectomy are still represented by the extent of oncological resection (complete mesocolic excision vs. standard resection) and the fashioning of the anastomosis (intracorporeal vs. extracorporeal).

The principle of complete mesocolic excision (CME) [9] with central vascular ligation with complete exposure and lymphadenectomy along the superior mesenteric axis may potentially increase the technical difficulties of minimally invasive surgery, especially when dealing with right colon cancer and its related highly variable vascular anatomy in the peripancreatic area [10].

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Moreover, conventional laparoscopy has unresolved questions on the type of anastomosis that should be performed for the reconstructive phase (intracorporeal vs. extracorporeal), even though evidence from the literature in favor of intracorporeal fashioning (more technically demanding) of the anastomosis is constantly growing [11, 12].

Herein, we present our surgical technique of robotic right colectomy with CME, intracorporeal anastomosis and bottom-up approach, as performed with the da Vinci Xi robotic platform (Intuitive Surgical, Sunnyvale, CA, USA).

6.2 Patient Positioning, Operating Room Setup, and Trocar Layout

The patient is placed on the operating room table in supine position, with arms tucked and legs closed. After induction of pneumoperitoneum using a Veress needle at Palmer's point, a 12-mm trocar for the assistant is inserted in the left flank, about 10–15 cm above the left iliac spine; four robotic trocars are inserted along a transverse suprapubic line, about 3 to 4 cm above the pubis (three 8-mm trocars and one 12-mm trocar for the robotic stapler in the left iliac fossa). Trocar layout is shown in Fig. 6.1.

The table is placed in a Trendelenburg position with a slight angle (5–10°) and left tilt (5–10°). The robot is then docked from the patient's right side and a da Vinci

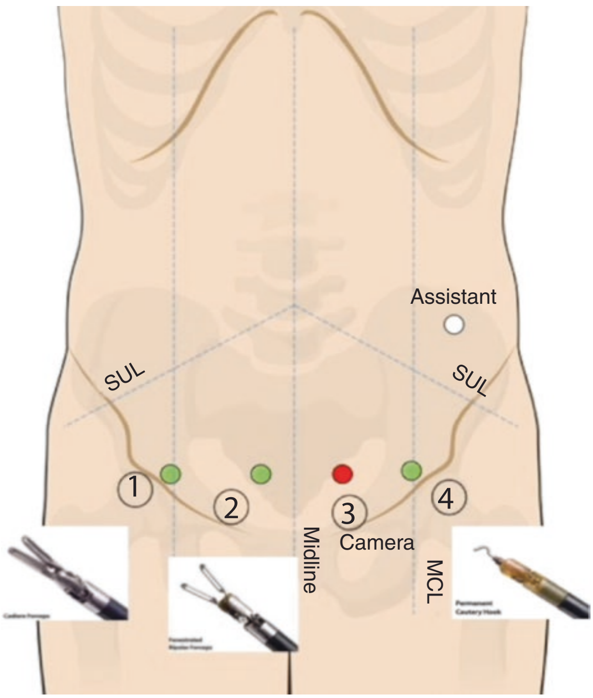

Fig. 6.1 Trocar layout with da Vinci Xi system: (1) Cadiere forceps; (2) bipolar forceps; (3) camera; (4) monopolar hook

Xi system (Intuitive Surgical, Sunnyvale, CA, USA) is used. Targeting is completed at the level of the middle transverse colon. Cadiere forceps, bipolar forceps and monopolar hook (monopolar scissors can be used according to the operating surgeon's preference) are mounted on robotic arm 1 (R1), robotic arm 2 (R2) and robotic arm 4 (R4), respectively. The 30-degree down optical system is mounted on robotic arm 3 (R3). If necessary, the scope can be mounted on R2 to allow for better visualization of the mesenteric root/superior mesenteric vessels during the first steps of bottom-up dissection.

6.3 Surgical Technique

The procedure starts with the dissection of the mesenteric root of the last ileal loop from the posterior plane: this is obtained by suspending anteriorly and cranially the cecum with the robotic graspers in R4 and the last ileal loop (20 to 30 cm from the ileocecal valve) with the assistant's instrument. After mobilization of the cecum, dissection continues cranially to separate the ascending mesocolon and the mesenteric root from Gerota's fascia, paying great attention to preserve the integrity of the posterior proper mesocolic fascia and thus respecting the embriologically based principles of CME; the duodenum and the head of pancreas are thus easily reached in the cranial aspect of the dissection, as well as the superior mesenteric axis on the medial aspect. Dissection at the level of the mesenteric root should be performed as far cranial and medial as possible in order to achieve adequate mobilization of the posterolateral aspect of the mesenteric axis, thus maximizing the potential benefit of this approach in terms of central lymphadenectomy. A gauze is placed underneath the mesentery and above the third portion of the duodenum as a landmark; the cecum and the last ileal loops are then pulled back towards the right iliac fossa in their anatomical position.

The Cadiere forceps can be alternatively used to lift the transverse mesocolon or the ileocolic vessels, according to the different steps of the procedure (Fig. 6.2). When used for ileocolic vessel traction and exposure, the root of the transverse mesocolon is lifted up by the assistant's graspers to highlight the prominence of the superior mesenteric axis.

The ileocolic pedicle is lifted with the Cadiere forceps in R1 and the transverse colon is thus pulled cranially by the assistant. The peritoneal sheath just below their prominence is incised to obtain easy access to the plane that has been previously developed with the bottom-up mesenteric root detachment. The anterior surfaces of the superior mesenteric vein and the superior mesenteric artery are exposed and then an extended central lymphadenectomy is performed up to the posterolateral border of the superior mesenteric axis.

The ileocolic vessels (Fig. 6.3), right colic vessels (when present) and the superior right colic/middle colic veins/accessory veins (according to the anatomical variations that are commonly encountered in this area) are isolated at their roots and divided between self-locking clips after having obtained a complete exposure of the pancreatic head, Henle's trunk and its branches (bifurcated vs. trifurcated, right gastroepiploic vein, anterior superior pancreaticoduodenal vein, superior right colic

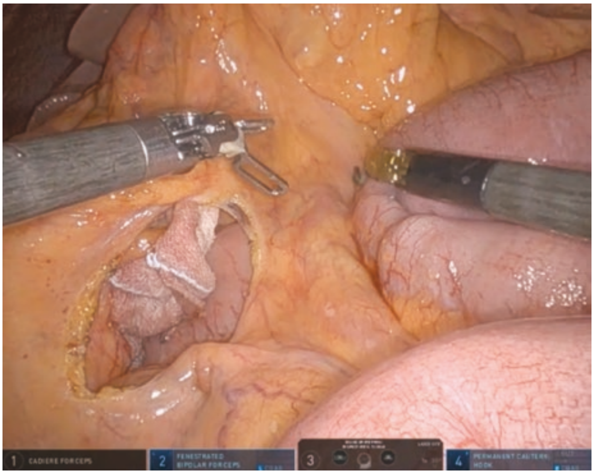

Fig. 6.2 Exposure and traction on ileocolic vessels and transverse mesocolon

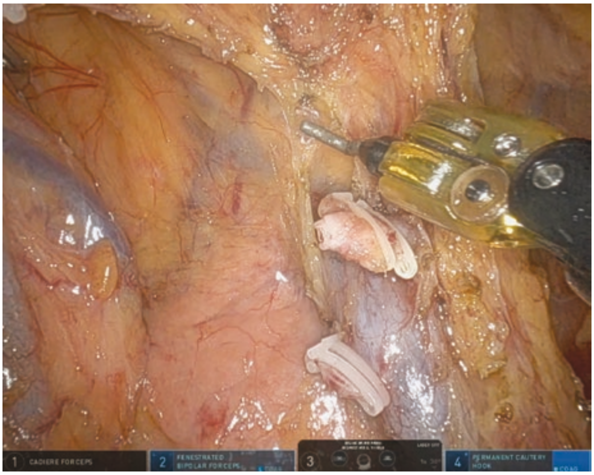

Fig. 6.3 Identification and transection of ileocolic vessels

vein) (Figs. 6.4 and 6.5). Identification of gastroepiploic vessels/mesentery can be performed and completed with a supramesocolic approach after having gained access to the lesser sac, leaving a gauze as a landmark. A robotic clip applier is commonly used and mounted on R4. A common laparoscopic clip applier can be also used, taking into account the expertise of the table assistant and the suboptimal angle for straight-stick clip applier. The transverse mesocolon is pulled caudally by the assistant, the greater omentum is lifted up by the robotic forceps in R1 and divided; the lesser sac is then entered in its medial aspect.

For cancers of the cecum and ascending colon, the right branch of the middle colic artery is clipped and divided after having identified the main trunk of the middle colic artery. The common trunk of the middle colic artery is usually divided at its root when dealing with hepatic flexure, proximal and middle transverse colon

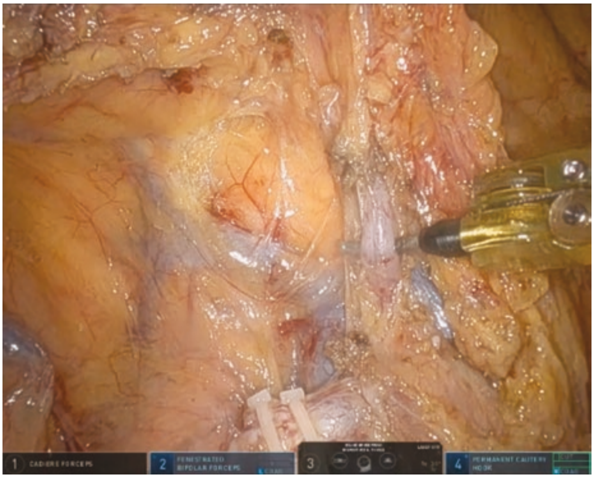

Fig. 6.4 Henle trunk dissection and identification of its branches. Middle colic artery is identified and dissected free at its root

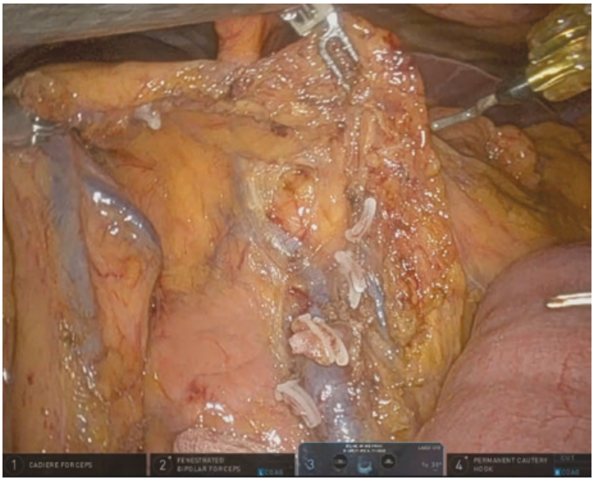

Fig. 6.5 Final view after vascular control. Middle colic artery is clipped and divided at its origin in case of extended right colectomy

cancer thus performing an extended right colectomy. Moreover, in these clinical scenarios, a vessel-preserving lymphadenectomy of the right gastroepiploic vessels is carried out after opening of the lesser sac, when dealing with locally advanced tumors at these locations.

Frontal visualization of the transverse mesocolic root and middle/distal transverse colon is another potential advantage of the suprapubic bottom-up approach, since it allows for optimal vascular exposure as well as easier fashioning of the intracorporeal anastomosis in cases of extended right colectomy, when compared to the conventional medial-to-lateral approach.

Hepatic flexure/ascending colon mobilization is then performed and completed. The transverse mesocolon and the mesentery of the last ileal loop are then divided with the Vessel Sealer device (Intuitive Surgical, Sunnyvale, CA, USA) mounted on R4.

Indocyanine green (ICG) is administered intravenously (10 mg) and both the ileal and colonic stumps are evaluated for perfusion with the integrated ICG fluorescence imaging system and sectioned with a 60-mm robotic stapler with blue cartridge (SureForm 60, Intuitive Surgical, Sunnyvale, CA, USA).

A side-to-side isoperistaltic ileocolic anastomosis is then performed with the SureForm 60 stapler with blue cartridge. The monopolar cautery in R1 is then replaced with a needle driver. The remaining enterotomy is subsequently closed with a robotically hand-sewn double-layer running suture using absorbable barbed suture (V-Loc, Covidien). We do not routinely close the mesenteric defect. Conventional 60-mm laparoscopic staplers can be also used for bowel transection and intracorporeal anastomosis.

The specimen is then extracted using an endobag through a small suprapubic incision performed by conjoining the two paramedian 8-mm suprapubic port sites. The advantages of intracorporeal anastomosis are minimal mesenteric and mesocolic traction, limited chance for anastomotic twisting and the possibility to choose the specimen extraction site (according to the patient's history of prior abdominal surgery). Intracorporeal anastomosis is beneficial especially in obese patients with short and thick mesentery.

Once the specimen is removed, the pneumoperitoneum is re-established for a final check of the operative field. No drain is routinely left in place.

6.4 Conclusions

Robotic right colectomy with CME and bottom-up suprapubic approach may potentially allow for a safe extended lymphadenectomy by providing high-quality surgical specimens and intact visceral embryological envelopes. Further data and highlights will be provided by multicenter prospective ongoing studies.

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7 Robotic Right Colectomy with Complete Mesocolic Excision and Central Vascular Ligation. Extended Right Colectomy

Graziano Ceccarelli, Walter Bugiantella, Lorenzo Mariani, Fabio Rondelli, Brian Tian, Federica Arteritano, and Michele De Rosa

7.1 Introduction

Disease recurrence after right colectomy for stage II–III cancer is estimated to be up to 10% of cases. This is potentially related to the understaging of nodal status [1]. Hohenberger thus proposed a translation of Heald's basic principles of total mesorectal excision for rectal cancer, into the management of right colon cancer. Hohenberger standardized the technique of complete mesocolic excision (CME) with central vascular ligation (CVL) and he demonstrated interesting oncological outcomes [2]. Originally described as an open procedure, the Hohenberger technique is today performed by minimally invasive approaches, although it is considered challenging and requires advanced laparoscopic skills [3]. Of note, however, is the recent uptake and diffusion of robotic systems in the field of colon cancer surgery, which offers interesting alternatives to conventional laparoscopy.

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7.2 Definition of Technique and Indications

The CME technique involves sharp dissection along the embryological planes of fusion (Gerota, Toldt and Fredet), whilst the CVL technique requires delicate sharp dissection along the anterior surfaces of the superior mesenteric vessels. The main aim of these techniques is the removal of the infrapancreatic and gastroepiploic arcade nodes, by transecting the accompanying vessels at their origin (ileocolic, right colic, Henle's trunk and middle colic vessels or the right branch of middle colic vessels) (Fig. 7.1a) [2, 3]. Tumor location is crucial to determine the exact extent of colon resection and the location of draining nodes that need to be removed (Fig. 7.1b). In the absence of strong evidence, indications for CME today remain a controversial issue. Major benefits have been reported for tumors located in the ascending colon, hepatic flexure and proximal transverse colon. Benefits of CME have also been demonstrated when there is preoperative computed tomography identification of positive nodes in young patients and those with poorly differentiated disease [4, 5].

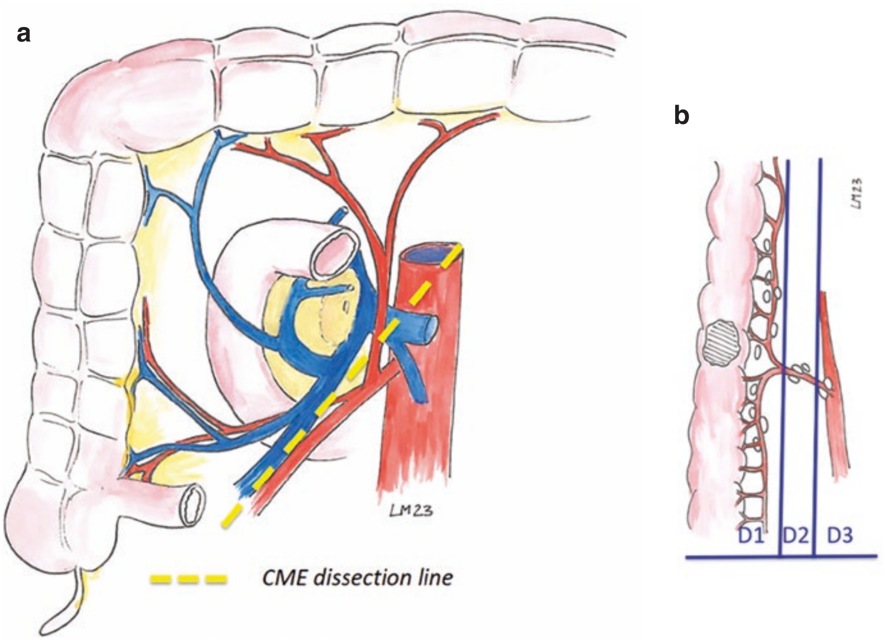

Fig. 7.1 The concept of complete mesocolic excision (*CME*): central vascular ligation at the root of superior mesenteric vessels (see text for details)

7.3 Variations in the Vascular Anatomy of the Right Colon

Surgeons must be well versed in the vascular anatomic variations of the right colon, to avoid causing catastrophic bleeding or iatrogenic injuries, especially for surgeons new to this technique. In 2015, the Japanese National Clinical Database reported a higher rate of surgical mortality for right colon resections compared to rectal resections (1.3% vs. 0.3%), mainly due to vascular injuries [6].

The ileocolic artery and the middle colic artery have been found in almost 100% of cases, while a right colic artery (as a direct branch from the superior mesenteric artery) was detected in about 30% of cases [7]. The gastrocolic (Henle's) trunk represents one of the most variable and crucial anatomic structures. It is composed of various veins from the colon, stomach, omentum and pancreas, merging together prior to draining into the superior mesenteric vein (SMV). These contributing veins have also been found to drain independently and directly into the SMV. Henle's trunk represents an important landmark and, together with the middle colic vessels, it is the cranial border of the CME surgery. Hohenberger called this region the "bleeding point" [2]. Major bleeding during laparoscopic surgery has been shown to occur in 3–9.2% of cases, with conversion to open surgery in 1–2% of cases [8].

7.4 Surgical Techniques of Robotic Right Colectomy with Complete Mesocolic Excision and Central Vascular Ligation

Descriptions of open, laparoscopic and robotic approaches have been reported in many papers, with many variations in robotic techniques [2, 9–11].

7.4.1 Medial-to-Lateral/Superior Mesenteric Vein-First Approach

The medial-to-lateral/SMV-first approach represents the most common technique. The port placement and robot set-up are shown in the Video 7.1 and in Chap. 5. In this approach, the mesocolon is first pulled upward and countertraction is applied downward to the ileocolic region. This exposes the anatomical fold created by the ileocolic vessels and the superior mesenteric axis. The peritoneal layer covering the superior mesenteric vein and artery is incised. Next, the lymphatic tissue and fat are removed en bloc, medially to laterally along the embryological planes between the Gerota's and Toldt's fascia and the pre-duodenopancreatic Fredet's fascia, using monopolar and bipolar energy. The ileocolic vessels are transected close to their origin. Following the path of the superior mesenteric vessels upward, Henle's venous trunk and the origin of the middle colic vessels are dissected and sectioned. The proximal transverse colon is subsequently transected with endoscopic staplers (10 cm of free margin is recommended).

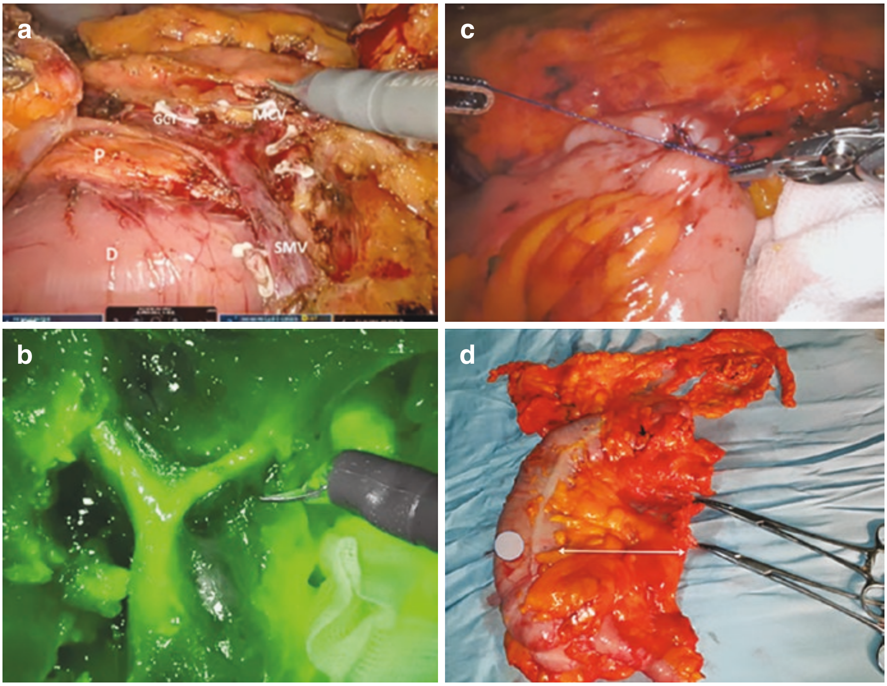

Fig. 7.2 (**a**) The surgical field at the end of the complete mesocolic excision (*D* duodenum; *P* pancreas; *SMV* superior mesenteric vessels; *GCT* gastrocolic trunk; *MCV* middle colic vessels). (**b**) The middle colic vessels with indocyanine green intraoperative identification. (**c**) Intracorporeal anastomosis. (**d**) Specimen showing the "mesocolic plane"

The decision as to whether or not to preserve the left branch of the middle colic vessel depends on the tumor location. The vascular supply of the remnant bowel is then evaluated using indocyanine green (ICG) fluorescence imaging. An intracorporeal side-to-side isoperistaltic anastomosis is then finally performed. For obese patients, the use of intraoperative ultrasound or ICG may be useful to help identify the main vessels [5] (Fig. 7.2) (see Video 7.1).

7.4.2 Top-Down/Cranial-to-Caudal Technique

The top-down/cranial-to-caudal technique, proposed especially for an extended right hemicolectomy [4, 12], consists of the early identification of the gastrocolic trunk and the middle colic vessels. This approach begins by first dissecting the gastrocolic ligament to identify the right gastroepiploic vein, which is the landmark for the gastrocolic trunk. Afterwards, the dissection proceeds downward along the SMV, toward the ileocolic vessels. This technique may prevent or reduce inadvertent vascular injuries to the mesenteric root of the transverse colon. A drawback of this technique is the need for double docking of the robot; with the first docking performed in a 30° reverse Trendelenburg position and the second docking in a 30° Trendelenburg position.

7.4.3 Bottom-to-Up Approach

The bottom-to-up approach, described by Petz et al. [13], requires preferably the last da Vinci Xi system (see Chap. 6). This technique involves a suprapubic positioning of the four ports, along a horizontal line 3–5 cm above the pubis, plus one 12-mm assistant trocar. A 25° Trendelenburg position with a slight left-sided tilt will provide an optimal view for retrocolic dissection and superior mesenteric vessel exposure for CME. The first step in this approach is to begin mobilization retrocecally, followed by further mobilization of the ascending and transverse mesocolon along the embryonic layers. The superior mesenteric vessels are thus identified during mobilization, keeping the "envelope" of the specimen intact prior to any vessel ligation. Excessive tension on the ileocolic vessels is also avoided to reduce the risk of iatrogenic vessel injuries, especially in obese patients. Specimen retrieval is performed via a horizontal minilaparotomy joining the two robotic ports. One of the main advantages of this technique is the retrieval of a higher number of lymph nodes (median of about 40 vs. 16 nodes ($p < 0.001$) compared to conventional medial-to-lateral techniques [14].

7.5 Complete Mesocolic Excision and Indocyanine Green Guidance

For better identification of the regional lymph nodes, an endoscopic submucosal injection of ICG around the tumor is preferably performed the day before surgery. During surgery, the site of the primary tumor and its corresponding lymphatic basin will then be clearly visible with the Firefly modality. Petz et al. demonstrated how effective this technique was, as it ensured high accuracy in the identification of lymph nodes during CME. It was demonstrated that in 17 out of 50 patients (34%), lymph nodes were identified that were out of the usual anatomical lymphatic routes. The main drawback of this approach is, however, the need for endoscopy the day before surgery and its corresponding bowel preparation [13, 15].

7.6 Quality of the Specimen in Complete Mesocolic Excision

The definition of completeness and quality of the CME specimen is not universal. On the basis of total mesorectal excision for rectal cancer, West et al. suggested a grading of the specimen based on the integrity of the mesocolon, and proposed that specimens be classified as either good, moderate or poor. The authors graded the quality of CME by reviewing specimen photographs, and described three grades [16]:

– *Grade A*: intact mesocolon
– *Grade B*: significant mesocolic disruptions
– *Grade C*: disruptions extending down to the muscularis.

Benz et al. also introduced a classification based on four grades of completeness and integrity of the mesocolon [17]. Another important aspect for grading the quality of surgery is the surgical field after specimen removal. It is essential to share all this information with the pathologist examining the specimen (Fig. 7.2d).

7.7 Robotic Complete Mesocolic Excision Outcomes from Literature

Operating time for CME is significantly longer compared to non-CME, for both open and minimally invasive approaches. For robotic surgery, there is the added time taken for the theatre set-up and docking. Spinoglio et al. reported longer mean operating room times for robotic surgery, as compared to laparoscopy (279 vs. 236 min; $p < 0.001$), with a significant difference between the earlier and the later robotic series, underlining the importance of the learning curve [18]. Operative time generally decreases significantly after a number of cases (30–40) [5].

A longer length of hospital stay in CME is sometimes associated with prolonged ileus, probably due to nerve injury along the superior mesenteric artery axis. Intracorporeal anastomosis may help reduce postoperative ileus by less mobilization of the transverse colon [5]. Ozben et al. reported a significantly higher rate of intracorporeal anastomosis using the robotic approach (86.8% vs. 20.0%) [19]. No difference in the postoperative length of stay was generally observed when comparing robotic and laparoscopic CME [18, 19]. Spinoglio et al., however, observed a difference in the conversion rates between the two groups (robotic 0% vs. laparoscopic 6.9%; $p = 0.01$), in favor of the robotic series [18].

Compared with conventional techniques, CME was not associated with higher risk of postoperative complications, including anastomotic leakage. Major vascular injury or chylous ascites were rarely described and can be prevented by not removing the neurolymphatic tissue surrounding the superior mesenteric artery. The use of intraoperative ultrasound in obese patients was reported to reduce vascular complications [20]. Spinoglio et al. reported no intraoperative complications in the robotic series. No incisional hernias were reported after 1 year using the Pfannenstiel incision for specimen extractions [18].

7.8 Lymph Node Yield in Complete Mesocolic Excision

Current guidelines consider the harvesting of 12 lymph nodes as the minimum target for accurate disease staging [21]. The incidence of central mesocolic lymph node metastases is estimated to be between 1% and 22%. This affects the local recurrence rates and represents an independent prognostic factor for survival. CME is associated with a higher number of lymph nodes retrieved [20, 22, 23]. Wong et al. demonstrated that when more than 28 lymph nodes were harvested during CME, this was associated with a better prognosis [24]. One of the reasons for the improved prognosis is the “stage migration effect” and consequent increased use of adjuvant therapy. A mean number of 46.1 ± 22.2 vs. 39.1 ± 17.8 lymph nodes were respectively reported in the comparative study between robotic and standard laparoscopic CME for transverse colon cancer [19].

CME has been shown to have better oncologic outcomes, as compared to standard techniques in selected cases. CME has been shown to reduce local recurrence rates, especially for stage III tumors with proximal lymph node metastases, with improved disease-free survival (DFS) and disease-specific survival (DSS) rates [22, 25]. A positive survival trend in terms of DFS in the CME group was observed in the meta-analysis of De Simoni et al. [20]. Spinoglio et al. also reported a 5-year overall survival rate of 77% for the robotic series versus 73% for the laparoscopic group ($p = 0.64$), with a DFS rate of 85% versus 83% for the robotic versus laparoscopic group ($p = 0.58$) [18].

7.9 Extended Right Colectomy for Right Transverse Colon Cancer

Colon cancer located in the hepatic flexure or transverse colon represents 3% and 5% of cases, respectively. Cancers in these locations are more likely to metastasize to the middle colic and gastrocolic lymph nodes. Adopting minimally invasive approaches in these cases may be challenging, and therefore the robotic system may represent an interesting tool. In these cases, extended lymph node dissections have to include the infrapyloric lymph nodes (No. 206 according to the Japanese classification), and those of the greater curvature of the stomach (No. 204) which are located 10–15 cm from the tumor. The No. 206 station is defined as the area surrounding the root of the right gastroepiploic artery, up to its first branch and down to the junction of the right gastroepiploic vein and the superior anterior pancreaticoduodenal vein. No. 204 includes nodes along the greater curvature of the stomach, distal to the first branch of the right gastroepiploic artery [26]. Toyota et al. reported a study where 2% of colonic hepatic flexure cancers had infrapyloric lymph node metastases, suggesting that when infrapyloric nodal metastases are suspected, they should be removed [27]. One of the typical complications reported after such an extended surgery is a higher incidence of gastroparesis.

Robotic extended right hemicolectomy may be performed using the medial-to-lateral approach, with a port placement slightly different with respect to the standard right colectomy with CME.

Some studies addressed specifically the robotic approach for transverse colon cancers [28, 29], but only a few were focused on the CME technique [30, 31]. In a comparative study of robotic and laparoscopic CME, de Angelis et al. reported fewer conversions, anastomotic leaks, ileus, and reoperation rates, as well as more intracorporeal bowel anastomosis and greater numbers of harvested lymph nodes, in the robotic series, whilst operative time and blood loss were in favor of laparoscopy [30].

7.10 Conclusions

Long-term oncological benefits of CME with CVL over standard techniques have yet to be definitively demonstrated. There is also no shared consensus on the definition of CME itself, nor on CME's indications, technical details and complications. The minimally invasive approach appears possible but challenging, and generally requires a long learning curve. The robotic technique, conversely, offers more precise dissection and a shorter learning curve as compared to conventional laparoscopy. The robotic approach is also particularly helpful when applied to obese patients. Prospective randomized studies with long-term follow-up and large series are required before recommending the CME technique and the robotic approach in routine practice.

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8 Robotic Splenic Flexure and Segmental Transverse Resections

Giuseppe Giuliani, Francesco Guerra, Gianluca Saccucci, Michele Di Marino, and Andrea Coratti

8.1 Background

The most important randomized controlled trials [1–3] that demonstrated the oncological adequacy of laparoscopic surgery for colon cancer resection did not include cancers located at the level of the splenic flexure (SF) and the transverse colon (TC). Indeed, segmental resections of SF and TC can be technically challenging with concerns for an appropriate oncologic outcome. Lymph node dissection, vascular dissection and intracorporeal anastomosis are considered the most demanding steps during segmental resections for TC and SF cancers [4].

The evidence currently available in the literature shows that the minimally invasive approach for segmental resections of SF and TC cancer has equivalent oncological outcomes and better short-term outcomes compared to conventional open surgery [5, 6]. Furthermore, a growing interest in the application of the robotic approach for these segmental resections was shown in the last year [5–8]. Compared to conventional laparoscopic colectomy, the robotic approach for segmental resections seems to have a higher rate of intracorporeal anastomosis, a longer mean operative time and a higher mean number of harvested lymph nodes [8].

In this chapter we describe our full-robotic standardized technique for SF and TC resection, using the da Vinci Xi robot (Intuitive Surgical Inc., Sunnyvale, CA).

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8.2 Robotic Instrumentation

Recommended main equipment:

- 30° endoscope
- fenestrated bipolar forceps
- monopolar scissors
- large needle driver
- vessel sealer (optional)
- tip-up grasper.

8.3 Splenic Flexure Resection

8.3.1 Patient Positioning, Trocar Layout and Operating Room Setup

The patient is placed in a lithotomy position with arms alongside the body. Pneumoperitoneum is established via a Veress needle inserted in the left hypochondrium at Palmer's point. Access to the abdominal cavity is gained with a 12-mm assistant port in the right flank.

Then a laparoscopic exploration is performed to correctly identify the level of the lesion before deploying the trocars and docking the robot. Four 8-mm robotic trocars are then placed along an oblique line, starting from the right subcostal to the suprapubic region, which may vary according to the confirmation of the abdomen, as well as to intra-abdominal anatomy. Trocar layout is shown in Fig. 8.1. With this

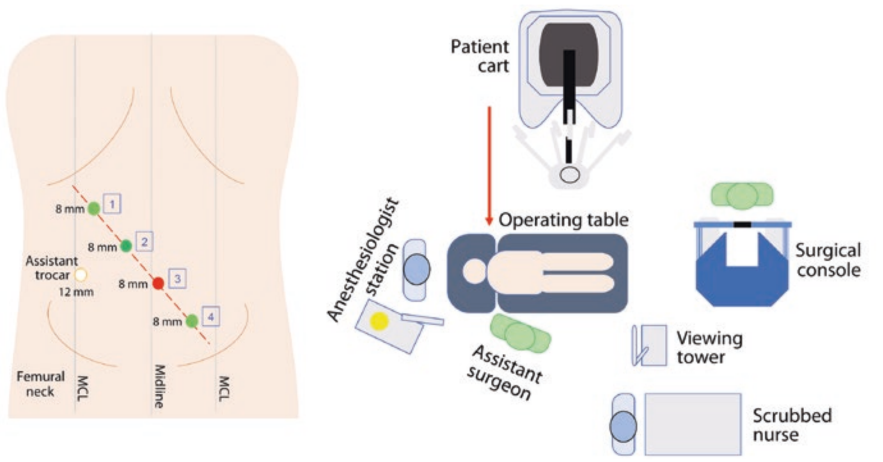

Fig. 8.1 Splenic flexure resection. Trocar layout (*left*): (1) tip-up grasper; (2) bipolar forceps; (3) camera 30°down; (4) monopolar scissors/robotic stapler. Operating room setup (*right*)

trocar placement, the surgical workspace (the space that must be reached by the instrument tips to perform the procedure) extends from the middle colonic vessels to the inferior mesenteric artery (IMA).

A limited lysis of adhesions, when present, is performed laparoscopically just to enable robotic trocar positioning under direct vision; adhesions are then taken down under robotic assistance.

The patient is then placed in a right tilt (10–15°) and in Trendelenburg position in order to achieve exposure of the operative field. During the procedure, the position can be modified according to the step of the operation. The small bowel is placed in the right abdominal quadrants: the TC and omentum are pulled up in the upper quadrants, the ligament of Treitz and the origin of the inferior mesenteric vein (IMV) are exposed.

The robotic cart is docked from the patient's left side and a da Vinci Xi system (Intuitive Surgical, Sunnyvale, CA, USA) is used. A full-robotic single-targeting procedure is performed. The assistant surgeon and the scrub nurse stand on the patient's right side (Fig. 8.1). The tip-up grasper, bipolar forceps and monopolar scissors/vessel sealer are mounted on robotic arm 1 (R1), arm 2 (R2), and arm 4 (R4), respectively. Robotic arm 3 (R3) is used for the 30°-down scope. Targeting is performed at the level of the SF.

8.3.2 Surgical Technique

For SF resection we start with a supramesocolic approach. The gastrocolic ligament is divided and the lesser sac opened. The gastrocolic ligament is lifted up with tip-up grasper (R1): the assistant retracts the TC from one epiploic appendage. The lesser sac is opened using fenestrated bipolar forceps (R2) and monopolar scissors (R4). The tip-up grasper (R1) is introduced in the lesser sac for omentum/posterior gastric wall traction, the transverse mesocolon is delivered from any attachment with the lesser sac, and TC is fully mobilized in a medial-to-lateral fashion. During this step the vessel sealer (R4), can be helpful to accelerate the dissection. Especially in locally advanced cancer and young patients, we remove the greater omentum in correspondence of SF and perform a lymph node sampling at the level of the left gastroepiploic vessels. Then the tip-up grasper (R1) lifts up the TC and the duodenal-jejunal angle is mobilized to achieve complete exposure of the origin of the IMV. This is dissected at its origin and divided between self-locking clips at the inferior border of the pancreas. The assistant maintains the jejunal loops in the right quadrants. The IMV is lifted up with the fenestrated bipolar forceps (R2) and the peritoneum under the IMV is incised. The dissection continues along the Toldt's planes, in a medial-to-lateral fashion as lateral as possible. The dissection continues downward to the origin of the IMA, where a lymph node sampling is carried out. Then the left colonic artery (LCA) is isolated and divided between self-locking clips. After that, mobilization of the left mesocolon and the SF is completed, with a

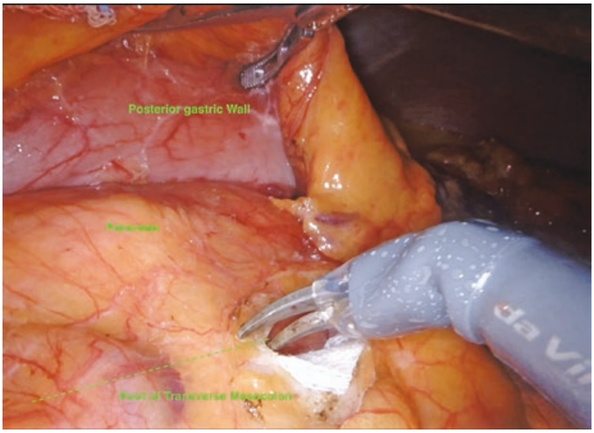

Fig. 8.2 Dissection of the root of the transverse mesocolon from the pancreatic body

lateral-to-medial dissection. The splenocolic and the phrenicocolic ligament are detached, gaining the previously delivered plane.

The root of mesocolon is incised from the pancreatic tail and the pancreatic body in a lateral-to-medial fashion (Fig. 8.2). The middle colonic vessels are identified and a lymph node sampling is performed. Then the left branches of the middle colic vessels are divided.

The transverse mesocolon is divided and the colon is sectioned with a 60-mm laparoscopic stapler, after bowel perfusion assessment with the indocyanine-green fluorescence imaging system. The reconstruction is performed with a robotic hand-sewn end-to-end colocolonic anastomosis (see Video 8.1).

The large needle driver is mounted on R4. To achieve a better exposure, a stay suture is placed on the proximal and distal colonic stump and lifted up by the tip-up grasper (R1). The anastomosis starts with approximation of the proximal and distal colonic stumps using a posterior wall interrupted absorbable suture. Then the two stapler lines are removed with monopolar scissors (R4). Starting from both corners, the posterior and anterior walls are closed using an absorbable barbed running suture. The colocolonic anastomosis is reinforced with seroserosal absorbable interrupted stitches and an omental flap.

The robot is undocked and, with the aid of an abdominal wall protection device, the specimen is usually retrieved through a suprapubic Pfannenstiel incision.

8.4 Transverse Colon Resection

8.4.1 Patient Positioning, Trocar Layout and Operating Room Setup

The patient is placed in a supine position with arms alongside the body and legs closed. Pneumoperitoneum is established via a Veress needle inserted in the left

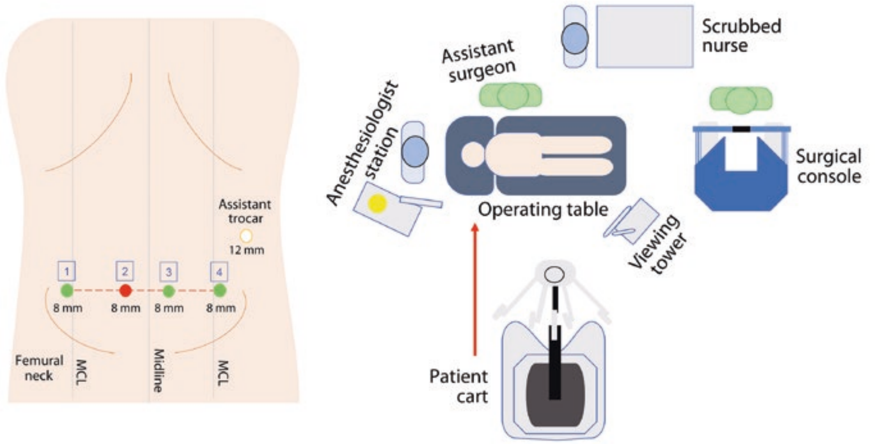

Fig. 8.3 Transverse colon resection. Trocar layout (*left*): (1) bipolar forceps; (2) camera 30°down; (3) monopolar scissors/robotic stapler; (4), tip-up grasper. Operating room setup (*right*)

hypochondrium at Palmer's point. Access to the abdominal cavity is gained with a 12-mm assistant port in the left flank.

Then a laparoscopic exploration is performed to correctly identify the level of the lesion and TC anatomy before placing the trocars and docking the robot. Four 8-mm robotic trocars are then inserted along a transverse suprapubic line about 4 to 5 cm above the pubis. Trocar layout is shown in Fig. 8.3.

With this trocar placement the surgical workspace (the space that must be reached by the instruments tips to perform the procedure) extends from the right to the left colon

The patient is then placed in a reverse Trendelenburg position (10–15°) in order to achieve exposure of the operative field.

The robot cart is docked from the patient's right side (Fig. 8.3). The da Vinci Xi system (Intuitive Surgical, Sunnyvale, CA, USA) is used. A full-robotic single-targeting procedure is performed. The assistant surgeon and the scrub nurse stand on the patient's left side.

Bipolar forceps, monopolar scissors/vessel sealer and tip-up grasper are mounted on robotic arm 1 (R1), arm 3 (R3) and arm 4 (R4), respectively. Robotic arm 2 (R2) is used for the 30°-down scope. Targeting is performed at the center of TC.

8.4.2 Surgical Technique

Also for segmental resection of TC we start with a supramesocolic approach. The gastrocolic ligament is sectioned and the lesser sac opened. The gastrocolic ligament is lifted up with a tip-up grasper (R4): the assistant retracts the TC from one epiploic appendage. The lesser sac is opened using fenestrated bipolar forceps (R1) and monopolar scissors (R3): the gastrocolic ligament is fully detached from the

TC, in a medial-to-lateral fashion, up to the SF. During this step the tip-up grasper (R4) is introduced in the lesser sac for omentum/posterior gastric wall traction, and the transverse mesocolon and posterior gastric wall are freed from any attachment with the lesser sac. During this step the vessel sealer (R3) can be helpful to accelerate the dissection, especially in the obese patients. In cases of complex dissection at the level of the gastrocolic ligament, with the impossibility to enter the lesser sac, we suggest dividing the coloepiploic ligament.

Then, in a lateral-to-medial fashion, the SF is fully mobilized: the splenocolic and phrenicocolic ligaments are detached. According to the localization of the tumor and the length of TC, the proximal part of the descending colon can be mobilized along the Toldt's plane. A gauze is lifted under the transverse mesocolon. At this point the root of the mesocolon is incised from the pancreatic tail and the pancreatic body in a lateral-to-medial fashion (Fig. 8.2). During this step the tip-up grasper (R4) retracts the posterior gastric wall, the assistant retracts the TC from one epiploic appendage toward the right iliac fossa, and the dissection is carried out with fenestrated bipolar forceps (R1) and monopolar scissors/vessel sealer (R3).

Then dissection continues toward the right side opening the lesser sac and separating the transverse mesocolon from the pancreas at the level of Fredet's plane and the anterior wall of duodenum.

The origin of the middle colic vessels, under the inferior pancreatic border, Henle's trunk and the right gastroepiploic vessels are identified. Depending on the case, the dissection can be performed via the supra- or inframesocolic space.

The middle colic vessels are divided. A lymph node sampling at the level of right gastroepiploic vessels is carried out. Then the right colonic flexure is mobilized.

The transverse mesocolon is divided and the colon is sectioned with a 60-mm laparoscopic stapler, after bowel perfusion assessment with the indocyanine green fluorescence imaging system. Reconstruction is performed with a robotic hand-sewn end-to-end colocolonic anastomosis, as described for reconstruction of the SF resection (see Video 8.1).

The robot is undocked and, with the aid of an abdominal wall protection device, the specimen is usually retrieved through a small suprapubic incision performed by conjoining the two paramedian 8-mm suprapubic port sites.

8.5 Conclusions

The minimally invasive approach for segmental resection of TC and SF cancers has comparable oncological outcomes to conventional open surgery [5]. The laparoscopic approach is considered technically demanding for these colorectal resections, mainly for vascular resection, lymph node dissection and intracorporeal anastomosis [4]. The robotic approach for these segmental resections, thanks to its intrinsic technological features, seems to increase the lymph node harvest, reducing the conversion rate and favoring the intracorporeal anastomosis [6–9].

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Robotic Left Colectomy

9

Wanda Luisa Petz

9.1 Introduction

Although the robotic approach in colorectal surgery has been mainly described for rectal resection and right colectomy [1–5], technical advantages of the robotic platform over standard laparoscopy (high-definition three-dimensional vision of the surgical field, stable camera, ergonomics of the instruments) can also be gained for left colectomy.

Evidence in the literature regarding robotic left colectomy is scarce, and primarily concerns diverticular disease: in 2019 Al-Temini et al. [6] reported on 6776 patients undergoing laparoscopic left colectomy compared to 441 patients undergoing robotic left colectomy. Operative time was higher in the robotic group but conversions to open surgery were significantly lower. Similar results were observed

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by Bastawrous et al. [7]. Beltzer et al. [8] described similar clinical outcomes after robotic or laparoscopic left colectomy for diverticular disease, but reported more cases of complicated diverticulitis, with abscess or recurrent disease, in the robotic group. Together, this evidence may indicate a role for the robotic platform in decreasing the complexity of the minimally invasive approach in a complex surgical scenario such as diverticulitis.

In this chapter, we shall focus of the technical aspects of robotic left colectomy for cancer with the Xi da Vinci platform.

9.2 Patient Position and Robot Docking

The patient is in a supine position with arms alongside the trunk and legs abducted. A slight Trendelenburg position and right tilt are maintained to expose the operative field from the ileal loops (Fig. 9.1).

The procedure starts with induction of pneumoperitoneum through a Veress needle inserted in the Palmer point; once an intra-abdominal pressure of 12 mmHg is reached, the assistant port (a 12-mm optical trocar) is inserted in the right flank.

A preliminary exploration of the abdominal cavity is performed through this port with the robotic camera; if the site and resectability of the tumor are confirmed, the remaining ports are inserted under direct vision.

Four 8-mm robotic trocars are inserted along a line traced from the left subcostal margin to the right greater trochanter; the point where this line crosses the midline represents the insertion point of the camera trocar (R2); the remaining ports are inserted at 6–8 cm between them. Robotic trocar number one (R1) is on the left of R2, and robotic trocars number three (R3) and four (R4) are on the right (Fig. 9.2).

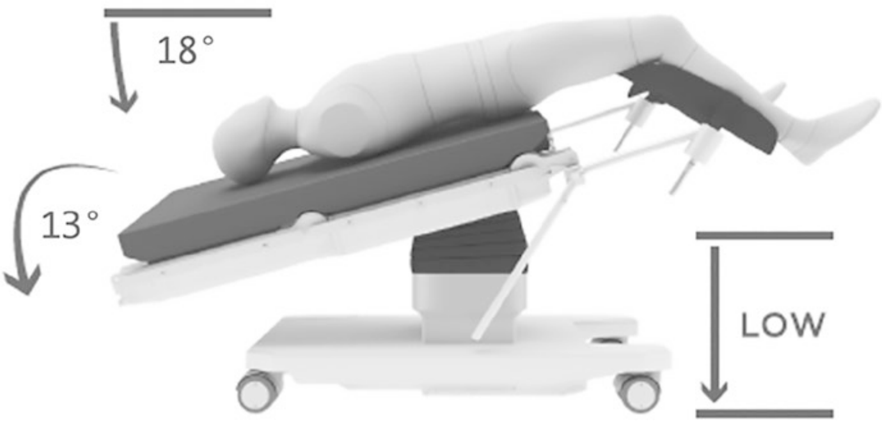

Fig. 9.1 Patient position

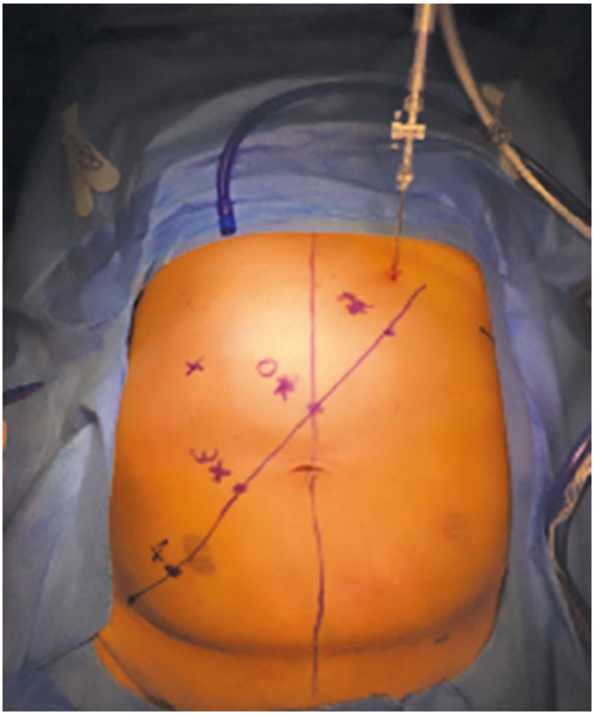

Fig. 9.2 Trocar positions

The robotic cart comes from the left side of the patient. R2 is connected to the arm, the camera is inserted and targeting is performed pointing on the sigmoid colon. After completing the targeting, arms one, three and four are connected to the trocars; a bipolar forceps is inserted in R1, a monopolar hook (or monopolar forceps) in R3, and a Cadiere grasper (or a tip-up grasper) in R4.

9.3 Dissection of the Left Mesocolon

The first step of the procedure is separation of the left mesocolon from the retroperitoneum: the bipolar forceps in R1 and the Cadiere forceps in R4 lift the mesocolon at the level of the inferior mesenteric vein (IMV), and the peritoneum is incised just below IMV, exposing the retrocolic plane.

The assistant forceps exerts countertraction on the retroperitoneum exposing the dissection plane (Fig. 9.3); the dissection is performed with the monopolar hook or scissors and proceeds from medial to lateral until reaching the colon.

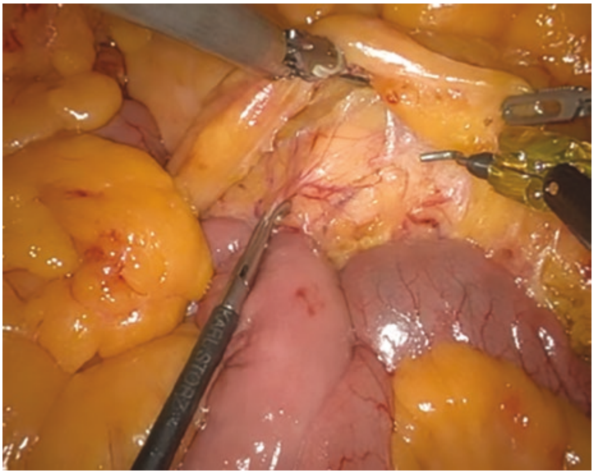

Fig. 9.3 Medial-to-lateral dissection. The bipolar forceps in R1 and the Cadiere forceps in R4 lift the descending mesocolon and the assistant grasper tractions the retroperitoneal reflection to expose the dissection plane

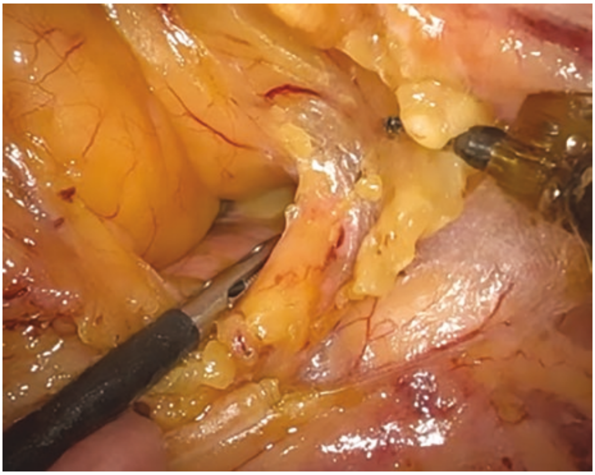

Fig. 9.4 Incision of the root of the transverse mesocolon. With the robotic graspers in R1 lifting the transverse mesocolon and the grasper in R4 lifting the descending mesocolon, the assistant forceps lowers the body of the pancreas and the root of the transverse mesocolon is completely detached from pancreas, to enter the lesser sac from below

9.4 Splenic Flexure Mobilization

The root of the transverse mesocolon is incised just anteriorly to the pancreas: the bipolar forceps lifts the transverse mesocolon cranially and the Cadiere forceps lifts the descending mesocolon; the assistant helps with a suction device or a grasper lowering the pancreatic body (Fig. 9.4). The root is incised two inches superiorly and two inches to the left of IMV, and the lesser sac in entered from below. Complete detachment of the root of transverse mesocolon from the pancreas is essential to fully mobilize the splenic flexure. IMV is isolated and sectioned between clips. The left coloparietal detachment is completed by reaching the previous medial-to-lateral dissection. Finally, a coloepiploic detachment is performed, and the splenic flexure is completely lowered.

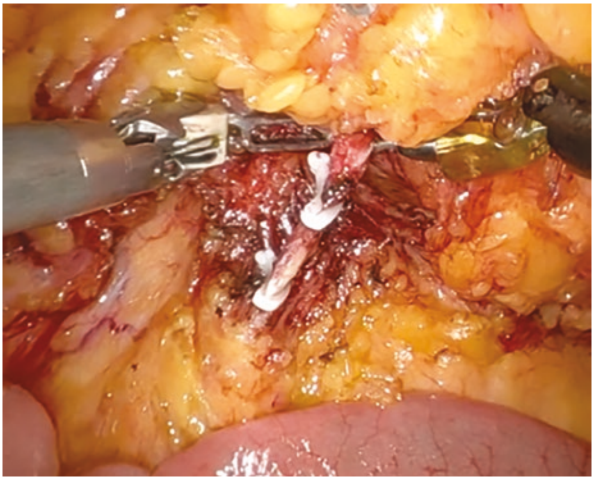

Fig. 9.5 Section of the inferior mesenteric artery

9.5 Inferior Mesenteric Artery Isolation and Lymphadenectomy

The peritoneum is incised at the level of sacral promontory and the mesorectal space is entered; the Cadiere forceps in R4 lifts the proximal rectum cranially to expose the root of inferior mesenteric artery (IMA), while the assistant forceps tractions the descending colon. The bipolar forceps in R2 lifts the left mesocolon and IMA is dissected at its origin, performing a central lymphadenectomy [9]; then, IMA is sectioned between clips (Fig. 9.5).

9.6 Section and Anastomosis

The upper mesorectum in dissected and the upper rectum is sectioned with a robotic linear stapler introduced in R3 after having removed the 8-mm trocar and having replaced it with a 12-mm robotic trocar able to harbor the stapler. Usually, a blue 45- or 60-mm cartridge is used for the transection; before extracting the colon, the mesocolon between the IMV and the IMA stumps is incised intracorporeally.

A suprapubic transverse incision is performed, and the colon is extracted; before the proximal transection, 3 mL of a reconstituted solution of indocyanine green with sodium chloride is injected intravenously, and the correct perfusion of the proximal colonic stump is assessed by switching the vision modality of the robotic camera from normal to infrared light (Fig. 9.6). This vision modality can be used extracorporeally, provided that all the operating room lights are switched off and a sterile drape is positioned over the robotic camera to lower the ambient light as much as possible.

After colon transection, the anvil of a circular stapler is introduced in the proximal colonic stump and fixed by a purse-string suture. During the extracorporeal phase of

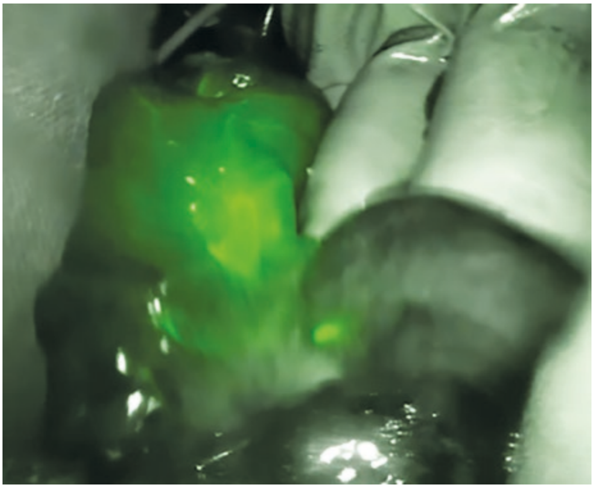

Fig. 9.6 Indocyanine green injection and assessment of colon perfusion. Extracorporeal assessment of proximal colon perfusion before section

the surgery, the robot remains docked. The colon is then reinserted in the abdominal cavity and the minilaparotomy is closed; the pneumoperitoneum is reinduced and a Knight-Griffen mechanical terminoterminal anastomosis is performed under robotic guidance.

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Part III

Rectal Cancer

Robotic Nerve-Sparing Total Mesorectal Excision

10

Walter Bugiantella, Michele De Rosa, Lorenzo Mariani, Fabio Rondelli, Stefano Scabini, and Graziano Ceccarelli

10.1 Introduction

In the last three decades, laparoscopic colorectal surgery has become the standard of care for benign and malignant diseases thanks to its better postoperative outcomes (less pain and morbidity, shorter length of stay, earlier return to daily activities) and to its oncological results, if compared to conventional open surgery [1].

The laparoscopic approach to rectal cancer (total mesorectal excision, TME) is a technically demanding procedure because the limited range of motion of the straight laparoscopic devices and the narrow operative field may reduce the accuracy of movements, leading to high rates of conversion to open surgery and the risk of involvement of the circumferential resection margins [2].

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The robotic-assisted approach may overcome the limitations of conventional laparoscopy in rectal surgery, thanks to wristed motion of instruments, steady camera, and ergonomic comfort [3–5], especially in narrow surgical fields and when high precision is required [6]. In the last two decades many studies have demonstrated that robotic rectal surgery (RRS) is feasible, effective and safe [7–9]. However, high quality of evidence regarding its superiority over open and laparoscopic rectal surgery (LRS) in postoperative outcomes is still lacking. Although the only RCT available to date failed to demonstrate the superiority of RRS in the conversion rate [9], two recent systematic reviews and meta-analysis concluded that RRS decreases the conversion rate when compared to LRS and is also associated with reduced blood loss [10, 11]. Moreover, long-term oncological outcomes remain to be demonstrated. Indeed, the costs of RRS are greater than those of LRS and this is a non-negligible aspect that impedes the wider spread of its use.

10.2 Robotic Surgical Techniques

Different surgical procedures have been described for RRS as a result of the technological evolution of the various devices, especially the da Vinci systems (Intuitive Surgical Inc., Sunnyvale, CA, USA).

Initially, because of the difficult and time-consuming docking of the first da Vinci robotic cart, the hybrid approach (with previous laparoscopic splenic flexure mobilization) was described. More recently, full-robotic procedures (with double or single docking) have been reported with the use of the Si and Xi da Vinci devices (which allow faster docking, easier setup and multiquadrant access) (see Video 10.1).

10.2.1 Patient Positioning and Robotic Cart Docking

The patient is placed supine with abducted legs positioned on adjustable stirrups, secured on the table to prevent sliding when Trendelenburg and lateral tilt are used. The robotic cart is placed at the patient's left side, docked according to the surgical step (splenic flexure or TME). After pneumoperitoneum induction, four 8-mm robotic ports are inserted along a straight line parallel and about 4 cm cranial to the costofemoral line, maintaining a distance of about 8 cm between ports. A 12-mm port is inserted in the right flank. The first assistant stands on the patient's right side.

10.2.2 Surgical Procedure

The three main steps of the surgical procedure are: splenic flexure mobilization (SFM), vascular control, and TME (Fig. 10.1).

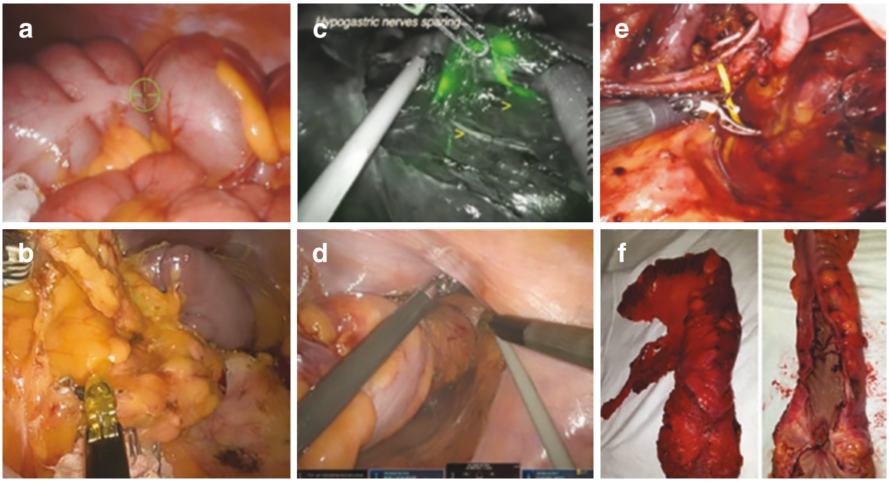

Fig. 10.1 (**a**) Splenic flexure docking. (**b**) Splenic flexure takedown completed. (**c**) Indocyanine green use for identification of lymph nodes (mesenteric artery ligation and nerve sparing). (**d**) View after total mesorectal dissection. (**e**) Lateral lymph node harvesting (in selected cases). (**f**) Specimen view

10.2.2.1 Splenic Flexure Mobilization

Different approaches have been described for SFM, according to the surgeons' preference. Commonly, it is performed using a medial-to-lateral approach with patient in reverse-Trendelenburg. Firstly, the origin of the inferior mesenteric vein (IMV) is identified and the Toldt-Gerota's plane is dissected; the transverse colon is lifted up with a grasper and, through the incision of the transverse mesocolic root at the level of the anterior pancreatic border, access to the lesser sac is obtained. The splenic flexure is then retracted medially by the assistant and the 4th arm, and the coloepiploic detachment is performed.

Other approaches are supramesocolic ("top-to-bottom", starting with the gastrocolic ligament transection to enter the lesser sac) or lateral (starting with the coloparietal detachment along the Toldt's fascia). A "bottom-to-up" approach along the pancreatic border is also described. SFM can be the last step as it may be omitted or partially performed in order to achieve a tension-free anastomosis (see Video 10.1).

10.2.2.2 Vascular Control

The approach to the origin of the inferior mesenteric artery (IMA) may be performed with the same docking as used for SFM or after re-docking for TME. In the latter case, the sigmoid colon is lifted up and the IMA is approached in a bottom-to-up fashion, cutting the peritoneum at the level of the sacral promontory to access the avascular presacral mesorectal plane, with identification and preservation of the hypogastric nerves. The superior rectal artery is identified as a landmark. The IMA is identified and isolated with the surrounding lymphatic tissue, divided 1–2 cm away from its origin (with or without left colic artery preservation) commonly using hem-o-lok clips (Teleflex, Wayne, PA, USA).

The medial-to-lateral dissection is performed to identify the left ureter and gonadal vessels up to the IMV, and the Toldt-Gerota's plane is identified. The IMV is isolated and transected. The dissection continues downward.

10.2.2.3 Total Mesorectal Excision

The patient is placed in a 20–25° Trendelenburg position with a slight right tilt. TME is carried out after redocking the robotic cart and with the bipolar forceps placed in the left flank, according to Heald's principles, along the avascular plane in order to preserve the hypogastric nerve and sacral venous plexus.

The dissection starts posteriorly along the plane between the endopelvic visceral fascia and endopelvic parietal fascia. The mesorectal dissection in a TME is performed in a "cylindrical" fashion down to the level of the levator ani; the assistant maintains a cranial traction of the sigmoid colon, during dissection, the seminal vesicles or vagina are important landmarks. The left lateral pelvic fascia is then dissected until the pelvic nerve plexus is identified. During this phase a 0° camera or up-down vision may be helpful for a better visualization.

Rectal transection is performed with robotic or conventional laparoscopic staplers. Vascular perfusion of the rectal stump and proximal colon may be evaluated with the integrated fluorescence imaging system after intravenous administration of indocyanine green [12].

A stapled end-to-end low/ultralow colorectal anastomosis or a manual coloanal anastomosis are performed depending on the tumor distance from the anal verge.

10.3 Results

10.3.1 Intraoperative Outcomes

Data from a meta-analysis and RCTs reported a longer operative time for RRS compared to LRS and open surgery [7–11, 13–16]. This was mainly due to time-consuming double-docking procedures and to the need to change the robotic instruments. In the last few years, the use of the da Vinci Xi platform, with its technology improvements (endoscope connection in any arm, multiquadrant access, longer instruments), has led to a significant reduction in operative time, now comparable to laparoscopy [7, 17].

The ROLARR trial failed to demonstrate superiority in the conversion rate for RRS compared to LRS [9]. However, other studies showed significantly lower conversion rates in the robotic group, especially in low rectal surgery and in the subgroup of high-risk patients (male, neoadjuvant radiochemotherapy, T3N1, obese) [7, 13, 18–21].

10.3.2 Short-Term Postoperative Outcomes

To date, no significant statistical difference was shown in complication rates between robotic, laparoscopic and open groups in most published studies [7, 9]. However, some recent papers reported lower overall septic complication rates in RRS versus LRS (1.6% vs. 3.1%, $p = 0.02$), lower wound dehiscence rates (0.1% vs. 0.7%, $p = 0.05$), shorter length of stay (3.8–4.8 vs. 4.7–6.3 days, $p < 0.001$), and shorter time to first flatus [22–25]. That is probably related to the reduction in conversion and complication rates.

10.3.3 Functional Outcomes

Two recent meta-analyses reported better functional results after RRS for cancer when compared to LRS: both urinary and sexual function in men at 6 and 12 months after surgery were significantly better in the RRS group [24, 25]. Mixed urinary and sexual function outcomes were also reported for women, with no significant differences in meta-analysis results.

10.3.4 Oncological Outcomes

The ROLARR trial reported no statistically significant differences in positivity of the circumferential resection margin (5.1% vs. 6.3% in RRS and LRS groups, respectively, $p = 0.56$), involvement of the distal resection margin, and the pathological assessment of the quality of the plane of surgery [9]. Another RCT from Korea reported the same results [26]. A recent meta-analysis showed that RRS is the better way to achieve a complete TME [25]. Therefore, to date it cannot be concluded that RRS is superior to LRS.

Reports of long-term oncologic outcomes for RRS are still limited. Park et al. and Cho et al. found no differences in the 5-year overall survival, disease-free survival and local recurrence rates [27, 28]. Kim et al. showed that RRS was a significant positive prognostic factor for overall survival in a multivariate analysis [29]. However, Park et al. found RRS to be advantageous in the subgroup of patients who received preoperative chemoradiation and had ypT3–4 tumors after neoadjuvant treatment. The 5-year distant and local recurrence rates were 44.8% and 5.0% in the LRS group and 9.8% and 9.8% in the RRS group, respectively, reaching statistical significance. These data suggest that RRS may be advantageous in most complex cases with high-risk features of recurrence [7].

10.3.5 Cost Analysis

One of the most debated questions of robotic surgery is the costs of acquisition and maintenance. To date, most of the available studies in different surgical specialties show higher costs related to robotic surgery compared to laparoscopy [30–32]. However, most of these studies focused only on the direct costs related to the purchase and maintenance of the robot and to the purchase of the robotic devices. The indirect costs related to the higher conversion rate (with consequent prolonged length of stay and postoperative complications) of laparoscopy and open surgery are rarely taken into account, but they could be carefully evaluated because they have a significant negative impact on the overall costs for each institution and may counterbalance the higher expenditure related to the robotic equipment.

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Robotic Intersphincteric Resection and Abdominoperineal Resection for Low Cancer

11

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Michele Di Marino, and Andrea Coratti

11.1 Background

Despite the exponential diffusion of robotic surgery in the whole field of colorectal surgery, its application is best suited for highly demanding procedures such as those required to treat low-lying rectal cancer [1]. Growing evidence exists supporting possible advantages of robotic surgery over conventional laparoscopic techniques in performing rectal anterior resection with intersphincteric resection (ISR) and robotic abdominoperineal resection (APR) [1–3]. Herein we examine the technical details of our practice of performing ISR and APR using a fourth-generation, four-arm surgical robot (da Vinci Xi, Intuitive Surgical, Sunnyvale, CA).

11.2 Equipment, Patient Positioning and Operating Room Setup

Recommended main equipment for both ISR and APR procedures:

- 30° endoscope
- 0° endoscope
- fenestrated bipolar forceps

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– monopolar scissors
– large needle driver
– VesselSealer (optional)
– laparoscopic endostapler: 60-mm blue cartridge.

The patient is initially placed in a lithotomy Trendelenburg position (modified Lloyd-Davis) with both arms abducted on arm boards and the legs are placed on stirrups. Adequate soft padding is provided to prevent pressure-related injuries. Generally, a 20° Trendelenburg position is given, with a steep right lateral tilt (15°). The bedside surgeon(s) is on the right of the patient. Pneumoperitoneum is obtained using the Veress needle in the left hypochondrium. A standard laparoscopic 10–12-mm port (L1), and five robotic 8-mm ports (R1–R5) are placed as illustrated in Fig. 11.1. Unlike most other surgical teams, we favor the use of the assistant retraction instrument (i.e., the tip-up grasper) through the robotic port on the right side of the surgical field. We do believe such port configuration has distinct advantages in terms of exposure during pelvic dissection as compared to the conventional specular positioning, while not impairing traction assistance during the remainder steps of the procedure. The peritoneal cavity is firstly inspected to confirm the preoperative diagnosis and rule out metastatic or concomitant disease. The greater omentum is lifted cranially over the transverse colon. The small bowel is carefully displaced cranially and to the right until adequate visualization of the retroperitoneal plane is achieved, ideally from the promontory to the ligament of Treitz. We routinely employ a single-docking technique by positioning the cart of the robot beside the left lower quadrant of the patient, which allows the arms to cover the entire range of movements required in both the abdominal and pelvic phase of the procedure. When moving from the abdominal to the pelvic phase of the procedure, the bipolar forceps in R4 is moved to the R5 access in the left flank (Fig. 11.1) and the targeting is

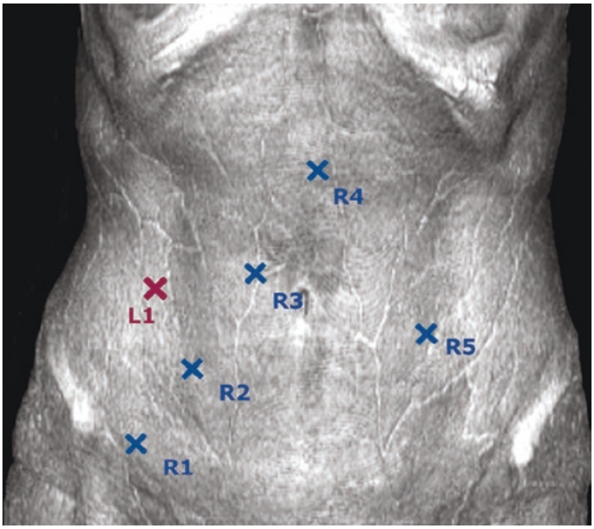

Fig. 11.1 Port setting in robotic intersphincteric resection for a low-lying rectal cancer

re-done, pointing at the midline of the pelvis. Typically, R2 is used for the monopolar scissors, which we favor for all dissections. The bipolar fenestrated forceps and the tip-up grasper are mounted on R4 and R1, respectively. The bedside surgeon utilizes the laparoscopic access (L1) to introduce gauzes and threads, and deliver irrigation and suction, as needed. The R2 port is usually placed at the site of future ileostomy, to limit surgical incisions. Similarly, R5 is usually positioned at the intended side of colostomy in the case of APR.

11.3 Technique/Procedure

The tip-up forceps in R1 grasps the distal sigmoid/sigmoid-rectal junction to put it under traction anteriorly and upwards to visualize the groove underneath the inferior mesenteric artery (IMA) at the level of the sacral promontory. This maneuver promotes stretching of the mesenteric-mesocolic fold which is scored transversally just medial to the right common iliac artery. This allows identification of the avascular plane to be dissected along the inferior aspect of the ileopelvic mesocolon and mesorectum, while maintaining the genitourinary and nervous structures such as the left ureter, gonadal vessels and hypogastric nerves just beneath the retroperitoneal layer. This avascular, inframesocolic window is taken from medial to lateral, with careful attention to avoid any thermal injury to the retroperitoneal structures. To do so, the tip-up grasper provides continuous traction of the ileopelvic mesocolon to the left and upwards toward the anterior abdominal wall, while the dissection is led using both the bipolar forceps in R4 and monopolar scissors in R2 with minimal electric dispersion. Cephalad dissection permits easy identification of the origin of the IMA along with the superior hypogastric plexus. Once the left ureter, left gonadal vessels, and origin of the hypogastric nerves are visualized, IMA is circumferentially isolated, skeletonized and divided between hem-o-lok clips. The IMA is divided proximally to obtain adequate clearance of the lymphatic and fatty tissue around its aortic origin, while ensuring adequate distance from the level of the superior hypogastric plexus, required for its careful preservation.

The tip-up grasper is now introduced underneath the inframesocolic window, which is gently elevated. The caudal portion of the ligament of Treitz is divided with utmost respect for the duodenojejunal flexure. The inferior mesenteric vein (IMV) is thus easily exposed right below the inferior border of the pancreas, prepared and divided between hem-o-lok clips. This permits further medial-to-lateral and cephalad dissection between the Toldt's fascia anteriorly and the Gerota's fascia posteriorly. This dissection is usually led as far as possible in both a lateral and cranial direction. A small gauze is usually introduced and pushed cranially and laterally into this window to facilitate subsequent dissection.

By retracting cranially the greater omentum, whose free inferior margin has been overturned over the transverse mesocolon and the stomach, the greater omentum is freed from the transverse colon to enter the lesser sac. This maneuver usually commences just to the left of the median line. Once the lesser sac is entered - this is confirmed by direct visualization of the posterior aspect of the stomach - the remaining attachments between the greater omentum and the splenic colonic flexure are dissected to the level of the inferior pole of the spleen. The splenocolic ligament and the so-called plica spleno-omentalis (also known as criminal fold of Morgenstern) are then carefully divided avoiding any undue traction maneuver [4]. The remaining transverse mesocolon must be dissected at its origin, just a few millimeters away from the pancreatic capsule, to completely release the distal transverse mesocolon along with the splenic flexure. To do so, the lateral attachments of the splenic flexure to the parietal peritoneum of the abdominal wall are first divided with a lateral-to-medial approach and the previously developed plane underneath the mesocolon is thus encountered, generally easily identifiable by the presence of the gauze, bulging through the thin layer of the transverse mesocolon itself. Having done this, the left portion of the root of the transverse mesocolon is divided proximally, up to the middle colic trunk. For the achievement of this step, we generally favor a superior, lateral-to-medial approach, although the inframesocolic route or a medial-to-lateral dissection may be used on a case-by-case basis. During the entire procedure of splenic flexure takedown, the use of the VesselSealer may aid in the presence of significant visceral obesity, though we do not recommend its routine use.

The camera arm (R3), now mounted with a 0° endoscope is re-targeted to the midline of the pelvis, while the bipolar forceps are moved to the robotic port in the left flank (R5). The bedside surgeon(s) remains on the right side of the patient, now employing the upper robotic port (R4) as a second access used to retract the sigmoid-rectal junction out of the pelvis. In female patients, the uterus is usually anchored to the anterior abdominal wall via a monofilament thread passed through the uterine fundus for better exposure. The descending and sigmoid colon are now mobilized, developing caudally and laterally the already created plane of dissection. In typical situations, this maneuver is almost bloodless and straightforward. With the help of gentle traction by the tip-up grasper of the upper rectum upwards and anteriorly, posterior dissection continues following the course of the superior rectal artery. This dissection is conducted in the avascular "holy" plane between the mesorectal fascia superiorly and the presacral Waldeyer's fascia inferiorly, thus preserving and leaving intact the underlying hypogastric nerves. The incision of the visceral peritoneum of the distal sigmoid is progressively prolonged caudally on both sides of the upper rectum, and then anteriorly, where the dissection proceeds along the recto-vaginal septum/the Denonvilliers' fascia (see Video 11.1). During this maneuver, the tip-up grasper in R1 has a crucial role in retracting and preserving such structures anteriorly. Laterally, a combination of traction and countertraction by the tip-up grasper and the bipolar forceps is of utmost importance to carefully identify the lateral aspects of the perirectal fascia and the rectogenital septum or Denonvilliers' fascia, which laterally fuses with the lateral pelvic fascia. Precise identification of such structures is particularly important in allowing complete preservation of the autonomic pelvic plexus and the so-called neurovascular bundles of Walsh. The middle rectal arteries are inconstantly encountered during lateral dissection as piercing on both sides the perirectal fascia. They are generally controlled with bipolar energy and easily divided. The TME dissection is taken down to the pelvic floor, until the distal rectum is completely and circumferentially isolated from the plane of the levator ani muscle, where the mesorectum thins out and is virtually absent.

11.3.1 Intersphincteric Resection

The so-called intersphincteric plane should now be entered. To do so, the so-called hiatal ligament, on the posterior aspect of the longitudinal muscle of the rectum must be cut firstly. The plane between the external surface of the longitudinal muscle of the anal canal and the internal surface of the external anal sphincter (EAS) is followed and developed as distally as needed to ensure free distal resection margins, ideally aiming at a 1-cm clear margin (see Video 11.1). Anterior and posterior dissection is generally more technically demanding as compared to lateral mobilization, owing to the intimate contiguity of the longitudinal muscle of the rectum to the rectourethralis muscle, and the anococcygeal ligament, respectively. However, entire excision of the internal anal sphincter (IAS) is not mandatory in all patients and a subtotal or partial ISR can be also performed depending on tumor location and length of the anal canal itself. The abdominal phase of the procedure terminates with the identification and isolation of the site of the future ileostomy in the distal ileum using a tape or a vessel loop. The robot is now undocked and transanal dissection follows. The patient is positioned in the lithotomy position. Usually, the Lone Star (CooperSurgical, Trumbull, CT, US) retractor system is employed during perineal dissection. The anal mucosa along with the corresponding IAS is scored circumferentially at the intended level of distal margin. The anorectal junction/rectum is thus carefully dissected free of the EAS and the levator ani circumferentially, until the transabdominal dissection plane is encountered. The future specimen is thus passed through the residual anal canal and delivered to the outside. Proximal division at the descending colon is then carried out after careful assessment of local microcirculation adequacy by indocyanine green fluorescence imaging, using the Firefly function. To fashion a coloanal anastomosis, the proximal colonic stump is firstly anchored to the EAS, just cranially to the mucosal section, and then the residual anal canal is anastomosed to the proximal colon using full-thickness, absorbable 4/0 interrupted sutures. Four cardinal stitches are initially placed, followed by two further stitches to each of the derived quadrants. The ileostomy loop is exteriorized in the right flank, usually enlarging the R2 port access. One drain is usually placed in the pelvis posterior to the transposed descending colon. Port incisions are closed and the loop ileostomy is opened.

11.3.2 Abdominoperineal Resection

During APR, splenic flexure release is generally not needed, and partial mobilization of the descending colon is usually sufficient to create a tension-free colostomy in the left flank. The vascular phases of the procedure, as well as TME dissection are performed in the same manner as for ISR. The descending colon, at the intended level of proximal resection, is now prepared along with its mesocolon. The marginal arcade is identified, doubly ligated and divided. The corresponding colon is thus transected using a linear endostapler. Subsequent dissection differs from ISR in that, once the plane of the levator ani muscle is reached, further dissection through the hiatal ligament and the raphe of iliococcygeus and pubococcygeus muscle is commenced in a perpendicular direction through the perineum, to encompass the entire EAS complex in the resection. Such posterior dissection is then prolonged laterally, and the pelvic floor is divided bilaterally. Any hematic oozing is carefully controlled with the bipolar forceps, to facilitate subsequent perineal rendez-vous. Dissection of the anterior aspect of the anorectum follows, which proceeds transabdominally as deep as possible, mostly using the scissors with minimal energy dispersion and constant care paid to avoid any direct or thermal damage to the vagina or membranous urethra. Finally, from the left portion of the greater omentum, a well-vascularized pedicle is created whenever possible and brought into the pelvis to reduce the risk of postoperative herniation through the pelvic defect. Then, the robot is undocked and the perineal phase of the procedure is commenced with the patient in the lithotomy position, with the lower limbs in stirrups and the buttocks centimeters off the edge of the operating table. The anus is usually sutured to limit contamination and favoring traction of the future specimen. An elliptical incision is created circumferentially around the anus to include the entire sphincter complex, and possibly extended in a specific direction to ensure adequate circumferential margins if any residual disease exists around the anal canal. The ischiorectal space is progressively dissected on both sides before proceeding with posterior and anterior dissection. Posteriorly, just above the coccyx, the anococcygeal ligament is divided to join the plane of abdominal dissection. At this point, usually after accurate digital exploration, the levator muscle is divided circumferentially until the specimen is released completely except for its anterior attachments. During this phase, according to tumor site and extent, we advocate a “selective extra-elevator (cylindrical) dissection” where needed, to ensure adequate circumferential surgical margins. The proximal end of the specimen is inverted and pulled out of the perineum, leaving it anchored only by its anterior attachments. With adequate traction and gentle exposure provided by the assistant, the specimen is entirely excised with sharp dissection. Direct assistance by gentle digital palpation of the rectovaginal or rectourethral septum is usually helpful to supervise the appropriate plane of division. The perineal wound is generously irrigated with saline. Careful perineal closure is crucial, as wound-related complications are responsible for most of the postoperative morbidity following robotic APR. A layer-by-layer reapproximation is the preferred method of closure, with the aim of minimizing the residual dead space. Finally, the descending colon is exteriorized in the left flank, usually utilizing the R5 port incision. Port incisions are closed in a conventional fashion and the end colostomy is eventually matured.

Patients can be started on clear liquids on the same day of surgery and advanced to a solid diet as tolerated. Urinary catheter and surgical drains are usually removed on postoperative day 2 and the patients typically discharged home between postoperative day 4 and 5.

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Robotic Lateral Pelvic Lymph Node Dissection for Advanced Low Rectal Cancer

12

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12.1 Introduction

The Western and Eastern classification of nodal metastases differ regarding the definition of regional lymph nodes. Historically, lateral pelvic nodes (LPN) in the obturator area were regarded as distant metastases according to the American Joint Committee on Cancer (AJCC) staging system, while the current edition of the AJCC staging manual defines internal iliac nodes as regional lymph nodes [1]. Conversely, the ninth edition of the Japanese guidelines considers all LPN as regional [2]. Interestingly, a study on 3487 Japanese patients with locally advanced low rectal cancer (LARC) who received LPN dissection (LPND) showed that overall and recurrence-free survival was slightly, but not significantly, worse in patients with obturator LPN metastases compared with those with internal iliac LPN metastases. Therefore, the authors proposed obturator LPN metastases as local disease [3]. Standard LPND for LARC includes the removal of the lymphoareolar tissue from both the obturator and internal iliac areas, given that they are the most common sites of LPN metastases [4].

Also, treatment of LARC differs between the East and the West. While Western countries contemplate neoadjuvant chemoradiotherapy (CRT) followed by total

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mesorectal excision (TME) [5], the Japanese routinely perform prophylactic or therapeutic LPND [2]. These practices are based on the results of large randomized controlled trials, which showed lower locoregional recurrence rates with preoperative radiotherapy (5%) [6, 7] or prophylactic bilateral LPND (7.7%) [8, 9] compared to TME alone (11–13%). Nonetheless, there is evidence that CRT and TME may not be sufficient in the case of suspicious LPN, as the vast majority of locoregional recurrences (54–83%) in these patients is found in the lateral pelvic sidewall [10, 11]. Moreover, LPN metastases are a strong predictor of survival and local recurrence [12]. Since the rate of metastatic LPN in prophylactic LPND is lower than 10% [9], some authors have suggested selective LPND after preoperative CRT for patients with suspicious LPN [11]. Debate still exists on the optimal criteria for the definition of suspicious LPN, but most authors consider the short or long axis of the largest LPN on pre- [11, 13–16] or post-treatment imaging [13, 17]. An international multicenter study by the Lateral Node Study Consortium re-evaluated the pretreatment MRI of 1216 patients with LARC. They identified a significantly higher risk of local recurrence (19.5%) and lateral local recurrence (15%) at 5 years in patients with LPN equal to or greater than 7 mm in short axis on pretreatment MRI [11]. The indication for LPND at the Colorectal Cancer Center at Kyungpook National University Hospital is an enlarged suspicious lymph node in the pelvic sidewall on pretreatment MRI with a short axis greater than 5 mm, regardless of response to preoperative treatment [18, 19].

LPND is considered by most surgeons a technically demanding procedure. The risk of intraoperative bleeding and postoperative genitourinary dysfunction limited its diffusion in the West [20]. Nonetheless, data from specialized Eastern centers demonstrated that the slight increase in short-term complications and functional morbidity is offset by improved long-term oncological outcomes. Data from the JCOG0212 trial comparing 351 patients receiving open TME plus prophylactic bilateral LPND, with 350 undergoing TME alone, reported increased intraoperative blood loss (576 mL vs. 337 mL, $p < 0.001$) in the LPND group, but no differences in terms of severe complications and anastomotic leak [21]. Moreover, laparoscopic LPND compared to the open approach showed reduced blood loss, shorter hospital stay, and a higher number of retrieved lymph nodes [22, 23]. The robotic platform represents an optimal option for LPND, providing good traction and countertraction, high-quality images and stable camera, as well as articulating and precise instruments for fine dissection. In fact, robotic LPND is associated with decreased intraoperative blood loss and lower rate of urinary retention compared to the laparoscopic approach [18]. Moreover, initial evaluation of long-term outcomes showed comparable local recurrence rates and disease-free survival of robotic and laparoscopic LPND [19]. Despite the advantages of the robotic platform, LPND remains technically demanding. Analysis of 100 patients undergoing robotic TME plus LPND showed a learning phase of about 50 cases. Even in the competence phase, urinary dysfunction represented the most frequent complication, although the incidence decreased from the learning to the competence phase (39.4% vs. 16.7%) [24].

Herein we report the details of our technique of LPND using a fourth-generation, four-arm surgical robot (da Vinci Xi, Intuitive Surgical, Sunnyvale, CA).

12.2 Equipment, Patient Positioning and Operating Room Setup

Recommended equipment:

- 30° down endoscope
- fenestrated bipolar forceps
- monopolar curved scissors
- tip-up grasper.

LPND is carried out after completion of rectal dissection and rectal transection and before creation of the anastomosis. Therefore, the patient is in the supine position, with a 15–20° Trendelenburg position and a left lateral tilt (10–15°). The bedside surgeon is on the right of the patient. Two different port setups are possible, depending on the availability of a Uni-Port (Dalim Medical, Korea) or similar single-port devices. Uni-Port is placed in the right-lower quadrant in the future ileostomy site and will accommodate one robotic 8-mm port as well as assistant trocars. As illustrated in Fig. 12.1a, one additional 5-mm assistant port, and four robotic 8-mm ports are placed. Figure 12.1b illustrates trocar setting in the absence of the Uni-Port (four robotic 8-mm ports and two 5-mm assistant ports). Robotic accesses are generally placed along an oblique line. After completion of rectal dissection, left LPND is generally performed first, maintaining the same trocar and instrument setup as for rectal resection. Typically, R1 is used for the tip-up grasper, which we favor for major tractions. The bipolar fenestrated forceps and the monopolar curved scissors are mounted on R2 and R4, respectively, for finer traction and dissection.

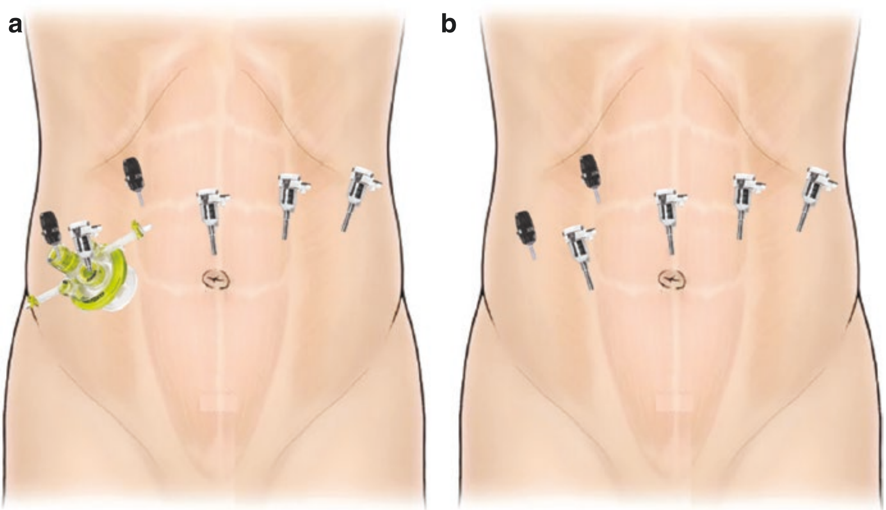

Fig. 12.1 Port setting. (**a**) Modified setting with Uni-Port device. (**b**) Standard setting

Bipolar fenestrated forceps can also be used as an energy device to control minor bleeds. R3 holds the 30° endoscope. The bedside surgeon utilizes the laparoscopic accesses to assist with the counter-traction, deliver irrigation and suction, and apply energy devices as needed. For right LPND, the bipolar fenestrated forceps, endoscope, monopolar curved scissors, and tip-up grasper are repositioned in robotic trocars R1 to R4, respectively. For female patients, a 2-0 Prolene suture with straight needle is usually recommended to suspend the uterus anteriorly and the Fallopian tube-ovary complex to the lateral abdominal wall to allow better exposure.

12.3 Technique/Procedure

12.3.1 Surgical Anatomy and Dissection

We standardized the surgical steps based on anatomical landmarks of the lateral pelvic sidewall, as previously reported [25]. The lateral pelvic sidewall is defined with three potential fascial planes, as illustrated in Fig. 12.2. The planes are developed in the order of A, B, and C, and they represent the boundaries of standard LPND. Dissection commences at plane A, which is the innermost layer containing the ureter, hypogastric nerve, pelvic splanchnic nerves, and pelvic plexus. Plane B

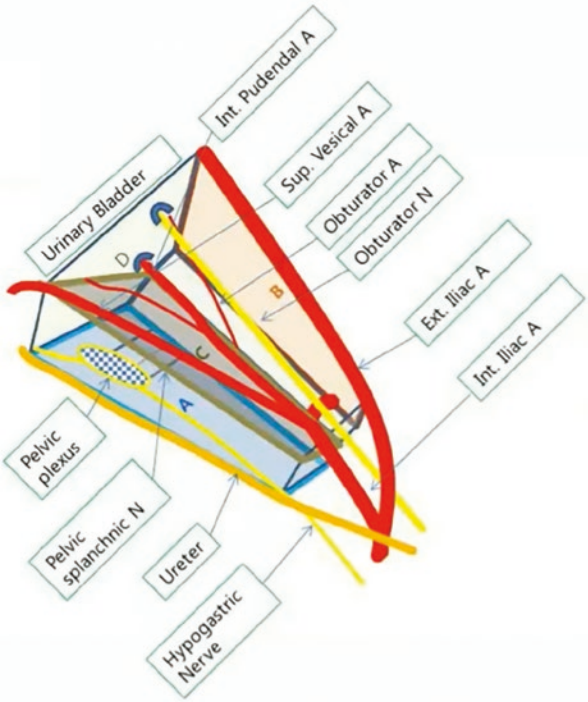

Fig. 12.2 Division of right lateral pelvic sidewall into three compartments by planes A (medial plane), B (lateral plane), and C (central plane)

is the outmost layer, defined by the medial aspect of the external iliac vessels and psoas and the obturator internus muscle. Plane C is a potential fascial plane just lateral to the internal iliac vessels and their branches, continuing to the dorsolateral wall of the urinary bladder. The floor is defined by the lumbosacral nerve trunk and a part of the pelvic bone and muscles. All vascular structures are preserved whenever possible, unless encapsulated by metastatic lymph nodes. In that case, en-bloc resection is performed, and vessel division is carried out with LigaSure delivered through the assistant port. Standard LPND usually involves dissection of the obturator and internal iliac nodes. External iliac and common iliac node dissection is performed only in selected cases with highly suspicious metastatic nodes in these areas.

Dissection starts along plane A, which separates the medial side of the internal iliac node group (see Video 12.1 for the detailed procedure). This plane is developed through the avascular space between the ureter and common iliac vessels, and then continued between the internal iliac vessels and the hypogastric nerve, and between the pelvic plexus, pelvic splanchnic nerves, and terminal branches of the internal iliac vessels on the bottom. The ureter near the common iliac artery is gently grasped with the bipolar grasper, retracted medially, and blunt or sharp dissection with the monopolar curved scissors is carried out to separate it within a fascia from the pelvic sidewall. Dissection is then continued caudally and dorsally to separate the thin medial layer containing the hypogastric nerve, the pelvic plexus, and the pelvic splanchnic nerves from the pelvic sidewall. Dissection is carried on until branches of the internal iliac vein are identified on the lateral side, and fibers of the pelvic autonomic nerves on the medial side. Subsequently, plane B is developed. An incision is made along the medial aspect of the external iliac artery to divide lymphoareolar tissue of the obturator node group. The tip-up grasper is used for lateral retraction of the external iliac vessels while dissection is continued downward over the surface of the external iliac vein, psoas muscle, and obturator internus muscle. Occasionally, an obturator accessory vein branches off from the external iliac vein, representing the distal landmark of dissection along this plane. Finally, we make plane C, which is medially bounded by the terminal branches of the anterior division of the internal iliac vessels, dividing the medial aspect of the obturator node group. The branches encountered in a cranial-to-caudal order include the umbilical artery, superior vesical artery, obturator artery, inferior vesical artery, and the internal pudendal artery at its entrance in the Alcock's canal as the most distal landmark of dissection.

The branches of the internal iliac artery can be grouped based on their direction.

- *Posterior division*: iliolumbar, lateral sacral, superior gluteal.
- *Anterior division*: obturator, umbilical and primary branch superior vesical, uterine (± vaginal), inferior vesical, middle rectal, inferior gluteal, internal pudendal.

Variations in the anatomy of the branches of the internal iliac artery are common, with the superior vesical artery that may arise directly from the internal iliac artery just distally to the umbilical artery. Caution should be used for dissection of the superior gluteal artery because it runs very close to the sciatic nerve.

12.3.2 Lymphadenectomy

After all three planes are securely developed, actual lymph node dissection is carried out. First, obturator node dissection starts from the bifurcation of the common iliac vessels to remove all lymphoareolar tissue between planes B and C. Special attention should be directed toward identification and preservation of the obturator nerve and the lumbosacral trunk at the bottom. The tip-up grasper in the third robotic arm is used for distal counter-traction in the bladder area, while the assistant aids with retraction of the external iliac vessels when needed. Bipolar fenestrated forceps with the open jaws technique can help to effectively expose the surgical field and conduct fine dissection. Again, obturator node dissection starts at the bifurcation of the common iliac vessels, where the nodes are separated from the obturator nerve, and continues caudally toward the obturator foramen. Distally, the surface of the bladder is exposed. The distal side of the obturator nerve and artery is exposed, and the lymph nodes are dissected from these structures. The dorsal boundary of dissection is the lumbosacral trunk, which should be carefully dissected without injury. Lymph nodes are also dissected from the lateral aspect of the umbilical artery and internal pudendal vessels and nerve. Dissection of the obturator nodes is completed by removing all lymphoareolar tissue between planes B and C. A suspicious index lymph node can be marked by applying a hem-o-lok.

Then, the internal iliac nodes are dissected between planes A and C and through the distal branches of the internal iliac artery. The assistant grasps the ureter and retracts it medially, while the tip-up grasper pushes the parietal peritoneum upwards and laterally. The most critical area is dissection of the distal internal iliac node group which is an entry of lateral lymphatic flow from the rectum. Complete dissection should be performed along the terminal branches of the internal iliac vessels until identification of the internal pudendal artery, because it is the site most commonly containing metastatic lymph nodes. Dissection starts on the medial side of the internal iliac artery and continues along the medial side of the umbilical artery. The superior vesical artery is then identified and preserved, and dissection is carried on along the terminal branches of the internal iliac vessels until identification of the internal pudendal artery. We then remove remaining lymphoareolar tissue around the inferior vesical artery and the deepest area of the pelvic sidewall. The final appearance of the dissected lateral pelvic sidewall is shown in Fig. 12.3.

The specimens are collected in a plastic bag and extracted through the Uni-Port, if present, or through a periumbilical minilaparotomy on the midline using a plastic wound retractor. Finally, the abdominal cavity is checked for adequate hemostasis and generously irrigated with saline. We routinely use one drain in the pelvis to prevent postoperative lymph collections. The abdomen is carefully desufflated and the port accesses and extraction site are closed. Loop ileostomy is created when deemed necessary.

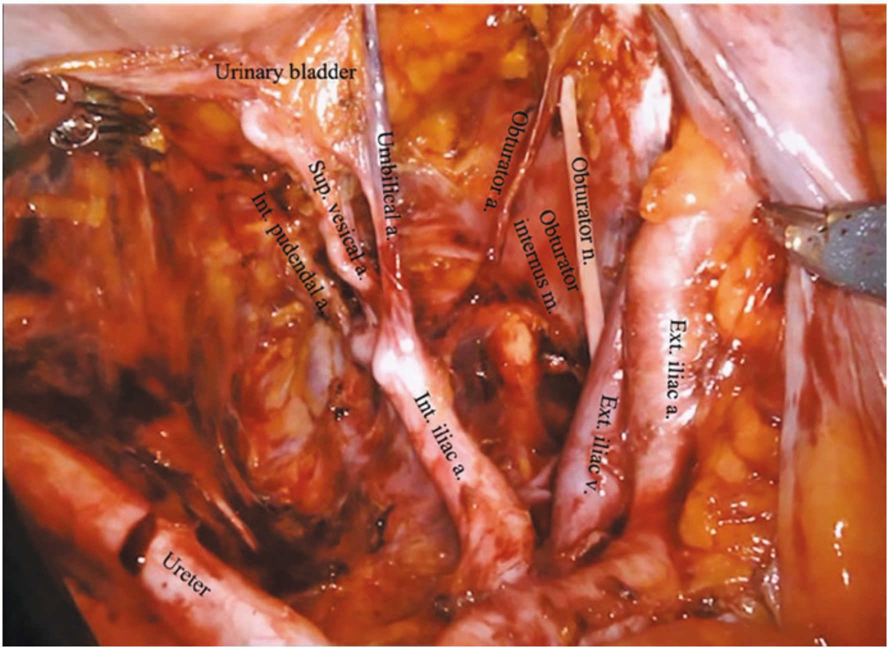

Fig. 12.3 Final view of dissected lateral pelvic sidewall

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Transanal Minimally Invasive Surgery: From Transanal Endoscopic Microsurgery to Robotic Surgery

13

Monica Ortenzi, Amir Szold, and Mario Guerrieri

13.1 A Brief History of a Long-Awaited Surgery

Rectal cancer treatment has advanced in nearly 300 years from producing hopeless morbid outcomes to being a potentially curative treatment, with constant improvements in quality of life.

The first description of the signs and symptoms of rectal cancer date back to 1376 [1], but no attempts to excise it were reported until 400 years later, and its excisional treatment maintained only a palliative purpose until the early eighteenth century [1], when the so-called posterior excision was described. This was a fairly rudimentary and disruptive technique, which remained popular until the 1940s [2]. Subsequent approaches, from the notorious Kraske to the York-Mason techniques were mere variants of this first approach [1, 3].

Early attempts to exploit an abdominal route for the resection of tumors were mostly experimental, sometimes accidental and, above all, performed with little attention to oncological principles [1, 2]. Excisional procedures utilizing the perineal, vaginal and sacral approaches prevailed until Miles' abdominoperineal resection in 1908 revolutionized the principles for a correct oncological resection [4]. The consequent improvement in survival caused attention to shift towards procedures ensuring sphincter preservation and better functional outcomes [5].

In 1948, rectal cancer surgery by anterior resection was introduced [6] and later technological advancements, such as the circular stapler in 1977, helped to develop and refine this technique [7–10]. From the establishment of the anterior resection

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steps by Dixon, blunt or manual presacral pelvic dissection for rectal cancer constituted the technique of choice [6]. However, this type of dissection was inevitably burdened by the risk of breaching the mesorectum by not following predefined planes, and consequently leaving residual cancer-containing mesorectum within the pelvis [6]. At this stage, the worldwide 5-year survival rates were only 45–50% for all curable stages and the expected local recurrence rates were 30–40% [11].

To Heald goes the merit to have recognized that the midline hindgut (rectum) and its mesorectum were embryologically derived together and to have introduced the concept of “total mesorectal excision” in 1982 [11]. Total mesorectal excision, which involves sharp en-bloc resection of the tumor and mesorectal tissue to the level of the levator muscles, rapidly became the gold standard for anterior rectal resection for rectal cancer [12].

At the same time, however, another revolution was underway: the transanal route.

13.2 The Transanal Revolution: Transanal Endoscopic Microsurgery

Transanal endoscopic microsurgery (TEM), as it was introduced in the 80 s, constituted an unthinkable revolution of what was still considered a disruptive and debilitating surgery [12].

TEM was first introduced as a valid alternative to resect adenomas not suitable for local or colonoscopic excision [12]. It was soon clear, however, that the technique was not only technically superior to the standard local excisions performed with the anal retractor, but it could also be considered a viable alternative to extensive resections for benign polyps at first, with good clinical and oncological outcomes [13–16].

There are, however, few but still important aspects that prevented a larger adoption of a life-saving technique.

The major drawback of this technique is that many aspects of its oncological safety are still debated. Indeed, local excision results in closer resection margins and does not allow for sampling of lymph nodes [17]. Additionally, adequate local staging methods utilizing either intrarectal ultrasound or pelvic magnetic resonance imaging have allowed only a small group of patients with distal rectal tumors to be candidates for a transanal local excision due to accuracy issues. Emerging technology allowing improved exposure has potentially made transanal approaches more feasible [17, 18]. For the above reasons, TEM is now recommended for small (<3 cm) and low grade (well-to-moderately differentiated) early-stage rectal cancers (T1N0), according to the international guidelines [19, 20]. Nonetheless, in high volume centers TEM has been proved to be feasible and oncologically safe even for localized tumors that extend into the muscularis propria (T2N0), and the very different oncological behavior of some of these tumors is the basis of fervent debate and research on this topic [21]. Local excision can also be offered as a palliative measure to address local disease in patients with advanced lesions (T3 or above, N1 or above) who are unable to safely tolerate a major abdominal surgery [15].

Another aspect concerns technical issues. TEM is a demanding technique that has a slow learning curve and that remains challenging even after the latest technological advancements and modification of the traditional instrumentation [15].

Lastly, TEM requires a specific set of dedicated instrumentation and the purchasing costs may constitute an issue. However, as always, the economic evaluation of a surgical procedure should take into account both the direct costs deriving from the purchase of the instrumentation, and the indirect costs deriving from occupation of the operating room and total charges for the patient and personnel. The question is whether, considering the early discharge, the possibility of TEM being an outpatient procedure, and the lower complication rates, those indirect costs could counterbalance the direct cost related to the purchase of the equipment and thus make TEM more cost-effective [17].

The indications for TEM overlaps those for endoscopic resection of rectal polyps. In the late 90 s, endoscopy was advocated as a diagnostic technique and a therapeutic method. First, large piecemeal snare ablations were reported. Then, the use of endoscopic electrosurgical knives made it possible to achieve en-bloc resection, known as "endoscopic submucosal dissection" [16]. The sharp increase in endoscopic resection of rectal polyps made the indications for TEM questioned [16].

However, it has to be remembered that TEM, by its nature, offers a surgical excision with higher en-bloc resection rates, and a good balance between complications and oncological outcomes still supports the superiority of surgical excision by TEM.

13.2.1 The Technique of Transanal Endoscopic Microsurgery

In summary, TEM consists of the full-thickness excision of rectal lesions located from the anal verge up to the pelvic brim, relying on a 3D magnified vision allowed by sophisticated lens technology, and the subsequent closure of the rectal defect [21–23].

The procedure is performed using a special proctoscope of 4 cm in diameter available in lengths of 12 cm and 20 cm. The rectum is insufflated with carbon dioxide at 10–15 mmHg. This can be achieved with the use of specific or usual laparoscopic CO_2 insufflators [21–23]. The optical six-fold increase and the stability provided by the equipment, attached to the operating table, allows for an excellent view of the rectum and lesion [22]. Patient positioning is strictly dependent on the side of the lesion (e.g., prone for anterior lesions, supine for posterior lesions) [21–23].

13.3 A Simplified Technique: Transanal Minimally Invasive Surgery

More recently, a variation of the previous technique has been proposed that combines the laparoscopic approach with TEM principles [24].

The aim was initially to avoid the costs deriving from purchase of the dedicated TEM instrumentation, since the proposed technique, the transanal minimally invasive surgery (TAMIS), could be performed using the available laparoscopic equipment [25]. The second purpose was to shorten the learning curve of transanal surgery [25]. The rationale for the introduction of this modified and simplified technique was that addressing these two major disadvantages of TEM could result in a larger spread of transanal excision for rectal cancer, with its related benefits [26].

Several transanal ports have been introduced for this approach, including either disposable or reusable single-ports (Fig. 13.1), [27].

Differently from TEM, by constitution a single-surgeon procedure, TAMIS requires the presence of an assistant surgeon to control the camera, a requirement that may cause also a loss in the stability of the image during the procedure [27].

Standard laparoscopic instruments are used and, once they are inserted, the surgeon performs the procedure with an excisional technique that reproduces the steps described for TEM. However, most single ports have only three portal entries so that aspiration of the cautery smoke is not continuous. Finally, access to the lower rectum might be more difficult due to the significant need for instrument angulation. On the other hand, access to the upper rectum may be limited by rectal folds in some patients [27]. These characteristics may limit the indication for TAMIS, making this type of excision best suited for middle rectal lesions [27].

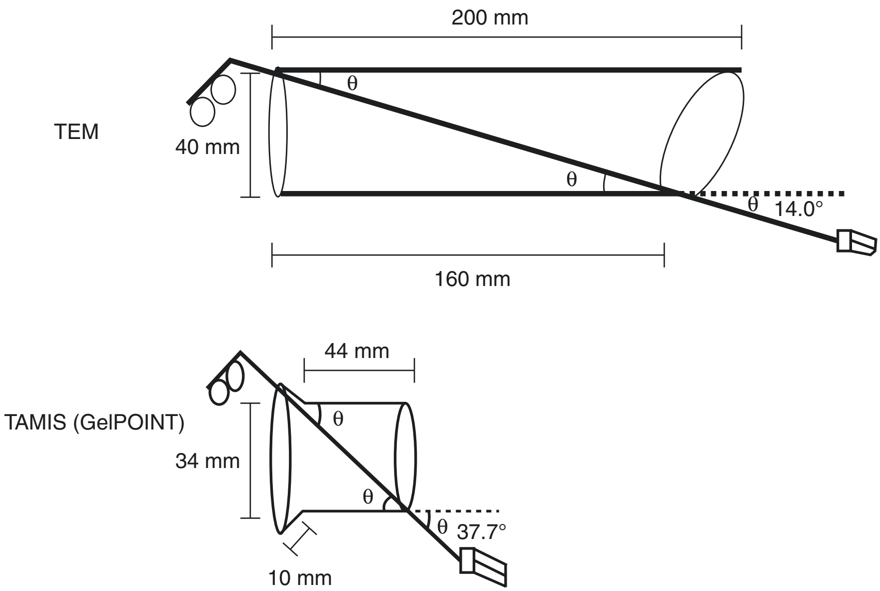

Fig. 13.1 Comparison of ports used in transanal endoscopic microsurgery (TEM) and transanal minimally invasive surgery (TAMIS). Reproduced from Martin-Perez et al. [27] with permission of Springer Nature

13.4 Robotics in Transanal Surgery

Robotics applied to transanal surgery constitutes nothing more than the natural translation of TEM principles into the modern era [28, 29]. Experiments with robotic transanal surgery date back to 2010, in the form of preclinical studies based on dry laboratory [28] and cadaveric models that initially showed the feasibility of this approach using the da Vinci robotic cart [29, 30]. The first robotic transanal resection in a human case was performed in 2012 [31]. Twelve articles were published between 2013 and 2022; of these, five were case reports, three were case series, two were prospective cohort studies, one was a retrospective cohort study, and one was a phase II clinical trial [32].

There are many variables involved in robotic transanal resection. The first is the platform used [32].

The studies reported using various robotic platforms, including the da Vinci Si, da Vinci Xi, da Vinci single port, and the Flex robotic system [32]. Other variables regard patient positioning, which almost in all papers depends on the location of the lesion [33]. The rationale for using robotic systems for this type of surgery lies in the augmented dexterity and improved ergonomics coupled with the 3D vision offered by these platforms. Ideally, a robotic approach could allow also access to larger, more proximal and more complex lesions, including circumferential lesions [33]. However, according to some authors, one of the advantages of the da Vinci Xi over laparoscopic systems is the higher maneuverability of the robotic arms, which allows for easier access to rectal lesions regardless of their location, while laparoscopic transanal excisions remain highly position-dependent, becoming more difficult to perform if the patients are not placed in the right position [34]. Since robotic transanal procedures are still in development, a clear approach that could be considered the gold standard is not yet defined [34, 35].

13.5 Conclusions

The treatment of cancer of the rectum is historically among the most debated. The management of rectal cancer has evolved both in technical and technological terms. The development of novel parallel therapies, such as radiotherapy, has contributed to make TEM a viable option even for more advanced rectal cancers. Besides, the robotics revolution has not left the field of transanal surgery untouched and may become the future of rectal surgery.

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Part IV

Miscellaneous

14 Robotic-Assisted One-Stage Resection of Colorectal Cancer with Liver Metastases

Graziano Ceccarelli, Aldo Rocca, Alberto Patriti, Walter Bugiantella, Fabio Ermili, Andrea Coratti, and Michele De Rosa

14.1 Introduction

Colorectal cancer (CC) is the third most common tumor in Western countries and the liver is the most common site of metastatic spread, with over 50% of patients developing liver metastases (LM) during the natural course of disease: synchronous and metachronous liver lesions are diagnosed in about 15–25% and 20–30% of patients, respectively [1]. Although synchronous disease is considered to have a less favorable biology and poorer prognosis compared to metachronous disease, surgery is nowadays the only therapy offering a potential cure. Although only 20% of these patients are eligible for surgery, radical resection of primary CC and LM may allow a 5-year survival rate ranging between 40–57%, compared to 3–9% of unresectable disease [2].

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14.2 Management of Synchronous Colorectal Metastatic Disease

A multidisciplinary approach is considered the correct management strategy. Three surgical options are available [3]: the "staged approach", with colorectal resection followed by adjuvant chemotherapy and finally liver resection, which has the advantage of a better control of bowel obstruction symptoms; the synchronous "one-stage resection" of both CC and LM; the "liver first approach". The best strategy for resectable synchronous colorectal LM is still a matter of debate [1, 2, 4]. The one-stage strategy is a safe and feasible option, especially when minor hepatectomies are performed, while for major live resections an increased risk of postoperative complications is reported [5]. A minimally invasive approach has demonstrated to be beneficial in both colorectal and liver surgery compared to the conventional open approach, with less intraoperative blood loss, quicker postoperative recovery, shorter hospital stays and fewer postoperative complications, especially if performed in high-volume centers. No difference in R0 resection margins and disease-free survival has also been reported [6]. Nevertheless, laparoscopy may prove to be a challenging procedure requiring two surgical teams or surgeons expert in minimally invasive colorectal and liver surgery.

14.3 Robotic Surgery for Synchronous Liver Colorectal Metastases

Robotic one-stage resection of synchronous CC and LM is reported in many case series worldwide [7–9]. With the last da Vinci Xi robotic platform, multiquadrant surgery is easier and re-docking of the device faster [10, 11]. The first case was published in 2008 by Choi et al. where a segment III and a low anterior rectal resections were performed robotically with a total operative time of 360 minutes [7]. Patriti et al. published in 2009 a series of seven laparoscopic and robotic procedures [8]. A systematic review by Garritano et al. in 2016 included 20 studies of laparoscopic and robot-assisted one-stage resections, concluding that the minimally invasive approach is advantageous over conventional open surgery, especially as regards short-term postoperative outcomes [12]. A systematic review published in 2018, examining over 1000 patients, showed how the robotic approach is safe and feasible for both minor and major resections [13]. Dwyer et al. reported a case series of six procedures with no conversions to laparotomy, a mean operative time of 401 min, an estimated blood loss (EBL) of 316 mL and a hospital stay of 4.5 days. One anastomotic leak and two pelvic abscesses, but no 30-day mortality were reported [14]. Soh et al. reported on four patients who underwent robotic rectal resection with an additional robotic hepatobiliary procedure, with no difference in length of stay and postoperative complications (anastomotic leak or bleeding) compared to a series of rectal resection alone [15]. In 2019 Navarro et al. published a series of 12 patients, and the liver surgery included six wedge hepatectomies, one caudate lobectomy, two right hepatectomies, one left hepatectomy, one left lateral segmentectomy, and one Associating Liver Partition and Portal vein ligation for Staged hepatectomy (ALPPS procedure). The mean operative time was 449 min with a mean EBL of 274.3 mL. There were no conversions to laparotomy, with two grade III complications, including one anastomotic leak and two liver abscesses [16]. The same year Giovanetti et al. reported a series of five patients undergoing robotic combined liver and colorectal resection with no 30-day mortality [17]. In a single-center series by Ceccarelli et al. in 2021, 28 patients with CC and synchronous LM were treated using a robotic procedure, demonstrating benefits especially for liver resection. Eighteen of 44 LM (40%) were located in posterior liver segments (4a, 7, 8 and 1), considered challenging locations for conventional laparoscopy; the mean operative time was 332 min, EBL 143 mL and length of stay 8 days; two conversions to laparotomy and three grade III–IV Clavien-Dindo complications were reported [18].

The use of robots allows optimal access to all liver segments, even for the most demanding posterior or paracaval tumors, facilitating parenchymal-sparing surgery [19]. Masetti et al. reported a fully robotic ALPPS with simultaneous left colectomy for synchronous CC and LM [20]. One case of synchronous resection of rectal, liver and lung metastases was also described [21].

The average operative time for one-stage surgery depends on the complexity of the two surgical procedures and different scores were made to plan the complexity of minimally invasive liver resections [22]. Generally, the operating time is longer in robotic surgery due to the docking process. Mc Guirk et al. reported a mean operative time of 420 minutes, not statistically different from the laparoscopic series of Zhu et al. (320 min), and Spampinato et al. (495 min) [23–25]. Length of hospital stay depends on many different factors, such as complexity of hepatectomies or colorectal resections, patient conditions, adherence to enhanced recovery program, complications.

14.4 Technical Aspects

With the aim of maximizing time efficiency and minimizing the risk of conversion, we suggest starting the operation with the most challenging procedure between liver and colorectal disease. Generally, major hepatectomies, posterior/paracaval or bilateral segments require longer time, as well as low rectal resection in obese/male patients. Sometimes a hybrid laparoscopic-robotic technique may be considered.

14.4.1 Robotic Liver Resection

If the operation starts with the liver resection, the patient lays supine with legs apart and the operative table is placed in the reverse Trendelenburg position, tilted on the opposite side to the liver tumor. For posterior segments a lateral or semilateral position or a pillow under the flank may be useful and one robotic port may be placed in the intercostal space. A preliminary abdominal cavity exploration allows exclusion of peritoneal carcinomatosis. Intraoperative ultrasound liver evaluation is routinely performed to exclude or identify other lesions and to plan and guide the resection margins during the procedure. Operative ports are positioned according to the target. Additional trocars are inserted for the assistant placed between the patient's legs. The da Vinci Xi (Sunnyvale, CA, USA) robot is docked with the arms from the patient head according to the target area (Fig. 14.1) [18]. Hepatic pedicle encirclement with loop for inflow vascular control (Pringle maneuver) is recommended for major or demanding resections, using extracorporeal or intracorporeal approaches. Liver parenchyma transection is performed using the clamp-crushing technique with robotic bipolar forceps (Maryland) and curved scissors or using others laparoscopic devices. Vessels of 3–4 mm may be managed by bipolar or energy devices, larger vessels are preferably secured using metallic clips or hem-o-lok or stitches. Indocyanine green dye may be used for intraoperative real-time identification of biliary tree and vascular anatomy or, if injected one or two days before surgery, to highlight liver lesions. It may also be useful to plan the transection line and to check biliary stasis at the end of the operation.

14.4.2 Robotic Colorectal Resection

Robotic colorectal resection generally requires a re-docking of the cart. Additional ports may be necessary according to colorectal tumor location. Right colectomy may be usually managed with a single docking (Fig. 14.1) [26]. For left colectomy and rectal resection a re-docking and new table positioning is required. For the technique we refer to the specific chapters. When colorectal resection is the first step and a Pringle maneuver is planned, the anastomosis should be performed after liver transection. After rectal resection a diverting loop ileostomy is generally considered. The specimens are extracted into different bags using a Pfannenstiel incision (Fig. 14.2) [18].

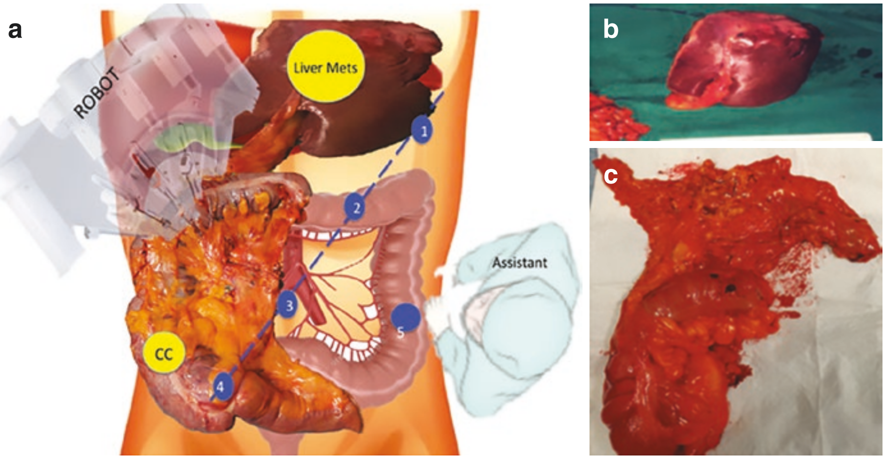

Fig. 14.1 (**a**) Single robotic docking for liver resection and right colectomy. (**b**, **c**) Specimens (left hepatectomy and right colectomy)

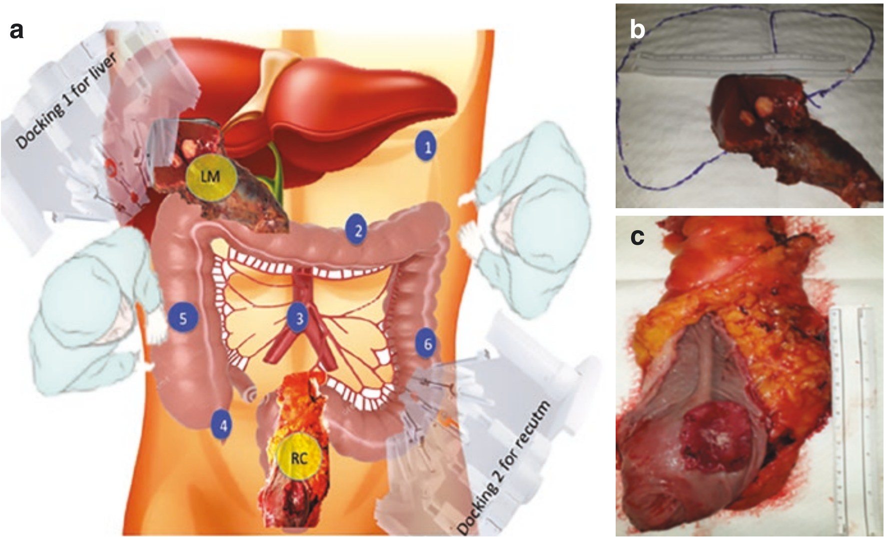

Fig. 14.2 (**a**) Double docking for liver resection (segment 5) and rectal resection (rectal cancer). (**b**, **c**) Specimens

14.5 Conclusions

The diffusion of robotic platforms has recently expanded their application for multivisceral-multiquadrant surgery and one-stage resection of LM. Compared to laparoscopy, robotic technology offers better accuracy in fine dissection and micro-suture and a better vascular management, facilitating parenchymal-sparing surgery especially for posterior segments, with a shorter learning curve. Conversion rates to open surgery seem to be reduced with robotic surgery. The hybrid approach (laparoscopy and robotic) may reduce overall operative time, reserving the robotic technology for the most challenging procedures. Randomized controlled trials are necessary to fully demonstrate the advantages of this technology, especially in terms of reduction of morbidity.

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Multiquadrant and Multiorgan Robotic Surgery with the da Vinci Xi

15

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15.1 Introduction

Thanks to prevention programs and diagnostics improvements, together with significant treatment advances that have led to increased overall survival in patients with cancer, the detection of multiple synchronous or metachronous malignancies requiring surgery is becoming more and more frequent in clinical practice. The frequency of multiple primary cancers is reported to range between 2% and 17%. Particularly when faced with a patient with two or more simultaneously diagnosed active cancers, the goal is to find the best therapeutic strategy [1]. Following a multidisciplinary oncologic team discussion, a combined minimally invasive surgical approach can nowadays be considered a valuable option for synchronous malignancies of the gastrointestinal, colorectal, urological, and gynecological districts, representing an alternative to sequential procedures with a potential favorable impact on postoperative morbidity, and on the timing of administration of adjuvant chemotherapy.

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15.2 The da Vinci System

Since the introduction of the da Vinci Si system (Intuitive Surgical, Sunnyvale, CA, USA), similar or superior results to laparoscopic surgery have been observed for several surgical indications. This system has become increasingly popular, particularly in general surgery, urology, gynecology and thoracic surgery, but for single quadrant procedures. Indeed, combined multiple organ surgery was not initially considered a good indication for a robotic approach, mainly because of instrument collision and need for an increased number of trocars with the da Vinci Si version. This limitation involved also some single organ/multiquadrant surgeries such as rectal resection. In order to overcome these drawbacks, double docking or hybrid procedures were often performed, although showing poor results in terms of workflow, with significantly longer operative times compared to open surgery and laparoscopy.

The introduction of the da Vinci Xi in 2015 had a strong impact on these aspects, drastically improving the ability to perform combined and simultaneous procedures by enhancing the workflow with a fully-robotic approach. Indeed, aiming to overcome the described limitations of the previous version, the Xi system presented new important features such as the greater flexibility of the robotic arms, the magnetic connectors, the FLEX function, the rotating boom, as well as the wirelessly connected operating table, the da Vinci Table Motion (dV TM). Thanks to these characteristics and technologies, docking has become easier and faster, the work space range has been increased and, through the dV TM, it has become possible to start moving patients along with the instruments inside the abdomen and without the need for undocking and re-docking maneuvers.

Therefore, all these aspects significantly increased the ability to perform multiquadrant/multiorgan procedures [2].

15.3 Technical Notes

In detail, the main technical aspects to be considered in order to successfully face a multiquadrant/multiorgan surgery are: use of the FLEX function, use of the dV TM if available (optional), and management of the boom-rotating system. Also, facilitated docking/undocking by the magnetic connectors, the targeting function and pointer laser, and a particular trocar positioning strategy play an essential role [3].

15.3.1 Flex Function

While the da Vinci Si required the external arms to be widely spaced in order to maximize the working field, this is not applicable for the da Vinci Xi. In fact, the horizontal joints of the Xi need to be compacted, leaving one-fist-width spacing between each arm. This configuration also permits the arms to move in parallel with each other, a function called FLEX that is particularly important in multiquadrant procedures in which the targets are in the same side of the patient. The operative field can be extended beyond the alignment of the Xi FLEX joints as the robot arms can be manually redirected towards the new target anatomy without undocking the ports (Fig. 15.1).

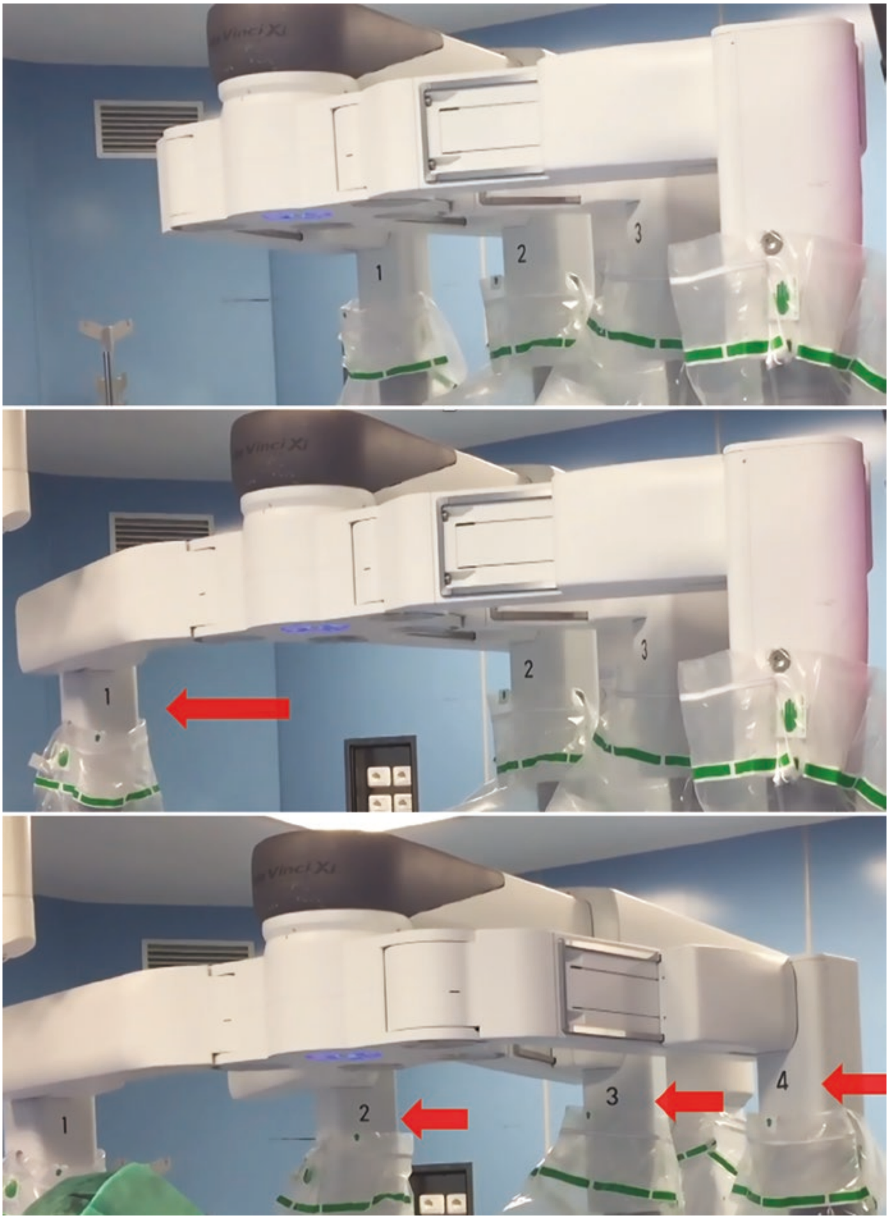


Fig. 15.1 Thanks to the FLEX function the robot arms can be manually redirected toward the new target anatomy without undocking the ports

15.3.2 Table Motion

Another important tool available for the da Vinci Xi is the dV TM. This operating table supports integrated table motion, enabling patients to be repositioned with instruments inside the abdomen and without undocking the robot [4]. These properties further enhance the workflow without the struggle and time needed to undock/re-dock the platform, allowing surgeons to maximize all the advantages of the robotic technique while reducing its specific drawbacks, enabling access to different quadrant/surgical target faster and more efficiently, especially during procedures with difficult anatomy.

In these situations, the da Vinci Xi plus the new operating table also enable the surgeon to optimize gravity exposure and provide the quick access to different surgical targets even in narrow spaces. Apart the positive influence of these facilities in reducing the operative time, the dV TM may increase patient safety as it can minimize the use of extreme position through graded Trendelenburg repositioning and stopping when surgical exposure is achieved. In fact, the dV TM enables what is best described as "controlled graded gravity exposure" by regulating the Trendelenburg and/or lateral tilt precisely and not beyond the required tilt. In addition, the anesthesiologist can control exactly the table position and display it to the entire surgical team in a cooperation manner. The dV TM is therefore a very interesting tool that specifically helps the surgeon to perform multiorgan and multiquadrant operations, enabling the patient's repositioning without disrupting the surgical workflow and allowing the robotic instruments to reach safely all the targets.

15.3.3 Boom Rotating System, Targeting, Magnetic Connectors, Pointer Laser

Thanks to the previously described features, some combined procedures can be performed with a single docking, particularly if the target organs are in two closed quadrants (e.g., pelvis and left hypochondrium), with or without changing the patient's position. However, in cases of opposite quadrants, or when the range of motion goes beyond the limits of the joints/collision, dual docking can be required. In these cases, the facilitated docking/undocking ensured by the magnetic connectors, the targeting function and the pointer laser can enhance the workflow as it is very fast to undock and dock again the robot.

In this regard, also the rotating boom mounted system, which can be rotated almost a full 360 degrees, is particularly useful as the robotic cart can achieve opposite surgical access without a need for changes of the robotic cart. The boom can be re-orientated to every part of the patient by undocking the port and performing a re-targeting and a new docking phase (opposite facing quadrant technique). This ability to rotate the boom while the robotic cart can remain in the same position makes this technique time-saving (Fig. 15.2).

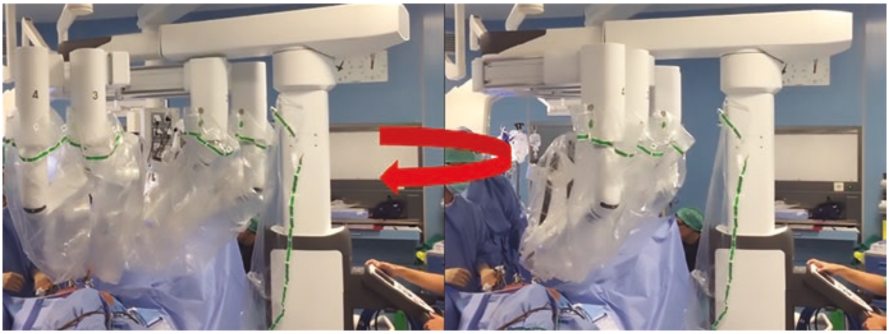
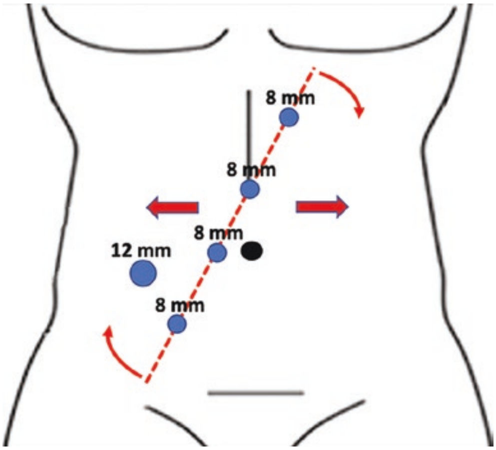


Fig. 15.2 The boom system can be re-orientated to every part of the patient by undocking the port performing a re-targeting and a new docking phase

Fig. 15.3 Different combined procedures are possible with an oblique linear trocar position, shifting the line to the left or right or by rotating the alignment to a more horizontal line based on the localization of the two surgical targets



15.3.4 Trocar Placement

To perform combined multiple organ/multiple quadrant procedures, trocar positions should be adjusted case by case, following some basic principles. The general rule of the straight line given by Intuitive for the da Vinci Xi is always followed. The starting point is the diagonal line from left subcostal area to right iliac fossa centered in the umbilical area, following the "classic" Universal Port placement guidelines suggested by Intuitive for "left lower" abdominal procedures. Based on the surgical site and the second target organ, however, it can be necessary to shift all trocars to the right or left side and/or change the angle of the alignment (Fig. 15.3). For example, in cases of right colectomy combined with left colectomy trocar alignment is centered at the level of the umbilical area, whereas if surgery predominantly involves the left quadrant (for example in the case of left colon resection plus distal pancreatectomy) all trocars should be moved 2 or 3 cm to the right. On the other hand, in cases of right hemicolectomy associated with right nephrectomy or hysterectomy, the trocar line should be moved 2–3 cm to the left, always in an oblique fashion. The assistant's trocar could then be placed at the level of the right or left flank depending on the type of multiquadrant procedure.

15.4 Combined Robotic Procedures

Below are described some examples reported in the literature of different combined procedures successfully performed through the described strategy [3, 5].

- *Right colectomy plus right adrenalectomy*: the patient is in left lateral decubitus, and the trocars are positioned as a standard robotic adrenalectomy; the patient is afterwards moved to supine decubitus, and a new docking is completed to perform the right colic resection.
- *Right hemicolectomy plus right partial nephrectomy*: trocar alignment is shifted about 3 cm to the left, the 12-mm assistant trocar is placed in the left flank, and the patient is positioned in 15° anti-Trendelenburg and tilted 15° to the left. Right hemicolectomy is performed initially, and then right partial nephrectomy is performed in the same position. Other authors describe the same procedure but with a need to undock the robot and reposition the patient. Starting with a supine decubitus, in 15° anti-Trendelenburg with parted legs, the robotic cart comes from the right of the patient. Targeting is performed at the level of the right flexure to reduce instrument collision. Then the right colectomy is performed as usual. However, before specimen extraction and fashioning of the intracorporeal anastomosis, partial nephrectomy with arterial clamping is performed usually with the patient in the same decubitus, but further tilting the table to the left. In other cases, in challenging partial nephrectomy cases, it is possible to undock the robot and place the patient on the left flank side with the right arm adducted over the head.
- *Anterior rectal resection plus pancreatic tail neuroendocrine tumor enucleation*: trocar alignment is shifted about 3 cm to the right, the assistant's 12-mm trocar is placed at the level of the right flank and using dV TM the patient's position can be changed twice. In this way, for the access to the inferior mesenteric vein, mobilization of the splenic flexure and descending colon, and enucleoresection at the level of the pancreatic tail, the patient is placed in 15° Trendelenburg and tilted 25° to the right. Then, to perform total mesorectal excision the patient is tilted only 15° to the right and placed in 20° Trendelenburg.
- *Right hemicolectomy plus hysterectomy*: the trocars are positioned centrally at the umbilical level, the 12-mm trocar for the assistant is at the left flank level. The patient is positioned in 30° Trendelenburg throughout the gynecologic phase, using dV TM to be able to precisely access to the pelvic cavity without compromising patient safety with extreme positions. Next, for the right hemicolectomy, undocking is performed, the boom is rotated 180° and the bed is tilted 10° to the left for ileocolic vessel ligation and mobilization of the right colon. Adjusting the tilt degree, the final steps of the intervention are accomplished and intracorporeal anastomosis is created.

- *Sigmoidectomy or anterior rectal resection plus right hemicolectomy*: trocars are centered in the umbilical region, the 12-mm assistant's trocar is placed at the level of the right flank. The procedure starts with right hemicolectomy and then the robot is undocked, the boom is rotated 180°, and the patient is tilted 15° to the right and 15° in Trendelenburg for mobilization of the left colon and access to the inferior mesenteric vein. Then, using the dV TM system, the patient is positioned 20° in Trendelenburg to complete the mobilization of the sigma and high rectum. Finally, the specimen extraction is performed through a suprapubic minilaparotomy and lastly colorectal anastomosis is performed.
- *Anterior rectal resection plus liver resection*: the position of the trocars is centered at the level of the umbilical region while the 12-mm assistant trocar is placed in the left flank. After completing the anterior resection of the rectum, the robot is undocked, the boom is rotated 180°, and the patient is placed 15° anti Trendelenburg and tilted 25° to the left for the liver resection.
- Ideally, by rotating the straight line of the trocars and/or shifting it towards the right or left, several other combined multiquadrant procedures can be performed.

15.5 Conclusions

According to the current literature, robotic multiorgan and multiquadrant combined procedures have already proved to be feasible and safe [6, 7], with a potential positive impact on postoperative outcomes, on global hospitalization time, as well as on an earlier start of adjuvant treatments [8, 9]. However, due to the great variety and heterogeneity of the described procedures, standardization is still completely lacking. In this setting, the potentialities of the da Vinci Xi and dV TM are fully exploited. Furthermore, the technology is advancing faster and faster leading to the development of new robotic platforms such as da Vinci SP, experimenting a single site approach to improve outcomes, allow better management of analgesia, and provide better cosmetic results and fewer long-term wall complications.

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Robotic Surgery for Diverticular Disease

16

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16.1 Background

Diverticular disease (DD) is a common benign condition that in Western countries has a remarkable clinical and economic impact on public health [1, 2]. Over the last decade, the non-operative management of acute DD has increased with a progressive reduction of emergent surgery and a relative shift toward elective resection [3, 4].

Minimally invasive surgery is now almost universally accepted as a valid option for the treatment of DD, provided specific expertise is available [1, 4].

Some of the main factors favoring minimally invasive surgery over conventional open colectomy are improved overall morbidity, lower rate of postoperative ileus, shorter hospitalization, and earlier return to daily activities [5, 6]. Nevertheless, the conversion rate during laparoscopic colectomy for DD ranges from 0% to 36% for complicated diverticulitis [7–9].

The use of robots in colorectal surgery has been spreading and evolving rapidly over the last two decades. The application of robots has also shifted to benign conditions, such as uncomplicated and complicated diverticulitis. Our group recently published a meta-analysis comparing the laparoscopic and robotic approach for the surgical treatment of DD, based on 4177 patients from nine studies. We found that patients undergoing laparoscopic colectomy compared to those who underwent

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surgery with a robotic approach had a significantly higher risk of conversion into an open procedure (12.5% vs. 7.4%, $p < 0.00001$) and abbreviated hospital stay ($p < 0.0001$), at the price of a longer operating time ($p < 0.00001$).

In this chapter, we describe our operative technique of robotic colorectal resection for diverticulitis.

16.2 Equipment, Patient Positioning and Operating Room Setup

Recommended main equipment:

- 30° endoscope
- fenestrated bipolar forceps
- monopolar scissors
- large needle driver
- vessel sealer (optional)
- SureForm endostapler: green cartridge (superior rectum)
- tip-up grasper.

The patient is placed in a lithotomy position with arms alongside the body. The pneumoperitoneum is established via a Veress needle inserted in the left hypochondrium at Palmer's point. Access to the abdominal cavity is gained with a 12-mm assistant port in the right flank. Three 8-mm and one 12-mm robotic trocars are placed along an oblique line which may vary according to the confirmation of the abdomen, as well as to intra-abdominal anatomy. Trocar layout is shown in Fig. 16.1.

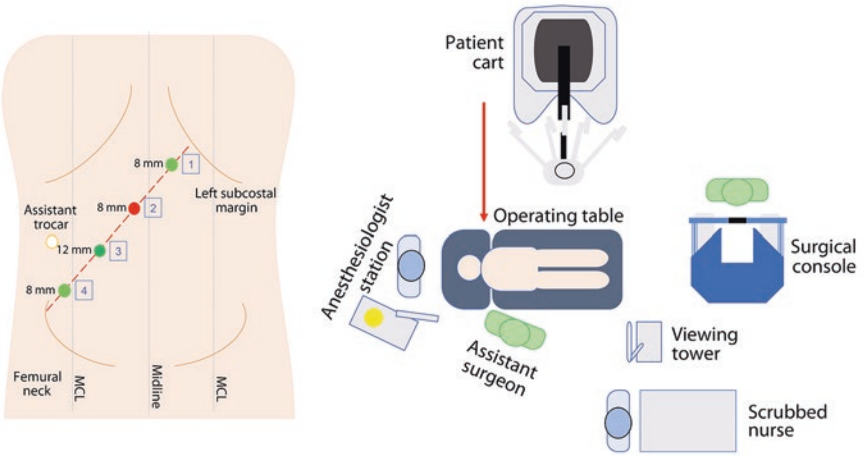

Fig. 16.1 Trocar layout (*left*): (1) bipolar forceps; (2) camera 30°down; (3) monopolar scissors/robotic stapler; (4) tip-up grasper. Operating room setup (*right*)

A limited lysis of adhesions, when present, is performed laparoscopically just to enable robotic trocar positioning under direct vision; adhesions are then taken down under robotic assistance (see Video 16.1).

The patient is then placed in a steep Trendelenburg and right tilt in order to achieve exposure of the operative field. The robotic cart is docked from the patient's left side and a da Vinci Xi system (Intuitive Surgical, Sunnyvale, CA, USA) is used. A full-robotic single-targeting procedure is performed. The assistant surgeon and the scrub nurse stand on the patient's right side (Fig. 16.1). The tip-up grasper, monopolar scissors/robotic stapler and bipolar forceps are mounted on robotic arm 4 (R4), arm 3 (R3) and arm 1 (R1), respectively. Robotic arm 2 (R2) is used for the 30°-down scope (Fig. 16.2). We place the tip-up grasper on arm 4 (in the right iliac fossa) because traction and exposure, especially during the pelvic dissection, is easier and more effective compared to the epigastric region where R1 is placed.

Fig. 16.2 Driving the laser lines to the scope port

16.3 Surgical Technique

With the tip-up grasper (R4) that has gently lifted up the sigmoid, the procedure starts with the incision of the peritoneum at the sacral promontory: the “holy plane” and superior rectal artery are identified. At this point, the tip-up grasper (R4) is placed under the mesosigmoid to traction it and facilitate the medial-to-lateral dissection. The mobilization of the sigmoid colon is then completed above or below the superior rectal artery depending on the level of vascular ligation planned.

The dissection is carried out with monopolar scissors (R3) and fenestrated bipolar forceps (R1), paying attention to preserve the hypogastric nerves, left ureter and gonadal vessels. This step can be technically demanding, especially in patients with previous abscess or recurrent episodes of diverticulitis, because of severely inflamed and fibrotic tissues making the dissection more demanding. The left ureter can be involved by the inflammatory process, causing a stricture with secondary hydroureteronephrosis [10]. It is mandatory to evaluate the computed tomography scan before the operation to assess the need for a preoperative double J catheter.

A lateral-to-medial dissection completes the mobilization of the sigmoid colon. The tip-up gasper (R4) and the assistant’s forceps pull the sigmoid colon in the right quadrants. Then, the lateral peritoneal reflection along the outer edge of the descending and sigmoid colon is opened and the plane previously developed is gained. Sometimes the sigmoid can be fused with the parietal peritoneum of the left iliac fossa/left side pelvic wall as a consequence of previous diverticulitis. In this case the traction of R4 associated with the traction of the assistant can help the colon mobilization.

Especially in young patients, to preserve the hypogastric nerve and innervation on the inferior mesenteric artery and superior rectal artery (to preserve the rectal emptying function), we suggest a vascular ligation at the level of the sigmoid arteries preserving the left colic and superior rectal arteries. However, in severely inflamed and thickened colon mesentery, ligation of the inferior mesenteric artery at the origin might facilitate the dissection achieving the embryological planes.

The dissection continues along the Toldt’s plane, in a bottom-to-up fashion: the peritoneum under the inferior mesenteric vein (IMV) is then incised. The integrity of the proper mesocolic fascia should be carefully preserved in order to ensure adequate perfusion to the splenic flexure/proximal descending colon. The transverse mesocolon is lifted with R4, and the origin of IMV is identified at the level of the duodenojejunal angle. The IMV is dissected at its origin and divided between self-locking clips at the inferior border of the pancreas. The dissection continues in a medial-to-lateral fashion. At this point the splenic flexure mobilization is carried out. Depending on the patient’s body characteristics and to the anatomy (e.g., high or low splenic flexure as well as the presence of colon-epiploic adherence) a medial approach, lateral approach, anterior approach, lesser sac approach or a combination of these might be adopted for the splenic flexure takedown.

Coloparietal detachment is completed and the distal transection site is chosen at the level of the sacral promontory, paying attention to remove the high-pressure zone at the level of colorectal junction. The upper rectum is transected with a 60-mm robotic SureForm linear stapler with green cartridge just a few centimeters below the sacral promontory (see Video 16.1).

The robot is undocked and the specimen is retrieved through a small suprapubic incision. The colon is transected and the anvil of a 28-mm circular stapler is introduced in the proximal stump. After re-docking of the cart, an assessment of bowel perfusion with indocyanine green fluorescence imaging system is performed and a conventional end-to-end colorectal anastomosis is performed according to the Knight-Griffen technique under robotic assistance. Colorectal anastomosis is reinforced with seroserosal absorbable interrupted stitches. An air leak test is performed and a drain is routinely left in place.

16.4 Conclusions

According to the data available in the literature, the application of the robotic approach compared to laparoscopic surgery offers significant advantages in terms of conversion rate and shortened hospital stay for the treatment of DD [11]. However, there is an absence of substantial evidence on the topic. In our experience the robotic approach is helpful especially in obese patients, with previous complicated DD or in those in whom other procedures are associated (small bowel resection, hysterectomy, ureteral reconstruction) [10].

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Robotic Hartmann's Reversal

17

Marco Milone, Michele Manigrasso, and Giovanni Domenico De Palma

17.1 Introduction

Hartmann's procedure was first introduced in 1920 by Hartmann [1], who performed a closure of the distal rectal stump and a descending colostomy after rectal cancer resection. The first reversal of a Hartmann's procedure was described by Boyden et al. [2], who reported on the reversal of six colostomies.

Since its introduction, the Hartmann's procedure has become the gold standard treatment for many procedures especially in emergency settings, such as complicated diverticulitis, perforated or obstructive colon/rectal cancer, obstructive colonic Crohn's disease or trauma-related colonic perforation. The Hartmann's procedure should be considered the gold standard procedure in cases in which creating an anastomosis is not prudent. Being usually performed in an emergency setting, it is often carried out as open surgery and consequently creates many intra-abdominal adhesions, which complicate subsequent colostomy closure and restoration of colonic continuity. As a result, also the reversal of Hartmann's procedure (Hartmann's reversal, HR) tends to be performed as an open approach, because, when done by laparoscopy, the conversion rate remains high.

Given this scenario, the introduction of robotics seemed to overcome some of the technical difficulties of laparoscopy. The stable 3D vision camera and the EndoWrist technology reduce the technical challenges of laparoscopic adhesiolysis, reducing the need for conversion. Indeed, the use of straight rigid laparoscopic instruments makes it very difficult to reach and lyse adhesions in the deep pelvis or at the abdominal wall, and for this reason the HR procedure could be considered a suitable field of application of robotic surgery.

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17.2 Literature Review on the Minimally Invasive Approach to Hartmann's Reversal

In the last 20 years several studies have demonstrated the feasibility of the minimally invasive approach to HR. The first case of laparoscopic HR was reported by Anderson et al. [3], who described the technique and the postoperative outcomes. The largest comparative study of laparoscopic and open HR was performed by Pei et al. in 2017 [4]. The authors recorded data for over 11,000 patients undergoing HR, assessing that open HR surgery had significantly higher complication rates than laparoscopy, as well as longer operative time and length of stay. Similar results were obtained by other authors, all of whom confirmed the superiority of laparoscopy over laparotomy also in terms of anastomotic leakage rate [5–13]. However, the challenge of the laparoscopic approach remained adhesiolysis, which caused a variable rate of conversion ranging from 0% to 50% [7, 14].

Recently, a meta-analysis by Chavrier et al. [15] combined the results of 23 studies comparing open and laparoscopic HR. The results confirmed the trends reported in the current literature. In fact, by pooling together 3139 laparoscopic HR and 10,325 open HR, the authors assessed that, compared with the open approach, the laparoscopic approach was significantly associated with a decreased rate of revision surgery, anastomotic leakage, postoperative morbidity, intra-abdominal or wound abscess and postoperative ileus, while mortality was comparable between the two types of procedure. However, a major limitation of the meta-analysis was that all the studies were retrospective, only four studies were case-matched comparisons and only one study was a propensity score-matched comparison; no randomized controlled trial has been performed to confirm these advantages.

17.3 State of the Art on the Robotic Approach to Hartmann's Reversal

The literature data on the robotic approach to HR are scarce and anecdotal.

The first paper on robotic HR was published by de' Angelis et al. [16], who reported on the case of an 84-year-old man with a colostomy after a Hartmann's procedure for a Hinchey IV diverticulitis. The authors described the technical details of the technique, highlighting the importance of robotic assistance during the adhesiolysis. The authors concluded that the robotic HR procedure could be considered safe, feasible, and valuable.

Only one cohort study can be found in the literature. This was performed by Giuliani et al. [17] in 2020 and describes the technical aspects of robotic HR and the results obtained in the authors' first 24 patients. An important finding was the absence of conversion to the open or laparoscopic approach, confirming the efficacy of robotic assistance during the adhesiolysis. No major complications were recorded by the authors, while three minor complications were noted.

The most recent study on robotic HR was performed in 2021 by Bardakcioglu [18], who reviewed the literature and described the technical phases of the procedure.

Analyzing the current literature, no randomized controlled trials, comparative studies or large cohort study have been proposed or performed, so that the perceived advantages of the robotic approach need to be further confirmed.

17.4 Surgical Technique

The patient is positioned in the lithotomy position with the arms alongside the body, with a 15°–20° Trendelenburg position and about 20° right tilt.

After the induction of pneumoperitoneum by a Veress needle introduced at Palmer's point, four robotic ports are placed along a straight diagonal line connecting the anterior superior iliac spine and the right subcostal margin. The distance between the ports is about 6–8 cm and the two most lateral ports (arm 1 and 4) are positioned at least at 2 cm from the bony structures (Fig. 17.1). We usually adopt three 8-mm ports for the robotic instruments and one 12-mm port in which we introduce the robotic stapler. A 12-mm assistant port is placed in the right flank for conventional laparoscopic instrumentation to be used by the assistant surgeon.

For this procedure, we usually employ the following instruments:

- Prograsp forceps (arm 1)
- bipolar fenestrated forceps (arm 2)
- 30° robotic scope (arm 3)
- permanent cautery hook (arm 4).

In the case of obese patients we use a high energy device (vessel sealer or harmonic scalpel, Intuitive) in arm 4.

The first phase of the procedure is adhesiolysis, performed to isolate the colostomy, mobilize the small-bowel loops in the pelvis and to identify the rectal

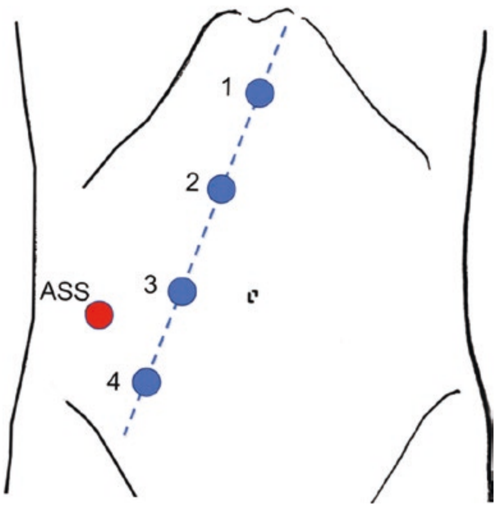

Fig. 17.1 Position of the ports during a robotic Hartmann's reversal (*ASS*, assistant port)

stump. Adhesiolysis is performed with a combination of blunt and sharp dissection using the bipolar forceps and the monopolar hook.

After isolation of the colostomy, the proximal colic stump is resected with a robotic 60-mm stapler (SureForm, blue cartridge). The proximal stump is completely mobilized by the mobilization of the splenic flexure, by dissection of the splenocolic and phrenicocolic ligaments and by separation of the Toldt's and Gerota's planes under the inferior mesenteric vein. When needed, mobilization is completed by coloepiploic detachment. Adequate vascularization of the colonic stump is ensured with the indocyanine green test.

After mobilization of the proximal stump, this is exteriorized by a mini-Pfannenstiel incision and the 31-mm anvil of the end-to-end stapler is secured to the colonic stump. An end-to-end Knight-Griffen colorectal anastomosis is then performed and a hydropneumatic leak test is done to assess its integrity. Usually, a pelvic drain is left in place. The procedure ends with extraction of the ports, direct visualization and closure of the port sites, mini-Pfannenstiel incision, and ostomy site.

17.5 Conclusions

From a clinical point of view, robotic technology seems to facilitate the approach to Hartmann's reversal by improving the visualization and dissection capabilities during adhesiolysis in a complex abdomen. The main advantages of the robotic approach seem to be the lower rate of conversions in comparison to the standard laparoscopic approach. However, although the current literature seems to show favorable outcomes for the robotic technique, the results are still scarce and no clear advantage of this approach can be defined as yet.

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18 Robotic Ventral Rectopexy for Rectal Prolapse

Antonio Sciuto, Luca Montesarchio, Alfredo Pede, and Felice Pirozzi

18.1 Introduction

Rectal prolapse or procidentia is a pelvic floor disorder that typically presents in parous older women but can occur in men and women of all ages. It is a debilitating condition that results in local symptoms (seepage of mucus, bleeding, pain, rectal and pelvic pressure), bowel dysfunction (irregularity, incomplete evacuation, fecal urgency, fecal incontinence, outlet dysfunction constipation), and an impaired quality of life.

Surgery is the mainstay for the treatment of rectal prolapse and can be performed through a transabdominal or a perineal approach [1]. Abdominal repairs may offer lower recurrence rates than perineal surgery, allow for correction of a concomitant pelvic organ prolapse, and should be offered to physically fit patients. Abdominal surgery involves either posterior or anterior rectopexy by using sutures or a mesh. Posterior rectopexy can produce or worsen constipation maybe due to autonomic denervation from posterior mobilization of the rectum or to angulation of a redundant sigmoid colon. Adding a sigmoid resection to posterior suture rectopexy (also known as the Frykman-Goldberg procedure: see Video 18.1) decreases the risk of postoperative constipation and is a good option for patients who present with this complaint preoperatively and often have a redundant sigmoid colon, although anastomotic leak may occur [2].

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Ventral mesh rectopexy was first described by D'Hoore in 2004 for the treatment of rectal procidentia. It involves a pure anterior rectal mobilization and mesh suspension of the anterior rectal wall to the sacral promontory. Ventral mesh rectopexy avoids injury to the parasympathetic and sympathetic innervation that can occur with posterior rectal mobilization and division of the lateral stalks, thus reducing the risk of postoperative constipation and the need for a sigmoid resection [3]. This approach gives the opportunity to correct symptomatic internal rectal prolapse as well as concomitant rectocele and enterocele, and can be combined with vaginal prolapse procedures, such as colpopexy, in patients with multicompartment pelvic floor defects. Due to the good functional results and low recurrence rates, ventral mesh rectopexy has rapidly gained acceptance as a favored surgical therapy for rectal prolapse [4].

A laparoscopic approach is usually selected for ventral mesh rectopexy due to improved morbidity and faster recovery compared to open surgery. However, the need for dissecting along the rectovaginal (or rectovesical) septum as well as suturing within the confined space of the deep pelvis makes ventral mesh rectopexy a procedure ideally suited for robotic surgery. Indeed, improved visualization, fine motions, and a stable exposure of the surgical field may optimize anatomical dissection, preservation of critical structures (autonomic nerves, presacral venous plexus, and right ureter) as well as mesh fixation. To date, robotic ventral mesh rectopexy has been reported as a feasible and safe procedure [5]. Few studies and with relatively small sample sizes have compared outcomes after robotic and laparoscopic ventral mesh rectopexy. It is important to note that most studies are performed by surgeons who are experts in laparoscopy but relatively new to robotic surgery [6]. With this limitation, perioperative as well as functional outcomes and recurrence rates have been shown to be similar regardless of the approach used. However, data from recent meta-analyses suggest that the robotic platform may reduce intraoperative blood loss, length of hospital stay, and postoperative complication rates when compared with conventional laparoscopy [7, 8]. This may offset the additional theatre costs associated with robotic surgery. Also, it has been shown that operative time – which is one of the main criticisms of robotic rectopexy – decreases with increasing experience and that the trend toward a longer duration of the robotic procedure may not be statistically significant. Furthermore, a shorter learning curve has been demonstrated, with nearly twenty cases needed to gain proficiency with the robotic approach compared to almost one hundred cases for the laparoscopic approach [9].

The type of mesh material, whether synthetic or biologic, continues to be a matter of debate regarding mesh-related complications and recurrence rates. Synthetic mesh is usually made of lightweight or heavyweight polypropylene, with polyester not being recommended due to a much higher risk of erosion. To date, it is difficult to draw definitive conclusions on this topic. However, current data do not support the idea that biologic mesh entails a higher risk of recurrence compared to synthetic mesh. There might be a small advantage of a lower risk on mesh-related complaints in favor of biologic mesh, which should be considered against the higher costs. This may suggest the use of a biologic mesh in high-risk patients such as smokers, diabetics, patients with inflammatory bowel disease, previous pelvic irradiation, and intraoperative leak from the rectum or vagina [10].

Preoperative diagnostic evaluation includes a careful history and full physical exam, colonoscopy as per screening guidelines, defecography, anorectal physiology studies, and colonic transit study in patients with a severe or lifelong history of constipation. A multidisciplinary evaluation can improve outcomes. Perioperative care is provided according to an enhanced recovery pathway.

18.2 Operating Room Setup, Patient Position and Port Placement

A full robotic procedure is performed by using a da Vinci Xi surgical system (Intuitive Surgical, Inc., Sunnyvale, CA, USA). The patient cart is docked from the patient's left side, while the assistant surgeon and scrub nurse stand on the patient's right side.

Surgery is performed under general anesthesia. An orogastric tube and a Foley catheter are inserted. The patient is placed supine with both arms alongside the body and legs apart on Allen stirrups. A viscoelastic mat (CarePad) is placed on the operating table to prevent the patient sliding throughout the surgical procedure and to reduce the risk of pressure injuries. A lateral support with adequate padding is also placed at the level of the right shoulder.

A 12-mmHg pneumoperitoneum is achieved by using a Veress needle through a small incision at Palmer's point in the left hypochondrium.

Four 8-mm robotic ports and one 12-mm assistant port (AirSeal Access Port) are used. Three robotic ports are placed in the right abdomen at least 8 cm from each other along a straight line that is parallel and approximately 4 cm lateral to the costofemoral line. An additional robotic port is placed in the left flank, while the assistant port is placed in the right subcostal region, 5–10 cm away from the robotic ports.

The robotic port for the endoscope is placed first after a saline drop test, while the remaining working ports are placed under direct vision. Limited laparoscopic lysis is performed to allow positioning of ports when adhesions are encountered. Then adhesiolysis is completed under robotic assistance.

The patient is positioned in a steep Trendelenburg with right tilt (20–25°), allowing the small bowel to be displaced out of the pelvis under gravity, thus obtaining a good surgical field exposure. The patient cart is deployed and, after a 30° endoscope has been installed on robotic arm 3 (R3), targeting is done towards the pelvis. Next, the rest of the arms are docked and positioned, and the instruments are inserted. A tip-up fenestrated grasper, a force bipolar and a permanent cautery hook are mounted on arm 1 (R1), arm 2 (R2), and arm 4 (R4), respectively. A medium-large clip applier, or a large SutureCut needle driver are used in R4 during the procedure. Curved scissors may be employed instead of the cautery hook according to surgeon's preference.

18.3 Rectal Mobilization

If present, the uterus is retracted by placing a straight needle 2–0 polypropylene suture which passes through the fundus and the anterior abdominal wall and is tied extracorporeally over the pubis to better expose the rectovaginal plane. The recto-sigmoid junction is retracted cranially, anteriorly, and to the left by the tip-up grasper in R1, exposing the right pararectal fossa.

The right lateral peritoneum of the rectosigmoid mesentery is divided starting over the sacral promontory and advancing distally toward the rectovaginal septum (Fig. 18.1). The plane of the peritoneal incision is made medial to the right common iliac artery. Care is taken to avoid damage to the right hypogastric nerve and ureter, which may be visible through the lining of pelvic peritoneum. Dissection along the right pararectal fossa should remain superficial and limited to about 3 cm in width – just enough to admit a strip of mesh and without performing posterior mobilization of the rectum.

At the level of the pouch of Douglas, the peritoneal incision curves from right to left over the ventral aspect of the rectum in the shape of a smooth inverted letter "J" (Fig. 18.2). Then dissection is performed in an anterior plane between the

Fig. 18.1 Division of the pelvic peritoneum on the right side of the sigmoid-rectal junction

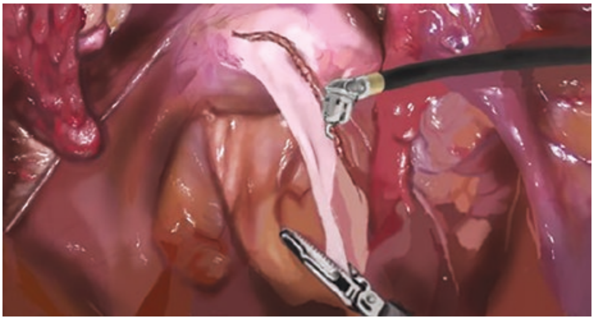

Fig. 18.2 Rectovaginal "soft J" dissection with monopolar cautery hook

vagina and rectum. A uterine and vaginal manipulator may be used to lift the posterior vaginal wall and helps identifying the rectovaginal plane. Once identified, the tip-up grasper is used as a retractor deep in the pelvis, while the assistant grasper retracts the rectum cranially. Dissection along the anterior rectal wall is carried out inferiorly down to the level of the pelvic floor and laterally to the cardinal ligaments. Rectal examination may help in assessing the distance from the anal verge, which should not be more than 3–4 cm from the pectinate line. The posterior and lateral attachments of the rectum are left intact to avoid injury to the autonomic nerves and reduce the risk of postoperative constipation and pelvic floor dysfunction.

18.4 Mesh Placement

A strip of lightweight macroporous polypropylene mesh, 3 cm wide and 15 to18 cm long, is inserted into the abdomen through the assistant port. The mesh is secured to anterior aspect of the distal rectum by using four 2–0 Ethibond interrupted stitches (Fig. 18.3). Care is taken to pierce the seromuscular layer of the rectal wall without penetrating the rectal lumen.

The mesh is passed on the right side of the rectum and its proximal end is fixed to the sacral promontory with two 2–0 Ethibond sutures, while taking care to avoid injury to the presacral veins, hypogastric nerves, right ureter, and iliac vessels (Fig. 18.4). The mesh should lie without tension or redundancy. The peritoneum is then re-approximated over the mesh with a 3–0 PDS (polydioxanone) barbed running suture. This provides elevation of the pelvic floor and leaves the mesh extraperitoneal to prevent mesh-related complications. No drain is routinely left in place. If placed, the suture for uterus retraction is removed. The trocars are removed under direct vision, and the fascial defect of the 12-mm assistant port is closed with absorbable sutures.

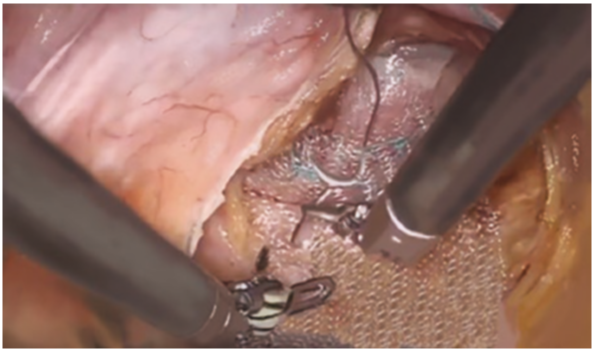

Fig. 18.3 Placement of a polypropylene mesh and fixation to the anterior rectal wall with nonabsorbable sutures

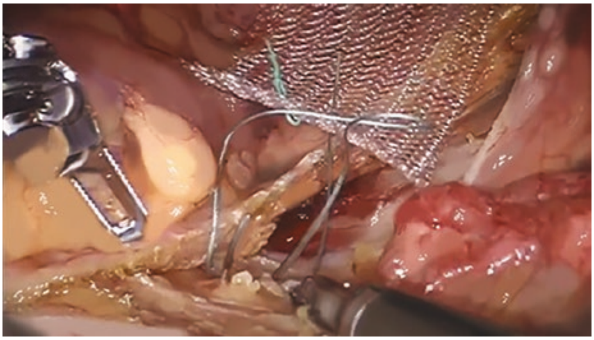

Fig. 18.4 The mesh is secured cranially to the sacral promontory with nonabsorbable sutures

18.5 Conclusions

Robotic ventral mesh rectopexy is an effective approach for the surgical treatment of rectal prolapse. The robotic approach helps to overcome the limitations of conventional laparoscopy in confined spaces like the pelvis and may potentially become the gold standard for ventral mesh rectopexy. Prospective high-quality data are needed to validate the preliminary results and to draw conclusions on the long-term functional outcomes and recurrence.

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19 Robotic Treatment of Colorectal Endometriosis

Elisa Bertocchi and Giacomo Ruffo

19.1 Introduction

Deep infiltrating endometriosis (DIE) is defined as endometriosis lesions infiltrating more than 5-mm beneath the peritoneal layer [1]. The endometriosis nodules generally arise from the posterior portion of the uterine cervix and spread to the recto-vaginal septum, uterosacral and parametrial ligaments. This leads to a chronic inflammatory reaction and fibrosis that can provoke a distortion of normal pelvic anatomy, pain, and subsequent infertility [2]. Bowel endometriosis is a type of DIE defined by the presence of ectopic endometrial glands and stroma outside the endometrial cavity and infiltrating at least the muscularis propria of the intestinal wall [3]. Patients with bowel endometriosis may suffer pain, dyschezia, abdominal bloating, constipation or diarrhea, passage of mucus with the stools, cyclical rectal bleeding, defecation urgency, a feeling of incomplete evacuation, and even bowel occlusion [2, 4]. Endometriosis prevalence varies from 7% to 10% among women of reproductive age rising to between 30% and 35% in infertile women. The percentage of bowel involvement ranges from 8% to 30% with high incidences in referral hospitals [4]. The main locations of intestinal endometriosis, in order of frequency, are the rectum and the sigmoid (83%) followed by the appendix, the small bowel, the cecum and ileocecal junction [2, 4]. Endometriosis could be seen as the tip of an iceberg, with a large proportion of women having a misdiagnosed and incorrectly treated disease.

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Hormonal therapies may improve the symptoms caused by bowel endometriosis. However, surgery is required in patients with occlusive or subocclusive symptoms, in those whose symptoms have not improved despite the use of hormonal treatments, in those with contraindications to the use of hormonal therapies and also in patients hoping to conceive [5]. Nowadays a minimally invasive approach is the standard of care in the surgical treatment of endometriosis [1, 2, 4, 5]. The robotic approach is a consolidated and developing technique that can lead to good surgical results in this field. In this chapter the technical details of robotic surgery for bowel endometriosis are reported.

19.2 Patients' Preoperative Work-Up

Endometriosis is staged according to the revised American Fertility Society Classification [6]. Preoperatively, all women are asked to define endometriosis-related symptoms and their intensity using the Visual Analog Scale [2, 3, 5]. All women with suspected bowel endometriosis should undergo a clinical rectovaginal examination, an abdominal and pelvic ultrasound scan and a double-contrast barium enema or magnetic resonance imaging to map deep endometriotic lesions which may affect the rectovaginal septum and the posterior compartment [2, 3, 5].

19.3 Colorectal Surgery for Endometriosis

19.3.1 Patient Positioning and Docking

The patient is placed in a lithotomic position on a specific pad which creates friction. The arms are positioned alongside the trunk and the legs are bent/apart and abducted using specialized stirrups. A 30° Trendelenburg position and a right tilt are the first movement to expose the pelvic operative field from the small bowel loops. A bladder catheter and a uterine manipulator are placed before starting the surgery. Pneumoperitoneum is induced using the Veress needle in the Palmer's point. The 12-mm camera port can be placed infraumbilically with the aim of maintaining the operative field on the pelvis, focusing on the fundus of the uterus. Two or three additional 8-mm robotic ports are then positioned for the robotic instruments, paying close attention to maintaining a distance of at least 10 cm (the breadth of four fingers) from one another to avoid collision of the robotic arms upon docking. We usually put two 8-mm robotic accesses on the two oblique lines that connect the camera's port and the anterior superior iliac spine bilaterally at 8–10 cm from the camera port. A third robotic arm could be placed along the left side of the abdomen to create the correct traction in the complex pelvic field. In addition to the two robotic 8-mm trocars, we usually put one 5-mm laparoscopic assistant port of about 10 cm, in a lateral position to the camera port on the right. In cases of a rectal resection, a 12-mm laparoscopic port is placed in the suprapubic position for the bowel transection with the laparoscopic linear stapler. Docking could be performed by placing the robotic cart at a 45° angle to the operating table, or parallel to the operative bed or between the patient's legs. The gynecologists and the urologists use a 0° camera, and the colorectal surgeons use a 30° camera. We usually utilize a monopolar hook/scissors on the robotic arm on the right side and a robotic bipolar grasper on the robotic arm on the left side along the lines connecting the camera port and the anterior superior iliac spines.

19.3.2 Gynecological Surgical Steps

Eradication of DIE is a multidisciplinary surgery involving gynecologists and often colorectal surgeons and urologists. The first phase of this surgery, which is a nerve-sparing technique [5], is gynecological and involves the following main stages:

- Performing adhesiolysis, ovarian surgery and removing the involved peritoneal tissues.
- Opening the presacral spaces (Latzko's and Okabayashi's lateral and medial pararectal spaces) and then isolating and preserving the pelvic sympathetic fibers of the inferior mesenteric plexus, the superior hypogastric plexus, the upper hypogastric nerves, the lumbosacral sympathetic trunk and ganglia.
- Dissecting the parametrial planes, isolating the ureteral course, lateral parametrectomy and preserving the sympathetic fibers of posterolateral parametrium and lower mesorectum.
- Performing posterior parametrectomy and if necessary, doing a surgical dissection of Waldeyer's presacral space and Heald's retrorectal space.
- Developing the rectovaginal septum and sparing the distal portion of the inferior hypogastric plexus. This step allows for the isolation of the endometriotic nodule of the rectovaginal septum and/or the rectal nodule. In the case of infiltration of the vaginal wall, a portion of the wall is resected and the vaginal margins are sutured by laparoscopy or hand-sewn through the vagina.
- Opening of the tunnel of the ureter to separate the medial vascular portion of the vesicouterine ligament from its lateral part, in which the nerves of the inferior hypogastric plexus run. When the anterior parametrium is involved a complete unroofing of the ureter to the bladder is performed.

19.3.3 Type of Colorectal Surgery

Colorectal surgery for DIE is performed after both the gynecological and urological steps.

19.3.3.1 Rectal Shaving

Rectal shaving is carried out in the case of the presence of rectal/sigmoid nodules ≤3 cm with involvement up to the muscular layer of the viscera. This technique involves the removal of the endometriotic nodule without opening the intestinal lumen. In cases of evident deep damage of the muscular layer, a possible reinforcement suture could be applied [4, 7, 8]. This type of surgery could easily be performed using the two robotic arms with scissors and a bipolar grasper.

19.3.3.2 Disc Excision

Disc excision is performed in the case of rectal/sigmoid nodules ≤3 cm of the anterior wall of the bowel with muscle or full-thickness infiltration. This technique is a full-thickness resection of the anterior intestinal wall [2]. The first step is shaving of the redundant portion of the endometriotic nodule to reduce its size, and it is performed using the two robotic arms with scissors and bipolar grasper. The full-thickness disc excision of the shaved nodule is performed using a 29- or 31-mm transanal circular stapler placed under robotic vision and opened once it reaches the bowel nodule [2, 7, 8]. A gap is then created between the anvil and the shoulder of the stapler, placing the targeted anterior rectal/sigmoid surface inside this gap with the aid of a previous robotic intracorporeal single stitch used for pushing the nodule inside the jaws of the stapler. The stapler is closed and fired, resecting a half-moon shaped rectal nodule specimen. The stapler is then removed, and the integrity of the suture is checked by rectal endoscopy and a “bubble-test”. This technique does not require additional laparoscopic or robotic trocars [2, 7, 8].

19.3.3.3 Segmental Resection

Segmental resection is carried out in the case of large, circumferential, obstructive nodules and when multiple endometriotic nodules are present in the same bowel segment [5]. In this case, a 5-mm laparoscopic assistant trocar is placed about 10 cm lateral to the camera port on the right and a 12-mm laparoscopic trocar is put in the suprapubic position for the bowel transection with the linear stapler. The first step is the identification and isolation of the inferior mesenteric vessels at the sacral promontory which are closed between clips positioned through the 5-mm laparoscopic trocar [5]. Using the robotic arms, the surgeon completes the dissection on the rectum developing posteriorly the avascular plane between the Waldeyer’s fascia and the mesorectal fascia. The rectum is prepared below the endometriosis nodule and is transected using a linear stapler through a 12-mm laparoscopic suprapubic trocar. Based on the size of the bowel resection, which is the bare minimum including the nodule, a partial mobilization of the left colon is sometimes required to obtain a floppy and tension-free anastomosis [5, 7, 8]. In this case, at the end of the robotic phase, a partial laparoscopic lateral-to-medial mobilization of the left colon is performed developing the avascular plane between Gerota’s and Toldt’s fascias. After exteriorization of the surgical specimen through a Pfannenstiel incision, an end-to-end colorectal anastomosis according to Knight-Griffen is performed and is checked by rectal proctoscopy and a “bubble-test”. Loop ileostomy is created in all cases of ultra-low rectal resection, double bowel resection, concomitant vaginal suture or ureteral reimplantation or in the case of a large bladder resection.

19.4 Advantages and Limitations of the Robotic Approach to Colorectal Endometriosis

The robotic approach to colorectal endometriosis, like the robotic approach for all colorectal surgeries, allows the surgeon to be less reliant on a surgical assistant. A sitting position at a console improves the ergonomics, particularly during a long and complex surgery [7–9]. The robotic equipment guarantees other benefits such as excellent 3D stereoscopic visualization, a stable camera platform and improved dexterity [7–9]. As a result, a surgeon's possible tremor disappears and a free and high level of movement of the instruments is provided. All these aspects could be helpful in increasing the precision and the accuracy of dissection with potentially better functional outcomes (sexual, bowel and urinary function) in types of surgery, such as eradication of DIE, which require a procedure close to the nerves [9, 10]. Because of the better visualization and therefore excision, robotic procedures could improve the eradication of DIE, as stated by Mosbrucker et al. These gynecologists detected more endometriotic lesions using the robotic technique than with the standard laparoscopic approach [10]. The early postoperative outcomes, such as post- and intraoperative complications and the length of the hospital stay, are similar when comparing the laparoscopic and the robotic approaches for colorectal endometriosis [7–9]. A large number of studies have demonstrated that in this surgical field the main limits of robotic surgery compared to laparoscopy include longer operative time and higher costs. Most of the authors who analyzed the disadvantage of the longer surgical duration reported that docking and trocar setup were the main causes for the longer operative time [7–9]. However, a large number of papers have demonstrated that the robotic learning curve is shorter than that of laparoscopic technology [7, 8].

Further studies, possibly controlled trials, comparing the long-term functional outcomes between laparoscopic and robotic surgery for the eradication of bowel DIE are required.

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20 Robotic Colorectal Surgery with the da Vinci SP

Dario Ribero, Diana Baldassarri, and Giuseppe Spinoglio

20.1 Introduction

Over the past few decades, multiport laparoscopy has become the standard surgical approach in the treatment of colorectal diseases. Several randomized trials have, in fact, proven a number of advantages of laparoscopy over open surgery in performing colonic or rectal resections [1].

By aiming to further minimize trauma to the abdominal wall and improve cosmetic outcomes, in the late 2000s, technological advances allowed pioneer surgeons to explore new techniques such as single-incision laparoscopic surgery (SILS) and natural orifice transluminal endoscopic surgery (NOTES), as less invasive alternatives to conventional laparoscopy. However, their widespread adoption has been limited due to intrinsic problems such as the lack of camera and instrument triangulation, limited range of motion with reduced dexterity, and instrument collision. Although some of these issues have been partially solved with a cross-handing technique, use of curved instruments and adoption of robotic platforms, these techniques remain only for skilled surgeons who have completed an adequate learning curve.

In 2018, Intuitive Surgical released for clinical application the da Vinci SP (dV SP), a unique platform specifically designed for single-incision surgery. This system utilizes a C-shaped arm connected to a 25-mm port with four channels to allow the parallel entry of an 8-mm flexible 3D camera and three 6-mm

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instruments. All instruments are fully wristed with 7 degrees of movement and have an additional elbow flexion for proper triangulation around the target. A hologram located in the bottom center of the display tracks, in real-time, the spatial location of the camera and instruments, thus permitting minimization of internal collisions. In addition, the platform's boom can rotate 360° outside and inside the port's remote center. This facilitates multiquadrant surgeries and the coordinated movement of the camera and robotic instruments as one unit, helping, for example, to visualize all four quadrants of the rectum. This maneuverability coupled with camera control represents a significant improvement over previous robotic platforms. Overall, it seems that the dV SP platform addresses many of the limitations of single-port transabdominal or transanal surgery. At present the dV SP is not yet available in Europe. Therefore, most of the experiences come from eastern countries and the USA.

The aim of this chapter is to analyze available data in the field of colorectal surgery and to present the authors' initial experience in a cadaveric model to highlight the pros and cons of this new platform.

20.2 Clinical Results of the da Vinci SP in Colorectal Surgery

Limited data still exist on the use of the dV SP in colorectal surgery. The first report was published in 2020 by Noh et al. [2], who described their initial experience with five right colectomies and two anterior resections with favorable short-term clinical outcomes and adequate pathologic results in terms of number of harvested lymph nodes, length of proximal and distal margins and quality of mesocolic or mesorectal fascias. Thereafter, few studies from both eastern [3–7] and western [8–10] institutions confirmed the technical feasibility of different types of colic (right and left colectomies, transverse colectomy) and transabdominal rectal resections, including intersphincteric and abdominoperineal resections. At the time of drafting the present chapter, the largest series of dV SP procedures has been reported by Choi et al. [11]. The authors analyzed 57 consecutive patients with rectal cancer who underwent 34 low anterior resections, 14 ultra-low anterior resections, 7 intersphincteric resections and 2 abdominoperineal resections, with satisfactory short-term outcomes. In fact, despite a 36% overall 30-day morbidity rate, only 2 patients (3.6%) suffered from major (Clavien IIIb–IV) complications, the most frequently recorded being intra-abdominal fluid collection and urinary retention (7 patients each). Final pathology confirmed the excellent performance of the dV SP in rectal resections, with a median number of harvested lymph nodes of 15.8 ± 6.1 and a positive circumferential resection margin rate of 5.3%. Interestingly, due to technical difficulties, 10 surgeries were completed with a single-port laparoscopic hybrid technique using the same robotic access without any additional trocar. Of note, most of the conversions to the laparoscopic approach happened during the first 16 cases. Analysis of the operative time, docking time and surgeon console time also permitted the authors to analyze the learning curve, showing an improvement in surgical performance after 21 cases.

In recent years, an increasing number of total mesorectal excisions (TME) have been made from bottom to up transanally (TaTME), either laparoscopically [12] or robotically (rTaTME) [13]. After the demonstration, in a preclinical cadaveric model [14], that the dV SP can be a viable option to safely and proficiently realize the transanal phase of TaTME, Marks et al. [15] reported the first clinical experience of dV SP rTaTME in two patients who underwent proctosigmoidectomy with hand-sewn coloanal anastomosis. In both patients the authors completed the TME phase transanally; interestingly, while in one patient, the abdominal phase of the operation was completed through an abdominal single-incision with robot re-docking, in the second patient the operation was entirely performed transanally as a pure NOTES procedure.

Over the last decade, the transanal minimally invasive surgery (TAMIS) technique has been increasingly used in the treatment of rectal benign lesions and low-risk T1 adenocarcinomas. Several studies have shown that this approach has several benefits over traditional transanal surgery. However, it remains a challenging procedure due to several shortcomings, such as the lack of a stable platform, the limited space for the surgeon and assistant between the patient's legs, the difficulty of tissue dissection and suturing due the poor ergonomics and antagonism of contralateral instruments, a limited reach and a long learning curve [16]. The new dV SP has the potential to surpass all the technical challenges of conventional TAMIS. After exploring in a cadaveric study the potential of the dV SP in performing TAMIS procedures [17], Marks et al. evaluated, in a phase II trial on 26 patients, the feasibility and safety of a dV SP rTAMIS [18]. They documented excellent outcomes including no piecemeal extractions and 100% negative margins on final pathology with no mortality and a 15.8% morbidity rate. Although two patients were converted to TME, the authors showed the potential of this new platform in this type of surgery.

20.3 Authors' Experience in Cadaveric Models

In March 2018, we had the opportunity to use the dV SP on cadavers. Access to the robotic platform, laboratory time and cadavers were provided by Intuitive Surgical, Inc. After 3 hours of training lab with the dV SP platform to familiarize with control of the flexible endoscope and instruments and use of the holographic navigation aid, two different operations were performed: a rTaTME and a transvaginal right colectomy with complete mesocolic excision (CME) and D3 lymphadenectomy.

20.3.1 Robotic Transanal Total Mesorectal Excision with the da Vinci SP

The cadavers were placed in the modified lithotomy position in Allen stirrups. A slight Trendelenburg (~10°) position was adopted. The patient-side cart was placed at a 90° angle to the left of the body with the vision cart over the left shoulder.

Two different scenarios were imagined, simulating a distance of the tumor's inferior margin to the anorectal junction of 1 cm in one cadaver and 4 cm in the other.

The first case initiated by manually creating a purse-string closure of the rectal lumen, at the level of the dentate line. Then, a partial intersphincteric resection was performed robotically and the dissection was continued cephalad until the levator ani plane was reached, allowing introduction of the GelPOINT Path Transanal Access Platform (Applied Medical, Inc.). This part of the operation was done positioning the remote center of the robotic trocar approximately 15 cm from the anus. The setup of the instruments and camera was as follows: the camera was inserted through the camera port, a Cadiere forceps, monopolar curved scissors, and a fenestrated bipolar forceps were inserted through ports 1, 2 and 3, respectively. The second case began with the introduction of the transanal platform. The robotic trocar was positioned at 12 o'clock of the gelatinous membrane of the device, and a 10-mm port was inserted in the inferior part of the GelSeal cap. After docking the dV SP, the instruments were set up as in the other case. A 15-mmHg pneumorectum was established and closure of the rectum with a full thickness purse-string was constructed and tightened with the robotic instruments (needle driver in arm 2). After circumferentially marking the site of rectotomy, a full thickness and perpendicular transection of the rectal wall was performed with monopolar scissors. Then, the initial dissection was conducted until the posterior avascular presacral plane was encountered. The mesorectal dissection proceeded in the posterior quadrants first, followed by dissection of the distal anterior plane. Then, the lateral sides were approached. Thereafter, dissection following the TME plane proceeded cephalad in a cylindrical fashion until the abdominal cavity was entered by opening the peritoneum of the Douglas pouch. The specimen was extracted to evaluate the quality of TME which was graded as "complete" with an intact mesorectum in both cases.

20.3.2 Robotic Transvaginal Right Colectomy with the da Vinci SP

Cadaver, patient-side cart and vision cart were placed as during the dV SP rTaTME, adding a 10° left rotation of the cadaver. The operation started with performing a posterior colpotomy through which an Alexis Wound Protector-Retractor (Applied Medical, Inc.) was inserted. Then the robotic trocar was placed transvaginally with the tip of the cannula in the abdominal cavity. The plastic sheath of the Alexis was closed around the trocar with an umbilical tape before establishing a 12-mmHg pneumoperitoneum. A 12-mm trocar was placed 5 cm above the left iliac spine. After docking the dV SP, a fenestrated bipolar forceps, monopolar curved scissors and a Cadiere forceps were placed in ports 1, 2 and 3. After positioning the small bowel in the left upper quadrant, a bottom-to-up right colectomy procedure with CME and D3 lymphadenectomy was performed, as previously described with the da Vinci Xi (dV Xi) [19]. Of note, the anastomosis was performed mechanically with a linear stapler introduced through the assistant trocar. The ileocolic anastomosis was mechanical, side-to-side, isoperistaltic with the enterotomies closed with a manual continuous barbed suture. The specimen was extracted transvaginally and inspected to evaluate the quality of the mesocolic dissection, which was graded C.

20.3.3 Technical Considerations

In the authors' experience performing rTaTME with the dV SP facilitated all critical steps of the procedure as compared to standard TaTME or rTaME with the dV Xi. First, it solved issues related to the limited space for the surgeon and assistant between the patient's legs while providing a stable surgical field with an enhanced 3D vision. Second, since all three instruments and endoscope are oriented parallel, external collisions between the arms or with the patient's thigh were avoided. Third, the instruments' articulation facilitated the initial posterior dissection which must be performed at a markedly caudal and posterior angle to enter the proper plane. In addition, improved ambidexterity and ergonomics enhanced the ease of performing the lateral dissection, a critical step for the risk of pelvic nerve injuries. This ease of dissection was further improved by the possibility to rotate the boom with coordinated instrument and camera movements to optimize the instruments' angle of approach throughout the procedure. Overall, all steps were simplified by the possibility of utilizing a third arm for traction/exposure. This represents a major advance compared to the da Vinci Si/Xi rTaTME or laparoscopic TaTME, where only two arms/instruments are available. In fact, a proper exposure has the potential to improve preservation of the integrity of the mesorectal envelope. All of these advantages might translate to a reduction of the surgeon's fatigue, stress and discomfort, resulting in an increased surgical performance.

In right colectomy, while no major differences in terms of instrument maneuverability, precise tissue handling, and meticulous dissection were observed compared to the dV Xi platform, the specific design for single-port surgery permitted us to explore a new surgical access. Although no objective data are available comparing the mechanical force of the dV SP and dV Xi instruments, we felt that in some steps the mechanical force was a little weak. In addition, compared to the multiport system, we noted a limited range in third arm traction, which in some circumstances might be a partial obstacle. An additional limitation is represented by the lack of a suction, stapling, and, more importantly, vessel sealing device.

In all our surgeries, the dV SP demonstrated to be straightforward to set up, easy to use and precise in dissection and suturing.

20.4 Conclusions

The available data and the authors' personal experience indicate that in colorectal surgery there is significant potential for the use of the dV SP, which might become competitive with the dV Xi. Many questions remain to be answered in the coming years. In particular, future studies will have to define the clinical role of this technology and establish which patients will benefit the most from its application.

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21 Robotic Surgery for Inflammatory Bowel Diseases and Total Colectomy

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21.1 Minimally Invasive Surgery for Inflammatory Bowel Diseases

Surgery still represents the mainstay of treatment for inflammatory bowel diseases (IBD) and over the last decades a minimally invasive approach has been pursued, especially for uncomplicated cases. Compared to open surgery, laparoscopy has demonstrated better postoperative recovery, less postoperative pain, shorter hospitalization and quicker return to bowel function and, above all, prevention of abdominal adhesions, which is of paramount importance in this group of often immunocompromised patients potentially requiring repeated surgery [1–3].

For patients affected by chronic ulcerative colitis that is medically refractory or presenting with dysplasia or malignancy, the standard surgical procedure is restorative proctocolectomy with ileal pouch-anal anastomosis (IPAA). IPAA, described in 1978

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by A. Parks and J. Nicholls [4], is the best option for patients desiring intestinal continuity. Originally performed using a hand-sewn open approach, the technique was reproduced in a minimally invasive fashion with the advent of laparoscopy, although the complexity of the operation and the paucity of indications limited its diffusion. Despite the often young age of patients undergoing IPAA, there is a high rate (30–40%) of post-operative complications, such as surgical site infection, ileus, anastomotic leak and 30-day readmission, even in high-volume centers [5, 6]. The major risk factors are high BMI, state of malnutrition and chronic use of steroids/immunosuppressants. Studies investigating the outcomes and potential advantages of a minimally invasive approach over open surgery have revealed in particular a long-term decreased incidence of adhesive small bowel obstruction [7]. Robotic surgery allows lower conversion rates and its use for proctocolectomy and IPAA in ulcerative colitis has demonstrated less intraoperative blood loss and fewer complications [8] and a safe IPAA [9–12].

For Crohn's disease, which generally requires a limited ileocolic resection, the use of the robotic approach showed a quicker restoration of bowel function with lower conversion and complication rates, compared to open surgery and laparoscopy. A hybrid approach was occasionally recommended in cases of disease complicated by abscess or fistula [13]. The use of the robotic approach for stricturoplasty has also been reported [14], even though the improved nerve preservation [15] makes this technology mostly useful for rectal surgery and in selected cases of reoperation, especially in male patients.

The robotic treatment of IBD requires completion of an adequate learning curve and training in robotic surgery, as well as extensive experience in open and conventional minimally invasive surgery of IBD [16, 17]. The robotic approach usually involves a longer operative time compared to standard laparoscopy, but this aspect may be improved by the growing experience and training of the surgical team [18, 19]. However, comparative studies have been unable to detect any substantial advantage of robotic surgery in terms of complications, anastomotic leaks and return to normal life.

21.2 Technical Aspects of Robotic Total Colectomy and Proctocolectomy

A total colectomy or total proctocolectomy, with or without IPAA, represents the treatment of choice for patients affected by different diseases such as chronic ulcerative colitis, familial adenomatous polyposis, and synchronous colorectal tumors. Further indications include reoperations after previous colectomy, selected cases of transverse and left splenic flexure colon tumors, toxic megacolon and functional disorders such as colonic inertia.

The patient is placed in the supine position with legs apart to allow a lithotomy position at the end of the operation (Fig. 21.1). The latest generation da Vinci X or Xi platform (Intuitive Surgical Inc., Sunnyvale, CA, USA) allows rotation of the cart without robot repositioning, with an easier and quicker multiquadrant procedure [20]. Differently from the previous robotic carts, this model is generally placed

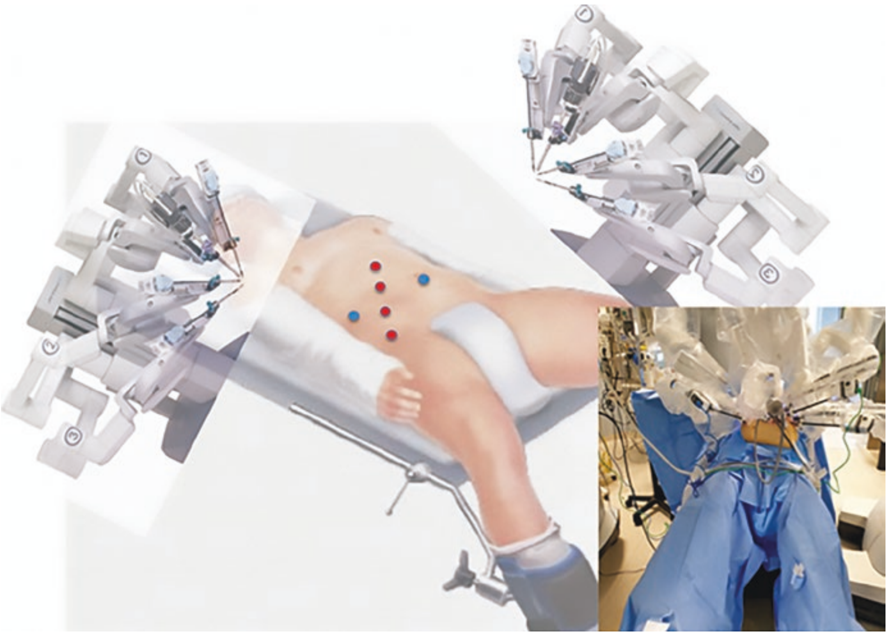

Fig. 21.1 Patient and trocar positioning for robotic total colectomy. In the inset, the patient cart location for double docking is shown

between the patient's legs for the whole procedure. Sometimes single docking is possible using the recent Xi da Vinci system, otherwise double or even triple docking is required during the main surgical steps. The rotation of the boom depends on the side of the colon to be started on and the operational steps. Four robotic ports (placed along a diagonal line as in Fig. 21.1) and one or two laparoscopic accessory ports are generally used. With the new da Vinci Xi system, two different boom positions are required. If we start from the right side, the right colon, transverse colon and splenic flexure are mobilized using the same docking with the robotic boom rotated to the right side of the patient, who is placed in a Trendelenburg position tilted to the left (20°). The second docking requires a rotation of the boom to the left side of the patient, who remains in Trendelenburg position but with a slight tilt to the right; this docking is used to complete the left colectomy, rectal resection and IPAA. A medial-to-lateral approach for the mesocolic vessels is generally performed. Lymph node harvesting up to the vessel origins as well as complete mesocolic excision and total mesorectal excision (TME) are reserved for oncologic diseases. Rectal resection may be performed using a conventional laparoscopic or robotic EndoWrist stapler. The specimen is generally extracted via a 4–5 cm suprapubic Pfannenstiel incision (Fig. 21.2) or transanally or by enlarging a paraumbilical incision. A 20-cm ileal J pouch is generally created extracorporeally with hand-sewn or stapled technique; a circular 29-mm stapler is used to fashion a transanal end-to-end ileoanal anastomosis. A protective diverting loop ileostomy is generally placed on the right iliac fossa [21–23].

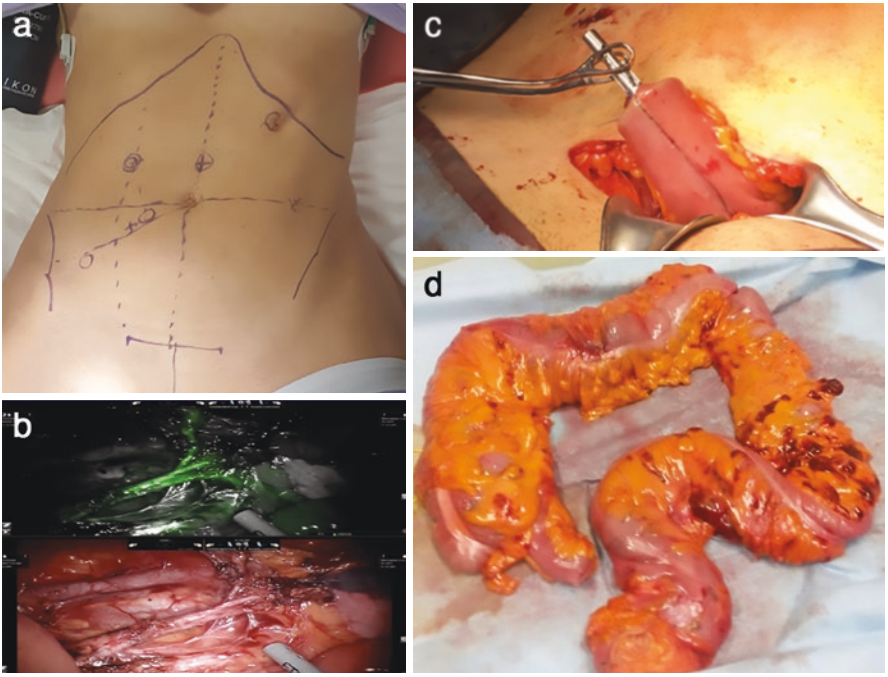

Fig. 21.2 (**a**) Pre-operative planning for trocar positioning. (**b**) Indocyanine green use for vessel identification. (**c**) Ileal-pouch packaging through Pfannenstiel incision. (**d**) Specimen of total proctocolectomy

21.3 Literature Review

The application of robotic surgery to IBD, compared to conventional laparoscopy, has shown an overall lower rate of conversion to open surgery, a shorter time to bowel function recovery especially after ileocolic resection for Crohn's disease, and an overall lower complication rate [17]. The advantages of robotic surgery for TME and nerve-sparing rectal resection have been widely demonstrated. When applied to proctocolectomy, extended colectomies and IPAA, the robotic approach has resulted in less estimated blood loss, fewer complications and lower readmission rates, compared to the laparoscopic approach [8, 15]. Hybrid approaches such as laparoscopic-open or laparoscopic-robotic have been described that may be useful when complications such as abscess, fistula, or phlegmon are present during surgery [13].

In 2016, Moghadamyeghaneh et al. published a series of 26,721 patients, from the U.S. Nationwide Inpatient Sample database, who underwent elective total colectomy during the period 2009–2012. Of these, 62.8% had open surgery, while 37.2% had a minimally invasive approach (9614 laparoscopy, 326 robotic). The most common indication was ulcerative colitis (31%). Patients who underwent open surgery had significantly higher mortality and morbidity compared to the minimally invasive approach. There was no significant difference in mortality and morbidity between the laparoscopic and robotic approaches. The conversion rate in the laparoscopic series was significantly higher than in the robotic approach. Mean hospital stay (8 days) was similar for both laparoscopy and robotic surgery and significantly lower compared to the 11 days of open surgery. Laparoscopic surgery had significantly lower total hospital charges compared to open surgery ($p < 0.01$), and total hospital charges for robotic surgery were significantly higher than for laparoscopic surgery, with a mean difference of $15,595 [24].

A systematic review of perioperative outcomes and adverse events in robotic colorectal resections for IBD was published by Renshaw et al. in 2018. Of the studies evaluated, three were case-matched observational studies, four were case series and one was a case report, for a total of 150 patients. No mortality was reported; overall complications occurred in 54% of patients, with 20% Clavien-Dindo grade III–IV complications. Mean length of hospital stay was 8.6 days; the conversion rate was 7.3%, and 24.7% of patients treated were readmitted. A significantly longer operative time was observed for the robotic procedure; however, conversion, complication, length of stay and readmission rates were similar for the robotic, laparoscopic and open approaches. None of the evaluated studies compared cost-effectiveness between the robotic and traditional approaches [19].

A systematic review by Flynn et al., including nine studies for a total of 640 patients treated with three different approaches (170 open, 174 laparoscopic, 286 robotic) for IPAA, concluded that the procedure can be performed safely, with equivalent rates of overall complications, anastomotic leaks and returns to theatre [8].

Opoku et al. analyzed, over a period of 4 years (2016–2019), 1067 open, 971 laparoscopic, and 341 robotic total colectomies with IPAA, where the most frequent indications were inflammatory bowel disease (64%), malignancy (18%), and familial adenomatous polyposis (7%). Overall morbidity was 26.8% for the entire cohort with 4% anastomotic leak, 6% reoperation, 21% ileus, and 21% readmission rate. In this series none of the techniques was associated with better short-term outcomes, including length of stay, overall morbidity, anastomotic leak, 30-day readmissions and reoperation. The traditional advantages of the minimally invasive approach (either laparoscopy or robotic) were less evident than for other operations, and the authors concluded that IPAA is associated with significant postoperative morbidity independently from the surgical approach [25].

In a recent paper, Bianchi et al. reported their personal experience of 16 consecutive patients treated with robotic total proctocolectomy and IPAA at the tertiary care center of Creteil Hospital (Henri Mondor University, France). Fourteen over 16 patients were affected by ulcerative colitis. No conversion, no readmission and no mortality were reported. Mean hospital stay was 8.2 days. The authors also performed a systematic literature review, including 23 retrospective studies with 736 robotic cases, showing that robotic surgery had a lower conversion rate compared to laparoscopy ($p = 0.03$), longer operative time ($p = 0.02$), and no difference in postoperative complications and hospital stay [26].

21.4 Conclusions

A growing interest and application of robotic surgery in IBD has been observed in the last decade. Challenging procedures, such as stricturoplasty in Crohn's disease or total colectomy or proctocolectomy for ulcerative colitis, may find in robotic technology an interesting alternative to conventional laparoscopy. However, high costs, longer operative time due to multiple docking and low availability represent the most important drawbacks of this technology. The shortage of literature on this surgery, which is performed in specialized high-volume centers in selected cases, is the reason for the lack of high-grade evidence. The lower conversion rate compared to laparoscopy is one of the main advantages reported. The new robotic devices have reduced the time required for the docking steps.

Finally, long-term outcomes, such bowel and genitourinary function, incisional hernias, quality of life, small bowel obstructions secondary to adhesions, have not been adequately investigated in this generally young population. Randomized controlled trials analyzing these outcomes and the cost-effectiveness of robotic surgery are needed to confirm the usefulness of this technology.

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Robotic Colorectal Cancer in the Elderly

22

Antonio Crucitti, Giada Di Flumeri, Andrea Mazzari, Francesco Sionne, and Pasquina M. C. Tomaiuolo

22.1 Epidemiology of Colorectal Cancer

Cancer of the colon and rectum (CRC) is the third most common cancer in men and the second most common in women with 1,340,000 new diagnoses worldwide [1] and is therefore considered one of the most life-threatening and common neoplastic diseases all over the world [2].

Asia contributes with the highest rate (1,009,400/52.3% of incident cases and 506,499/54.2% of deaths in 2020). In the United States, in the same year, there were about 104,610 new cases of colon cancer and 43,340 patients affected by rectal cancer [3]. According to the AIOM (Italian Association of Medical Oncology) registry, there were approximately 43,700 new diagnoses in Italy in 2020 (men 23,400; women 20,300) [4]. In terms of mortality, 21,700 deaths were expected in Italy in 2021 (men 11,500; women 10,200). Disease-free survival at 5 years from diagnosis is 65% and 66% in men and in women, respectively [4]. The relative cumulative survival rate following a diagnosis of CRC is 64% at 5 years and 58% at 10 years. Stage at diagnosis remains the most important predictor of CRC survival. The 5-year survival rate is 90% for the 39% of patients diagnosed with localized-stage

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disease, but declines to 71% and 14% for those diagnosed with regional and distant stages, respectively [4, 5]. Black ethnicity, age > 60 years, and low socioeconomic status are also well-known factors associated with a diagnosis of advanced-stage CRC.

22.2 Who's "Elderly"?

Many publications evaluate clinical and prognostic data in populations of different ages, varying from 65 to 80 years; consequently, the lack of a clear definition of an elderly patient is one of the most difficult problems in evaluating the outcomes of colorectal surgery in the older population.

"Elderly" is a very variable definition that arises from the environmental culture of the patient; a chronological age of ≥65 years has been defined and, more recently, it has been divided into "early elderly" for those aged 65 to 74 years and "late elderly" for those aged over 75 years. Frailty can be defined as an increased susceptibility to develop multiple chronic diseases; it relates to senescence and represents a major risk factor for multimorbidity and mortality [6]. Difficulties in enrolling in clinical trials elderly patients from a specific population are related to the presence of comorbidities, disability and organ-specific physiological changes that impair the application of current guidelines, as these are established for younger patients. Hence the importance of a multidisciplinary onco-geriatric approach that can take into account the patient in his complexity and make use of objective tools for evaluating multiple pathologies.

Vulnerability assessment, Multidimensional Geriatric Assessment (MGA) or Comprehensive Geriatric Assessment (CGA) are evaluation tools developed by geriatric medicine with the aim of planning medical and socio-health care for the patient [7, 8]. MGA has been defined as a methodology "with which the multiple problems of the elderly individual are identified and explained, their limitations and resources are assessed, their care needs are defined and an overall care program is developed to interventions to meet these needs". After an accurate MGA or CGA of the limited physiologic reserves and comorbidity, and application of a pre-habilitation program, all the patients with CRC able to undergo surgery should receive the same treatment as the younger population, according to the International Society of Geriatric Oncology (SIOG). Also surgery alone, however, can achieve favorable long-term outcomes and age is not independently associated with complications after open surgery for CRC.

22.3 Epidemiology of Colorectal Cancer in the Elderly

It should be considered that 30–40% of CRC cases occur in patients above 75 years, confirming a higher incidence in older patients [1–5]. Literature reports indicate that 75% of CRC diagnoses are in patients over 65 years, with a peak risk around the age of 70 years, while it is infrequently diagnosed before the age of 40 years.

Subjects over 80 years account for 20% of the total number of cancer diagnoses, which can be quantified in about 2 cases per 100 women and in 3–4 cases per 100 men every year [4].

22.4 Robotic Colorectal Surgery

Since the Food and Drug Administration approval of Intuitive Surgical's da Vinci robotic system in 2000, more than 20 years of robotic-assisted surgery has been performed all over the world.

The progressive discovery of the potential benefits of robotic-assisted surgery versus open or laparoscopic surgery resulted in increasing numbers of robotic procedures being performed across different surgical specialties. The introduction of robotic 3D imaging, independent camera control, wristed instruments, motion scaling and tremor filtration has helped to overcome some laparoscopic challenges in an ergonomically favorable environment.

The use of the robotic procedure for colorectal surgery was first introduced by Weber et al. in 2002 [9]. In the early years, patients older than 70 years were excluded and only young people with low ASA scores, low BMI and good performance status were selected. Prolonged and steep Trendelenburg position and the longer operative time in cases of colorectal surgery scared the pioneers of this surgery. On the contrary, improved skill and stability, particularly within confined spaces such as the pelvis, enhance the ability of the surgeon to perform a procedure via a minimally invasive approach. Moreover, lower conversion rates, less blood loss, and shorter length of stay are often reported in the literature; in colorectal surgery, the conversion rate from laparoscopic to open approach is still in the order of 15%. All these advantages are gained only after a slow learning curve and longer operating time [10]. Several studies have assessed the number of cases required to achieve expertise in robotic surgery. As reported by Müller et al., approximately 40 cases is a reasonable number also for an expert surgeon [11]. However, one of the most critical factors influencing the perioperative outcome after colorectal robotic surgery is patient selection, and these authors confirm that case complexity and not only case load should be considered crucial for the safe implementation of robotic surgery in clinical practice.

Better short-term outcomes and reduced rates of conversion to open surgery compared to laparoscopic surgery, especially when applied in selected patients, are reported in some studies on laparoscopic-assisted colorectal surgery (LACS) and robotic-assisted colorectal surgery (RACS) [12–16].

In the systematic review and meta-analysis of Sheng et al. [17], including 40 studies comprehensively compared, the efficacy of RACS, LACS, and open surgery for CRC was evaluated with the potential scale reduction factor (PSRF): the values of operation time, estimated blood loss, length of hospital stay, complication, mortality, and anastomotic leakage ranged from 1.00 to 1.01, whereas those of wound infection, bleeding, and ileus ranged from 1.00 to 1.02. LACS and RACS had the longest operation time and the shortest hospital stay compared with open

Fig. 22.1 The CMR Versius robotic platform

procedures. In the LACS group, blood loss, complications, mortality, bleeding, and ileus occurred less frequently. Better, but without significant difference, were the rates of anastomotic leakage and wound infection in LACS if compared with RACS and open surgery. RACS might be a better treatment for patients with CRC. Recent comparisons of new platforms, able to reduce expensive robotic procedures and simplify the preoperative set-up, suggest RACS may be the best method for the treatment of CRC (Fig. 22.1).

22.5 Robotic Colorectal Surgery in the Elderly

Evaluating the use of robotic surgery also in the elderly population is important if we consider that this population is increasing. The literature is still minimal, but some studies have demonstrated the feasibility of RACS in elderly patients with cancer [18–20].

In the review by Ceccarelli et al. [21], 363 patients (402 robotic procedures) were divided into three groups by age (group 1: <65 years; group 2: 65–79 years; group 3: ≥80 years) and subjected to minimally invasive robot-assisted surgery for different diseases (81% for oncologic reasons); 56% of them were male, with a mean age of 65.6 years (range 18–89). CRC surgery represented the most frequent procedure (43%) in the entire patient cohort. Examining only the right colectomy group, despite a higher conversion rate in the two older groups and the small sample of ≥80-year-old patients, the authors report a similar mean operative time and hospital stay. Overall, the study concludes that robot-assisted surgery is a safe and effective technique for the aging patient population, especially for major abdominal cancer surgery in terms of risk of death or morbidity. Moreover, prolonged operative time and steep positions (Trendelenburg) did not represent an issue for the majority of patients. In clinical practice, considering the high direct costs, the decision for robotic surgical treatment in elderly patients should be made with a tailored approach.

Another prospective study was conducted by Hugo Cuellar-Gomez et al. [22] on a CRC database of 76 consecutive patients (≥75 years) who underwent a robotic-assisted CRC curative resection at Korea University Anam Hospital with the da Vinci S, Si or Xi Surgical Systems (Intuitive Surgical Inc., Sunnyvale, CA, USA). After dividing the sample into three groups, i.e., young-old (YO: 75–80 years), medium-old (MO: 81–85), and oldest-old (OO: ≥86 years), the intraoperative and postoperative findings and the oncological outcomes were compared. Postoperative complications were not statistically different between the groups. Mean follow-up time for cancer-specific survival (CSS) and recurrence risk were statistically different ($p = 0.045$ and $p = 0.008$, respectively). The CSS rates at 5 years were 27.0%, 21.0%, and 0%, respectively. At multivariate analysis, TNM stage was not a risk factor for CSS in any of the groups and the number of harvested nodes was an independent protective factor for recurrence ($p = 0.027$) and CSS ($p = 0.047$) in elderly patients. Robotic surgery is consequently considered highly feasible in elderly and very elderly CRC patients, providing a favorable operative safety profile and an acceptable CSS outcome.

Oldani et al. [23], although in a two-year limited experience with 50 colorectal surgeries in 28 young and 22 old patients, showed a significantly higher mean ASA score in the elderly but no statistically significant differences in terms of postoperative morbidity, hospital stay, first diet intake, first flatus canalization and oncological outcome in comparison with the younger group.

In a retrospective review, Asako Fukuoka et al. [24] evaluated the surgical outcomes, postoperative short-term outcomes and prognosis of 1240 patients (1131/91.2%, <85 years old) in order to better select elderly patients for robotic surgery. ASA scores were significantly poorer in the elderly group; on the contrary, the rate of reduction of lymph node dissection range, overall morbidity and respective frequencies of pneumonia and thromboembolism were significantly higher in the elderly. The CSS was not statistically different between the groups. Postoperative hospital stay was significantly longer in the elderly group ($p < 0.05$); overall survival was significantly lower in the elderly ($p < 0.05$) but relapse-free survival was not significant. The authors conclude that, after proper assessment and careful management of perioperative surgical risks, robotic CRC surgery can be indicated in elderly patients.

Westrich et al. [25] performed an evaluation of short-term outcomes in 58 consecutive patients undergoing robotic curative CRC resection, divided into two groups: old (OG: 80–85 years) and very old (VOG: ≥86 years). No statistical differences were found in terms of short-term results; major complications were globally seen in 12% of patients, and the 90-day mortality rate was 1.7%. Overall and disease-free survival were 81% and 87.3%, respectively, with a significant difference in overall survival in favor of the OG ($p = 0.024$). Also these authors consider robotic CRC surgery feasible in octogenarians, with good clinical outcomes and survival.

The literature examined, though mostly based on retrospective clinical records or with limited numbers of patients, confirms that the robotic CRC surgical approach is safe and feasible and offers many systemic benefits in elderly patients. Age alone should not be considered an exclusion criterion for robotic procedures.

22.6 Conclusions

The majority of older patients are affected by gastrointestinal and oncologic diseases and CRC surgery is increasingly performed today. Unfortunately, the use of multidimensional evaluations or better, an onco-geriatric selection is rare. Cooperation between surgeons, anesthesiologists and geriatricians is infrequent, although the literature confirms that, for this category of patients, preoperative selection and assessment are crucial.

After the good results of ERAS (Enhanced Recovery After Surgery) protocols in aged people, we have to take into account the pre-habilitation phase, in order to obtain better outcomes.

It is widely demonstrated that patients with CRC can tolerate a minimally invasive (laparoscopic or robotic) approach and that age alone is not a recognized absolute contraindication. The elderly population, even if selected for open or laparoscopic surgery, should not be excluded from the now well-known benefits of robotic procedures.

According to reports from high-volume robotic centers, RACS is safe, feasible, and well tolerated for elderly and very elderly patients. Aged populations show postoperative clinical outcomes comparable to those of younger patients. Further and larger observational and randomized prospective studies are necessary to validate the application of robotic colorectal surgery in the elderly population, to achieve better short- and long-term postoperative results. Finally, considering the high direct costs of the procedure, minimally invasive robot-assisted surgery should be performed on a case-by-case basis and tailored to each patient so as to better evaluate also the final effect on their quality of life.

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23 Robotic Procedure for Rare Rectal Conditions: GIST and Tailgut Cysts

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23.1 Tailgut Cysts and Rectal GIST: An Overview

23.1.1 Anatomic Considerations

Tailgut cysts (TGC) and rectal gastrointestinal stromal tumors (GIST) are rare tumors found in the retrorectal space, which is bounded anteriorly by the rectum and mesorectal fascia, posteriorly by the presacral fascia, superiorly by the peritoneal reflection, inferiorly by the rectosacral and Waldeyer's fascia, and laterally by the lateral ligaments, iliac vessels and ureters [1].

23.1.2 Tailgut Cysts

TGC predominantly affect female patients in the third to the sixth decade of life, although malignancy is most common in males. They are asymptomatic in 50% of cases; in the other half of patients, they may present with mass effect-related urinary and intestinal symptoms, such as constipation and rectal tenesmus. Other symptoms

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include vague, long-standing pain in the sacrococcygeal or perineal area. Lower limb neurologic symptoms have also been described in the literature. Most TGC are benign; malignant lesions tend to be symptomatic and are not detected until later in their development. Complications include cyst infection, defecation disorders, or dystocia.

23.1.3 Rectal Gastrointestinal Stromal Tumors

GIST are rare tumors arising from Cajal cells. Rectal GIST account for 5% of all GIST [2]. The incidence of GIST is higher in the fifth to sixth decade of life. Symptoms may be nonspecific as with TGC, with pelvic or anal pain, gastrointestinal bleeding, anemia or weight loss, or be absent. Contrast-enhanced computed tomography (CT) is the imaging modality of choice for the diagnosis of GIST. Fluorodeoxyglucose-positron emission tomography (FDG-PET) has good specificity and sensitivity for assessing tumor response after imatinib mesylate treatment. Approximately only 30% of GIST are malignant. Rectal GIST are classified by the National Institutes of Health (NIH) as "very low", "low", "intermediate", or "high" risk tumors, depending on location, mitotic index and size [3]. Diagnosis of a rectal GIST has been associated with a poor overall prognosis. One reason for the poor prognosis of rectal GIST is that the rate of tumor rupture is more than four times that of non-rectal GIST, and perforation is associated with a high-risk prognosis [4]. Radical resection with en-bloc excision of the mass is the standard first-line treatment for all localized GIST. Local excision, low anterior resection, abdomino-perineal excision of the rectum (APER), and pelvic exenteration might be needed. The primary goal of surgery is to obtain negative microscopic margins without causing bleeding or rupture of the pseudocapsule [5]. Transanal resection is one of the most minimally invasive methods but is limited by the distance from the dentate line [6]. Transcoccygeal excision is adequate for lower rectal GIST but has high postoperative morbidity, with fistulae occurring in 21% of patients [7]. For small rectal GIST, local resection may be safe [8]. Treatment of advanced rectal GIST requires a multimodal therapy with imatinib mesylate and is indicated for first-line treatment of metastatic or unresectable GIST.

23.2 Advantages of Robotic Surgery Compared with Open and Laparoscopic Approaches

Traditional approaches include laparotomy, perineal excision or a combination of both. Although most retrorectal lesions can be safely removed with a posterior and transperineal approach, particular challenges may arise when the lesion is large, extends deep into the pelvis, and may be fused to surrounding pelvic structures; in these cases, traditional extraperitoneal approaches may not be safe or appropriate

[9, 10]. Laparoscopic surgery has been shown to be safe, effective, and advantageous in resecting rectal GIST, including anus-preserving surgery, due to the minimally invasive approach [11]. Robotic technology allows for better visualization, making it easier to remove the tumor from the pelvic viscera and extend it to the pelvic floor [12].

23.3 Preoperative Considerations, Patient Positioning, and Port Placement for the Robotic Approach

23.3.1 Preoperative Considerations

For rectal GIST resections, there is no standard approach: an individualized approach is required, ranging from transanal excision, transanal minimally invasive (TAMIS) excision, transcoccygeal excision, rectal resection, or APER and pelvic exenteration in locally advanced cases. For TGC, transabdominal, transperineal, parasacral, or mixed approaches have been described. The decision on the ideal approach depends largely on the anatomical relationship of the tumor to the S3 sacral level [13]. Tumors above S3 require an anterior transabdominal approach, whereas tumors below S3 may benefit from a posterior parasacral approach or a combined anteroposterior approach [14]. However, patients with tumors below S4 can be approached with a robotic-assisted anterior approach above the elevator muscles plane, with good results and low postoperative morbidity. Preoperative planning is crucial and based on CT, magnetic resonance imaging (MRI) and 3D-based imaging [15]. Artificial intelligence-based reconstructions and 3D printing could also be used [16–18]. Such technologies can potentially be integrated into the robotic platforms,

23.3.2 Patient Positioning

Depending on the type of procedure required, different preoperative preparations could be considered [19, 20]. After general anesthesia, the patient is positioned supine in a modified Lloyd-Davies position.

23.3.3 Port Placement

An in-depth description of port placement and suggested steps for the robotic excision of TGC has been previously reported [21]. Robotic ports are placed in the position used for pelvic dissection. A curved line is drawn between the umbilicus and the two iliac spines to delineate the line where the trocars are to be placed (Fig. 23.1a). Pneumoperitoneum is formed with a Veress needle at the Palmer point.

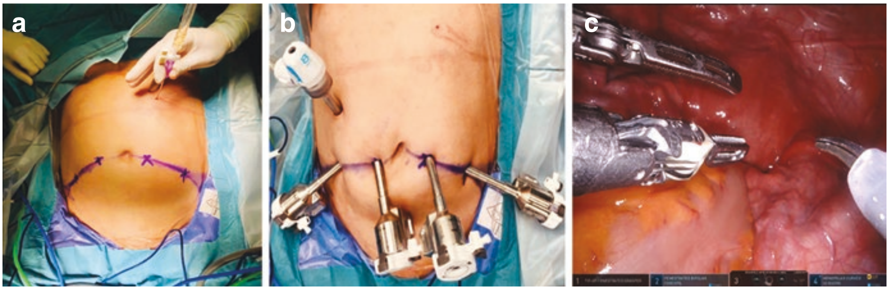

Fig. 23.1 (**a**) Curved line for port placement. (**b**) Ports in place. (**c**) Robotic instruments used

Four robotic 8-mm trocars are placed along the drawn curved line, at a distance of 6–8 cm (Fig. 23.1b), depending on BMI. An 8-mm port utilized as the assistant port is placed 5 cm cranially and laterally from the intersection of the trocar line and the right midclavicular line.

23.4 Surgical Technique in Steps

The patient is placed in a Trendelenburg position and tilted on the right side. The small intestine and the greater omentum are manually displaced toward the upper abdomen. Adhesiolysis is performed if needed.

23.4.1 Docking

The robotic cart comes from the left side of the patient at a 90° angle. The robotic arms are aligned with the trocars prior to docking. Camera targeting toward the pelvis is performed. The robotic arm distribution is: R1, fenestrated tip-up forceps; R2, bipolar forceps; R3, camera; R4, monopolar curved scissors or needle holder (Fig. 23.1c).

23.4.2 Lateral Mobilization of the Rectum

With the tip-up forceps in R1, the sigmoid colon is retracted cranially and laterally to expose the sacral promontory (Fig. 23.2a). Further countertraction can be provided with a laparoscopic grasper from the assistant port. Dissection begins anterior to the sacral promontory and continues to the right border of the mesorectum or pararectal groove (Fig. 23.2b). Care must be taken to clearly identify and protect the left common iliac vein, median sacral vessels, right hypogastric nerve, and both ureters. The tip-up grasper is repositioned continuously to allow for adequate traction (Fig. 23.2c–d). Careful dissection is performed in the mesorectal plane, allowing right-sided mobilization of the rectum down to the pelvic floor and adequate exposure of the perineal body.

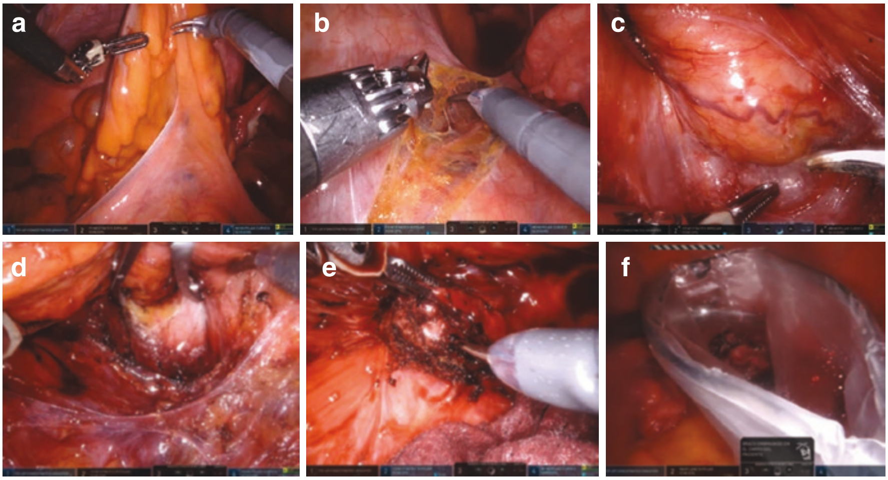

Fig. 23.2 (**a**) Sigmoid colon retraction. (**b**) Dissection anterior to the sacral promontory. (**c–d**) Tip-up grasper used for rectal retraction. (**e**) The tumor is dissected from the pelvic floor. (**f**) Extraction using a laparoscopic bag device

23.4.3 Dissection from the Pelvis

The tumor must be carefully separated from the posterior rectum to avoid damage to or perforation of the rectum but also of the tumor itself (Fig. 23.2e). After the tumor is fully mobilized, the surgical bed is washed out and hemostasis is confirmed. At this point, an air leak test can be performed to ensure no injury has been caused to the rectum. The specimen is extracted using a laparoscopic bag device either through the port or a small Pfannenstiel incision, depending on the size of the specimen (Fig. 23.2f). The trocars are removed under direct vision.

23.5 Postoperative Course, Follow-Up, and Outcomes

Intraoperative complications include hemorrhage from the presacral venous plexuses, rectal injury, sacral plexus nerve injury, or urethral injury [22]. Early postoperative complications include bleeding, wound infection, rectal and urethral injury, temporary sensory loss, and formation of a presacral abscess. Long-term complications may occur (low back pain, numbness, and neuropathic lower limb pain). Median follow-up ranges from a few months to 4 years [23]. For malignant tumors, the 5-year survival rate for patients who have undergone surgical treatment for presacral tumors ranges from 50% to 90% [24]. In benign tumors, surgical intervention does not appear to have an impact on overall survival [23].

23.6 Conclusions

TGC and rectal GIST are rare, and their diagnosis can be difficult. Once the diagnosis is established, surgical treatment is mandatory. The surgical intervention requires an experienced team in order to avoid tumor violation and ensure an en-bloc excision. A minimally invasive approach may be superior for patients who require a transabdominal approach, provided it can be performed safely and does not offer inferior surgical and oncologic outcomes. Robotic excision of retrorectal tumors is safe and particularly useful in difficult pelvic anatomy when care is taken with patient selection [10].

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Part V

New Perspectives

24 Indocyanine Green-Enhanced Fluorescence-Guided Surgery: Lymphatic Navigation, Perfusion Evaluation and Future Perspectives

Irene Urciuoli and Graziano Pernazza

24.1 Introduction

Indocyanine green (ICG) is the most commonly used fluorophore in fluorescence imaging. It is a water-soluble, tricarbocyanine dye that binds to blood lipoproteins and remains confined in the intravascular compartment until elimination. It is selectively taken up by hepatocytes and excreted into the bile. This fluorophore has tissue penetration up to 5 mm and a plasma half-life of 3–5 min with biliary excretion after 15–20 min, thus it is ideal for repeated applications [1].

ICG has several clinically excellent properties, which have been thoroughly verified during its long clinical use: (1) it is nontoxic and nonionizing and therefore has a good patient safety profile; (2) it binds efficiently to blood lipoproteins and does not leak from the circulation, which makes it ideal for angiography; (3) it has a short life-time in the blood circulation, allowing for repeated applications; (4) it offers a good signal-to-noise ratio since separate wavelengths are used for illumination and recording so that only the target, not the background, is visible; (5) it operates in tissue optical window (near infrared) so it provides deep imaging; (6) it is used with simple and cheap imaging devices.

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24.2 First Applications

ICG was initially used in photography, developed by Kodak during World War II for color imaging purposes. Medical applications of ICG were approved by the United States Food and Drug Administration in 1959. In 1960, Fox reported the characteristics of ICG and the results of its use in the Mayo Clinic centers [2]. ICG was originally, and is still, used to determine liver function [3]. In 1963, Walker applied ICG to determine renal blood flow, owing to its fluorescent characteristics. In 1965, Huffman investigated its applicability in detecting cardiac murmurs [4, 5]. ICG has since been applied to evaluate physiological brain perfusion [6]. Several perfusion and angiographic applications have been implemented with the advancement of fluorescence imaging [7, 8]. ICG is also widely applied in off-label use for real-time imaging for abdominal surgery, plastic surgery, and in oncologic staging and treatment [3].

24.3 Technology and Clinical Rationale

Fluorescence is caused by incident light that excites the target and causes light emission of a particular wavelength. When ICG is excited between 750 and 800 nm, fluorescence is viewed around the maximum peak of 832 nm. The fluorescent emitted light passes through a sensor in the optical device, displaying the green light in real-time visualization. Firefly is da Vinci's integrated fluorescence capability that uses near-infrared technology activated at the surgeon's console [9].

Fluorescence-guided imaging has widely evolved the last few years. With the implementation of advanced technologies, surgeons became able to perform more complex interventions with a minimally invasive technique and started to develop an interest in intraoperative imaging applications. ICG has applications in several surgical fields enabling real-time visualization of structures of interest and giving information that normally is uncertain under naked eyes. Tissue perfusion assessment, anatomic distinction, lymphography and other implementations have been described in general surgery, gynecology, urology, colorectal surgery and surgical oncology practice [8].

Robotic-assisted surgery is spreading quickly and has shown to overcome the intrinsic limitations of traditional laparoscopic surgery. Fluorescence imaging was integrated in the da Vinci Robotic Systems (Firefly Fluorescence Imaging Scope; Intuitive Surgical, Sunnyvale, CA) in 2010. Robotic-assisted surgery combined with fluorescence imaging technology represents a logical evolution in image-guided surgery and its benefits are still being discovered.

In general surgery, one of the very first applications was biliary duct identification. Because ICG was excreted into the bile entirely by the liver, its mechanism of enhancement became obvious. In their study, Ishizawa et al. demonstrate that fluorescent cholangiography enables real-time identification of biliary anatomy during dissection of Calot's triangle, suggesting that this simple technique may become standard practice for avoiding bile duct injury during laparoscopic cholecystectomy, replacing radiographic cholangiography, which is time consuming and may itself cause injury to the bile duct [10].

24.4 Perfusion Evaluation

Because of its ability to become fluorescent, ICG has been used in several clinical applications to evaluate real-time intraoperative organ perfusion. An amount of 25 mg of ICG is reconstituted in 10 mL of aqueous solvent under sterile conditions and then diluted in 10 mL of an isotonic solution. ICG administration may be performed via a central or peripheral venous line by the anesthesiologist whenever asked by the surgeon and multiple doses can be administered as required, up to the maximum recommended total dose of dye, kept below 2 mg/kg. The literature reports variable doses of ICG being used depending on the patient's body weight and ranging in most studies from 2.5 mg to 10 mg [3]. At the time of injection, the area of interest should be already exposed and targeted by the surgeon's endoscope. On the console display, the surgeon activates the Firefly mode to enable infrared light emission and promote excitation and fluorescence of the desired tissue. Intensity peak and washout may be affected by the patient's circulatory condition as well as by cardiocirculatory inotropes. The optimal time to detect a fluorescence signal varies between 25–60 seconds after administration and the signal peak is around 30–40 seconds after administration, losing intensity within 2 minutes [8] (Fig. 24.1).

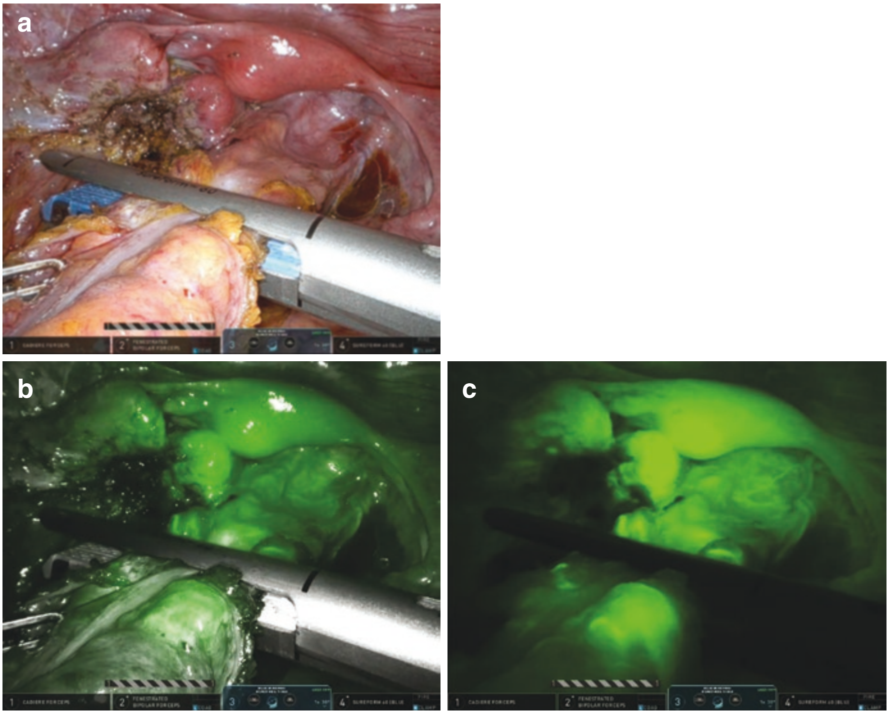

Fig. 24.1 Perfusion evaluation with indocyanine green before transecting the distal margin during left colectomy. (**a**) Direct vision under white light. (**b**) Vision under near infrared (NIR). (**c**) Deep vision under advanced NIR. The demarcation line is much more evident in NIR modalities

ICG tissue angiography can guide the identification of the optimal resection site and help to estimate the blood supply; it is used to assess the perfusion of anastomoses and sites before deciding, for example in colorectal surgery, where to resect the bowel.

24.5 Lymphatic Navigation

Another characteristic of ICG is its lymphatic tropism. Because of its inherent properties, ICG may lend itself to improved mapping rates. After submucosal or subserosal injection, it follows the lymphatic vessels and accumulates in the lymph nodes. In oncologic surgery, this property can be used to map the draining lymph nodes to assure a more precise resection, staging or lymphadenectomy.

In this case, a 1.25 mg/mL solution of ICG should be prepared as for the intravenous application, and administered according to the area of interest. In gastric or colorectal surgery, for example, an endoscopy-guided injection should be performed in four sites of the submucosal tissue around the tumor the day before surgery, for a total of 4 mL. With the Firefly mode turned on, the lymphatic tissue draining from the lesion appears ICG-enhanced on the surgeon's display and the lymph nodes will be recognized and harvested, providing accurate staging of the disease and better oncologic outcomes [11].

Intraoperative ICG administration through subserosal injection around the lesion is also possible; however, if any spill occurs during the injection, the surgical field becomes blushed and fluorescence image is compromised [8].

24.6 Clinical Application Experiences

Anastomotic leak is a serious complication in gastrointestinal surgery. Despite technical advances in colorectal surgery, the incidence of anastomotic leaks has remained steady over the past 25 years, occurring in 3–20% of patients who have colorectal surgery [12, 13]. The cause of anastomotic leaks is multifactorial, and these leaks have widespread effects that lead to a considerable clinical and economic burden on the patient and healthcare system, as well as a predisposition to local cancer recurrence [13, 14]. The diagnostic tests available are often unable to identify anastomotic leaks early enough to allow timely intervention and minimize morbidity and mortality [15]. Perfusion is vital for healing, and inadequate blood flow can result in the failure of anastomotic healing and leakage. Adequate perfusion of the anastomosis is commonly confirmed by subjective methods.

ICG perfusion assessment has found a broad field of application in colorectal surgery and is used mainly to assess the perfusion of anastomoses and sites before deciding where to resect the bowel [8].

Bowel perfusion around the anastomotic area can be successfully visualized and quantified using near-infrared fluorescence imaging. Prolonged T_0 might be a useful parameter for predicting anastomotic leak in colorectal surgery [16].

ICG use should be divided in two different steps: first, the planned point of proximal and distal transection area just before the bowel resection and, second, after completion of the anastomosis, another course of ICG injection is encouraged to visualize the integrity of anastomosis and its vascularity.

In his study, Kuzdus states that fluorescence imaging is a method that may significantly reduce not only the rate of severe complications in colorectal surgery but also the length of hospital stay [17].

There are of course some open questions about the use of fluorescence imaging to check the anastomosis: (a) timing of fluorescence (before or after transection); (b) time of fluorescence [18]; (c) distance between tissue and camera (5 cm?); (d) camera system (Karl Storz, Olympus, Stryker, Intuitive, Mitaka); (e) ICG dose (0.25 mg/kg–10 mg); (f) anastomotic technique (side-by-side, end-to-end, hand-sewn, stapled); g) anastomotic site (ileocolic, colocolic, colorectal, coloanal).

As stated, ICG can be used in colorectal surgery also for lymph node mapping, in order to recognize and properly harvest lymph nodes, to provide a more accurate lymphadenectomy and achieve better oncologic outcomes [19, 20].

In rectal cancer, in addition to assuring a correct transection line and well-perfused remnant bowel and visualizing the integrity of the anastomosis and its vascularity, if a low colorectal anastomosis is performed, a third optional step by visualization of the rectum and anastomosis mucosa may be achieved with an additional Firefly integrated endoscope via proctoscopy [8] (Fig. 24.2).

Some studies about rectal cancer surgery confirm that ICG fluorescence imaging is a promising tool that could be of help in clinical practice. It may reduce the anastomotic leak rate in patients undergoing colorectal resection for cancer [21] and it is also associated with fewer postoperative complications and a lower rate of secondary surgery [22].

Assessment of perfusion of the anastomosis is especially relevant in non-anatomic resections, whereby aberrant or altered vascular anatomy can impair perfusion to the remaining colon [14].

Similar considerations might be extended to upper gastrointestinal surgery. ICG tissue angiography might guide the identification of the optimal resection site and help estimate the blood supply of upper gastrointestinal tissue and visceral anastomosis.

Intraoperative evaluation with ICG fluorescence angiography offers a dynamic assessment of tubularized gastric graft perfusion and can guide anastomotic site selection during an esophagectomy, with a reduction of anastomotic leak rates [23, 24]. Zehetner et al. [25] also described lower leakage rates in patients following esophagectomy when the anastomosis was placed in an area of good perfusion after fluorescence imaging.

In gastric cancer, an accurate lymphadenectomy is a crucial prognostic factor.

ICG can noticeably improve the number of lymph nodes harvested and reduce lymph node noncompliance without increased complications in patients undergoing D2 lymphadenectomy [26]. It is helpful for the surgeon not only to identify node stations but also to better discriminate the borders of the dissection, enhancing the recognition of vascular structures and other organs.

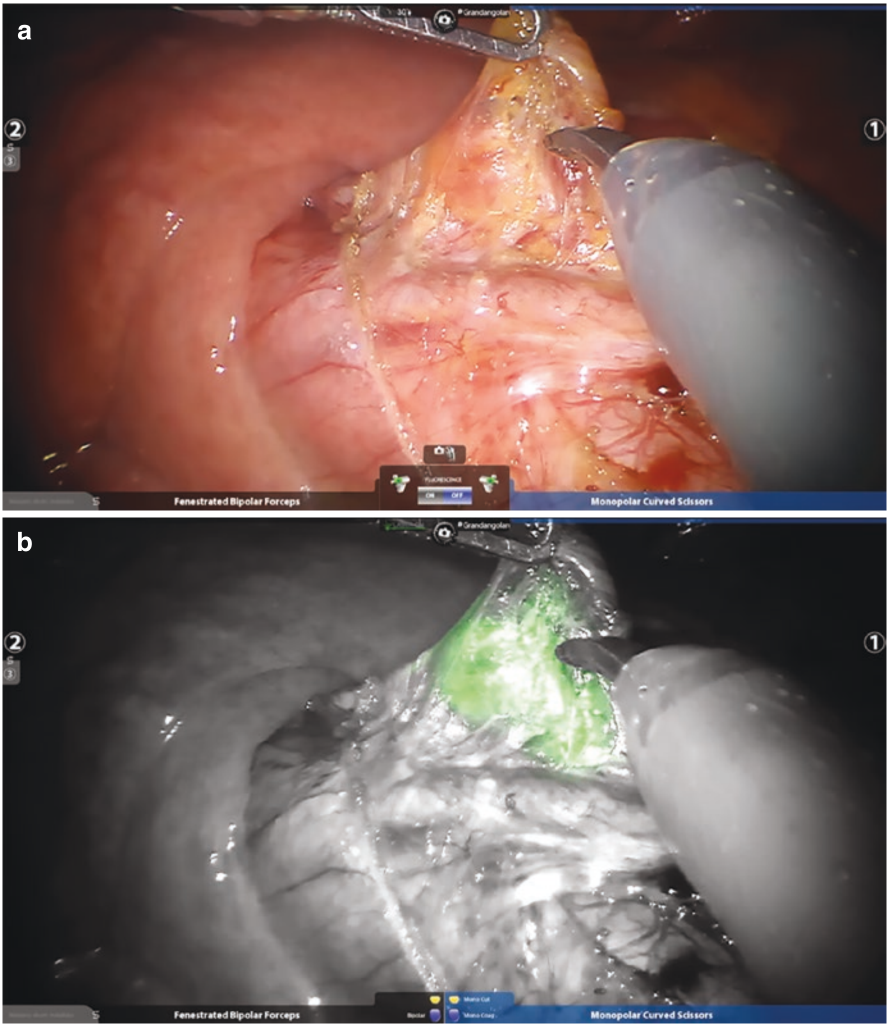

Fig. 24.2 Lymph nodes at the root of the mesenteric artery. Vision under white light (**a**) and under fluorescence (**b**). Highlighting of the lymphatic basin and lymph nodes after perilesional submucosal injection of indocyanine green, administered transanally, in a case of rectal cancer

In the treatment of achalasia, ICG-guided assessment of the mucosal layer after myotomy during a robot-assisted Heller-Dor procedure has been recently reported to exclude iatrogenic microperforations intraoperatively, but also to visualize ischemic areas caused by monopolar diathermy, which may develop into delayed esophageal perforations with life-threatening consequences [27]. This technique may have relevant potential advantages over intraoperative endoscopy. Moreover, this method may improve the identification of residual fibers, making a more accurate myotomy possible and thus preventing possible relapse of the disease (Fig. 24.3). Finally, its use was linked to shorter operating times.

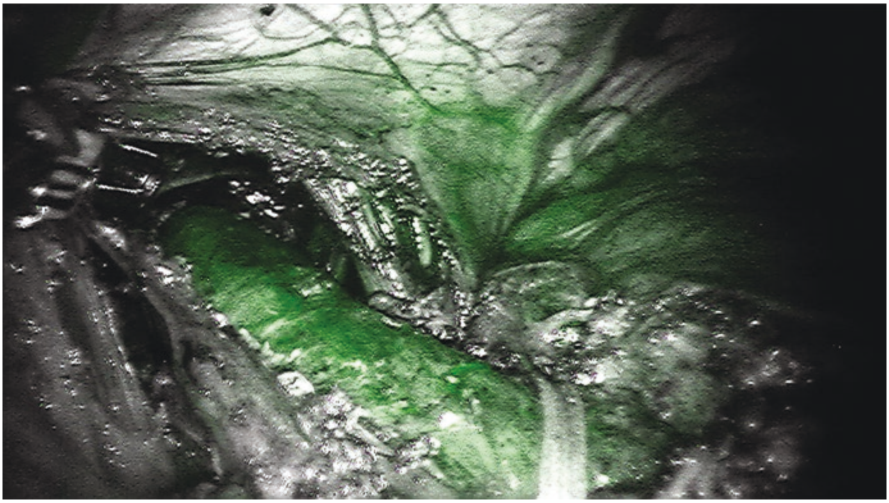

Fig. 24.3 Use of indocyanine green after a Heller myotomy to evaluate the mucosal layer. This method has been proposed as an alternative to intraoperative endoscopy to assess the mucosal integrity and to better identify any residual muscular fiber

In liver surgery, ICG is still mainly used as a reagent for the evaluation of hepatic function. Also, ICG accumulates in the cancerous tissues of hepatocellular carcinoma and in the noncancerous hepatic parenchyma around adenocarcinoma foci, which may be used to increase detection. Liver fluorescence may be achieved with intravenous peripheral or central access administration or by a local intraoperative injection into the portal vein or right gastric vessels.

A second manner of enhancing the visualization of lesions is by injecting the ICG the day before surgery, which will provide clearance of the substance in the normal hepatic parenchyma with residual stain in the altered tissue area. Also, for a better visualization of the hepatic transection line and perfusion enhancement in major hepatectomies, after clamping or ligation the portal pedicle and arterial branch, ICG administration will also enlighten the remnant liver tissue in contrast to the non-well perfused [8].

This imaging modality is emerging as a navigation tool for resection of metastatic hepatic tumors in laparoscopic hepatectomy. It might help surgeons to safely and accurately identify colorectal metastatic lesions and complete laparoscopic hepatectomies, compensating for the limitations in tactile feedback and intraoperative ultrasound of the hepatic surfaces [28, 29].

Regarding pancreatic surgery, ICG fluorescence can be useful to identify pancreas tumors in patients undergoing pancreas resection, specifically neuroendocrine tumors and cystic neoplasms. Neuroendocrine tumors are enhanced with a higher fluorescence signal compared to pancreatic tissue; on the contrary, cystic neoplasms will display lesser fluorescence intensity compared to normal tissue [8].

24.7 Future Perspectives

Even if its usefulness is increasingly recognized and its use is expanding in the field of surgery, some aspects of ICG fluorescence still need to be more thoroughly analyzed and developed in the future:

- *Time and volume*
  The assessment of administration time and volume is under debate. In published series, there is a wide variety in the reported dilution, time of administration, timing of observation (before or after transection), visualization system used, distance between tissue and camera, anastomotic technique. A standardized protocol is far from being defined and there is a lack of consensus on how to objectively judge the effect of ICG [18].
- *Lymphatic mapping*
  Lymphatic mapping and image-guided lymphadenectomy are interesting developments, but we need larger experiences. The number of noncompliant resections may be lowered with ICG fluorescence imaging, but it is still unclear why the dye fails to identify all the lymph nodes. A very interesting perspective could be in the field of molecular engineered selective dyes which will allow selective binding of tissues [30].
- *Artificial intelligence*
  Key surgical decisions are traditionally made by human visual judgements. To exclude variability in the judgement of the ICG effect on tissues, spectrophotometric objective evaluation of tissues will be possible in digital platforms (artificial intelligence and augmented reality) [31].

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New Robotic Platforms

25

Ludovica Baldari, Luigi Boni, and Elisa Cassinotti

25.1 Background

25.1.1 Limits of Endoscopic Surgery

Minimally invasive surgery has been performed for over 30 years leading to a new era, but improvements in instrumentation lagged behind the clinical developments. Standard laparoscopic instruments are rigid and can be opened and closed in order to catch or cut, allowing five degrees of freedom (DoF): in/out, up/down, left/right, rotation, open and close of the jaw [1]. Specific tasks are difficult to perform with standard laparoscopic instruments, including suturing in a horizontal direction or reaching some abdominal regions and organs, especially when a lateral approach to tissue is necessary [2].

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25.1.2 From Endoscopic Surgery to Robotic Surgery

Robotic surgery provides the same patient benefits as laparoscopy without the limits of traditional tools. Indeed, the end effector of robotic instruments is equipped with a miniaturized wrist achieving seven DoF: in/out, up/down, left/right, rotation, flexion/extension of the wrist, abduction/adduction of the wrist, open and close of the jaw [3]. Nevertheless, these benefits are associated with substantial financial costs.

As several key patents expired in 2019, competing companies are now allowed to adopt these technologies. Thus, in the last few years, many companies have developed new robotic platforms, applying for Food and Drug Administration (FDA) approval in the United States and for CE marking in the European Union for clinical use. This chapter will provide an overview of new robotic platforms already approved for clinical use.

25.2 New Robotic Platforms

New Robotic Platforms can be classified according to some of their features:

- *Console, closed or open*: the closed console allows the operator to fix her or his head in position without any alteration of the field of view during the procedure. By contrast, in the open console the operator is free to move her or his head, can achieve a better communication with the operating room team and has a view of the operating room.
- *Operating units*: the operating units can be boom-mounted, units mounted on multiple carts, or table-mounted.
- *Kinematics*: remote center of motion kinematics, or general serial kinematics.
- *Haptic feedback*: some robotic platforms are equipped with haptic feedback from the robot to the operating surgeon, which can result in a reduction of the force applied [4].
- *Augmented intelligence*: some systems can be provided with software that enables camera movement according to instrument movements [5].

25.2.1 Senhance Surgical Robotic System

Originally developed by SOFAR SpA (Milan, Italy) and called TeleLap Alf-X, this system was renamed after being acquired by TransEnterix (Morrisville, North Carolina, USA). Apart from the da Vinci by Intuitive, it is the only new robotic platform that has both the CE mark and FDA approval for general surgery. The Senhance surgical system has a seated-open console with 2D or 3D monitor, according to surgeon preference, keyboard and touch pad and a single pedal. The robot can control up to four detached and independent robotic arms. The platform provides advanced eye-sensing camera control, enabling the surgeon to maneuver the camera through eye movement and forward and backward head movement for zooming. The system has haptic feedback integrated in it, allowing surgeons to feel tissue consistency and force applied. One of the main advantages of the Senhance system is the reduced cost, as it utilizes a set of reusable non-wristed 5-mm laparoscopic instruments. However, this also represents a limit, because lack of articulation implies a decrease in dexterity: one of the main features of any robotic system [6].

In 2019, the TransEnterix's Senhance Ultrasonic System received FDA approval. It is an advanced energy device that couples with the Senhance robotic platform, allowing a better hemostasis through high-frequency vibration that denatures proteins with minimal thermal spread. Moreover, the system offers 3-mm instruments for microlaparoscopy. The Senhance includes a "machine vision system", which is a form of augmented intelligence that moves the camera according to instrument movements. This tool will learn procedure steps and how the surgeon approaches the cases [7].

McKechnie et al. published a systematic review on six observational studies including 223 patients who underwent colorectal procedures with the Senhance Surgical Robotic System. The authors concluded that the system has an acceptable safety profile, reasonable docking and console times, low conversion rates, and an affordable case cost across a variety of colorectal surgeries [8].

25.2.2 Cambridge Medical Robotics Versius System

Developed by Cambridge Medical Robotic Limited (CMR Ltd), the Versius system has obtained the CE mark, while FDA approval is still pending. The platform has an open console that allows both standing and sitting according to operator preference, with an HD-3D monitor. There is no foot pedal control, as all the functions are managed by the joystick controllers, including the camera (Fig. 25.1a). One of the main advantages of the system is the small and modular design of the independent cart-mounted robotic arms providing versatility to the system (Fig. 25.1b). With an arm footprint of 38 cm x 38 cm, the system is intended to be a versatile platform that can be moved between operating rooms and stored outside them. The surgeon can use up to five arms that allow 360° wrist motion thanks to the V-wrist technology with maximum freedom of port placement. The costs are reduced thanks to reusable wristed 5-mm instruments allowing seven DoF [9].

Some case series on colorectal resections using the Versius platform have been published. In all of them, the authors concluded that colorectal resections are feasible and safe even in the case of oncological procedures [10–12]. Moreover, they stated that the system presents dexterity and intuitive movements, allowing oncological safety throughout the procedure [12].

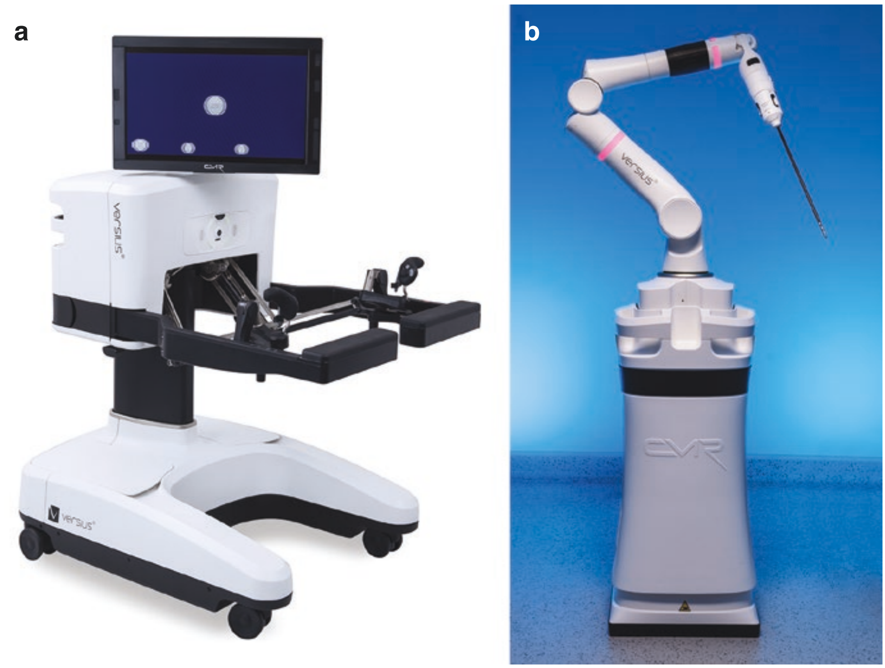

Fig. 25.1 (**a**) CMR Versius system console. (**b**) CMR Versius system operating units. Reproduced with permission from CMR Surgical

25.2.3 Hugo Robotic-Assisted Surgery System

The Hugo system is a robotic platform created by Medtronic, following the acquisition of German-based robotic system MicroSurge as part of the acquisition of Covidien in 2014. The system is a modular platform composed mainly of three elements: the Hugo vision cart, the modular robotic arms and the surgeon control console (Fig. 25.2). The Hugo vision cart is provided with a Karl Storz vision system that allows 2D and 3D visualization with fluorescence-guided surgery capabilities, the Valleylab FT10 energy generator for surgical instruments, a touch surgery video and recording analytics. The surgeon control console has a seated, semi-open design allowing fixed field of view during the procedure and, meanwhile, the possibility of interacting with the patient and operating staff more freely. Each robotic arm is attached to an individualized cart, allowing flexibility of placement and mobility, using seven DoF instruments. The design is more cost-effective than that of the da Vinci robot due to its more durable surgical instruments [13].

The Hugo does not have FDA approval, but it recently obtained CE mark for general abdominal surgery.

Fig. 25.2 Hugo robotic-assisted surgery system. Reproduced with permission from Medtronic

25.2.4 Revo-i Robotic Surgical System

In 2015, the Korean Meere Company developed the Revo-i system, a master-slave platform similar to the da Vinci robot. It is made up of three components: the 3D-HD vision cart, a seated-closed surgeon control console, a four-arm robotic operation cart. The closed console allows fixed position of the head and is provided with handles and pedal control, and precisely transfers the surgeon's hand movements to the robotic arms. The operating cart supports four arms with 12 DoF that can be equipped with instruments that can be reused up to 20 times, reducing the costs of the platform [14, 15].

The company developed the RevoSim, a virtual reality training system through which surgeons can gain proficiency in using the platform. The Revo-i received approval for commercial use in Korea, but it has not received FDA approval or CE mark.

25.2.5 Avatera Surgical System

The Avatera system is the result of a joint venture between Avateramedical (Jena, Germany) and Force Dimension (Nyon, Switzerland) and it has received the European CE mark. It is provided with a seated and semi-open console with 3D-HD resolution. The four robotic arms are mounted on a single cart, with 5-mm instruments with forceps-like handles and seven DoF. Some of the advantages include the absence of fans, which decreases the noise level, and the space-saving compact design. The company has developed a training program including virtual reality simulator and on-site training [16].

25.2.6 Hinotori Surgical Robot System

The Japanese companies Kawasaki Heavy Industries and Sysmex, through a joint venture, created Medicaroid that developed the Hinotori system. It consists of the surgeon semi-open console, the vision unit and the operation unit. The vision unit provides 3D HD images and supports audio communication between surgeon and assistants. The operation cart is made up of four arms attached to a single cart and instruments with eight DoF [17, 18].

The Hinotori system received Japanese regulatory approval, but it has not received FDA approval or CE mark.

25.2.7 Dexter Robotic System

The Dexter system is produced by the Swiss company Distalmotion. It provides a seated or standing open console, with a single foot pedal controller. The surgeon remains sterile while operating from the console, allowing to readily switch between laparoscopy and robotic surgery (Fig. 25.3a). The two independent cart-mounted

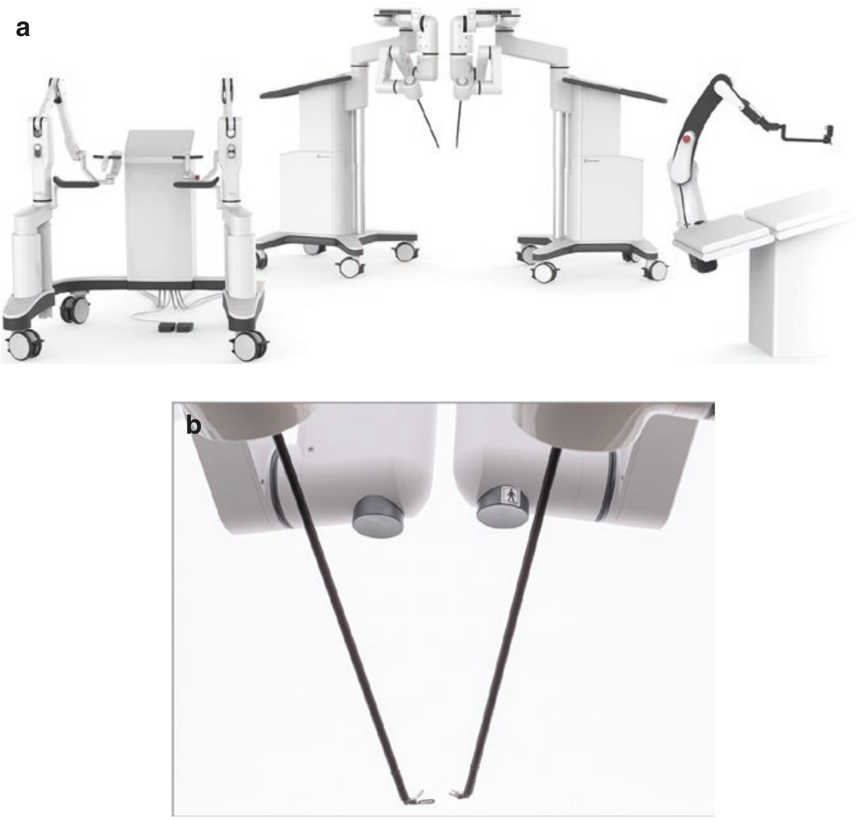

Fig. 25.3 (**a**) Dexter robotic system. (**b**) Dexter robotic system's articulating instruments. Reproduced with permission from Distalmotion

robotic arms are provided with single-use 8-mm instruments for suturing and dissection (Fig. 25.3b). The system integrates into any laparoscopic setup, preserving established laparoscopic trocar position. The platform can be used with any 3D commercial laparoscopic tower and is designed to be able to integrate future imaging technology. The Dexter system comes with an integrated robotic endoscope holder, compatible with all 5-mm and 10-mm endoscopes, that can be mounted on a cart or clipped to the bed and is controlled by the surgeon console [19].

The system has received the European CE mark.

25.3 Conclusion

The current state of the robotic approach in colorectal surgery is still dominated by the da Vinci surgical system. However, the development and the introduction of these new robotic platforms could change the spread of the robotic approach. Despite the increasing use of these platforms in surgery, there are still few literature data comparing the systems. Further data will be necessary to assess costs, clinical outcomes and sustainability.

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