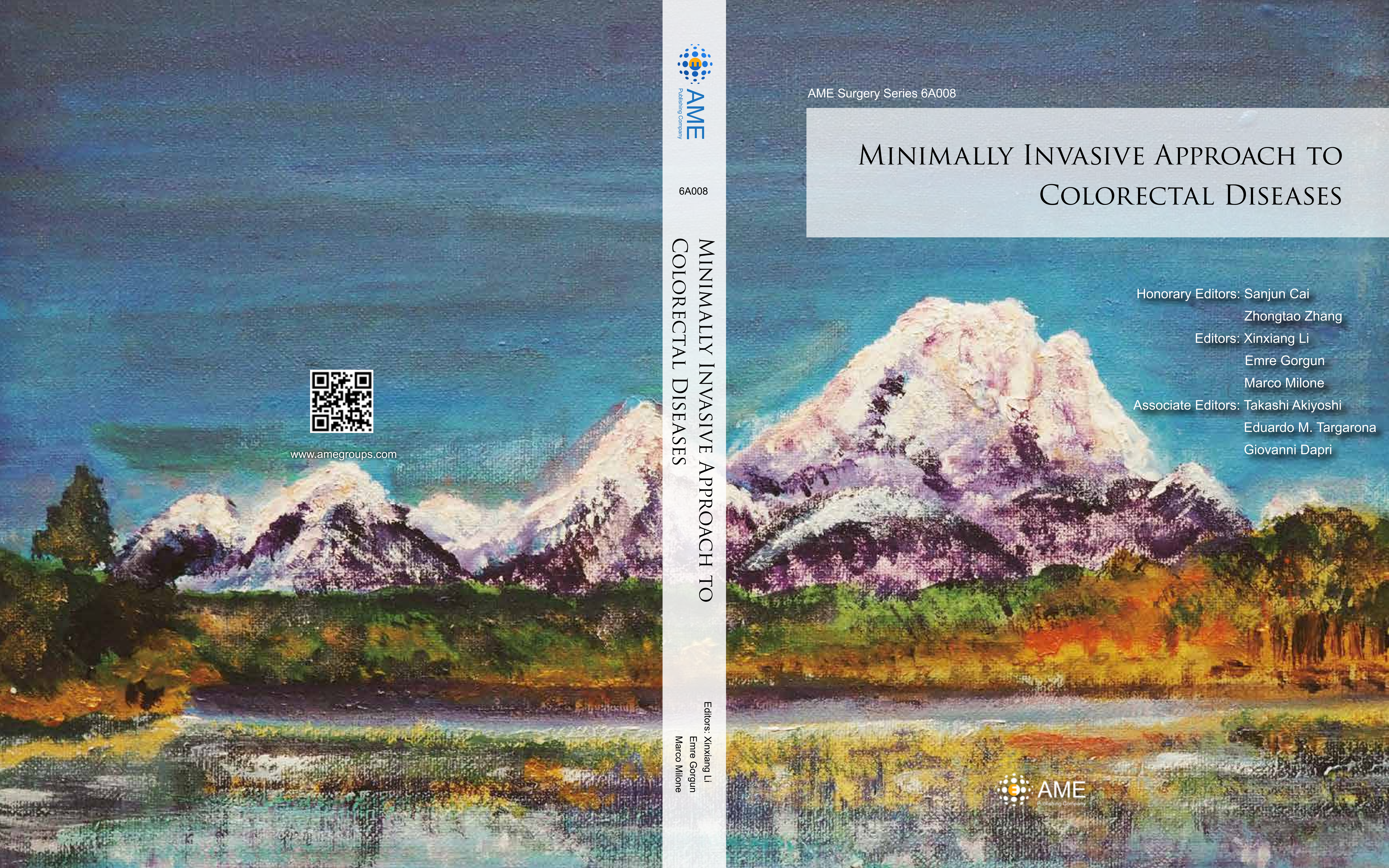

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MINIMALLY INVASIVE APPROACH TO COLORECTAL DISEASES

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The Annals of Cardiothoracic Surgery, one of AME's peer-reviewed journals, is lucky to have an author from Rochester, USA. He is left-handed. When he began his training in surgery, he encountered huge obstacles. For example, when using scissors or knotting during a surgery, his actions were the opposite of what was described in textbooks. Therefore, he often "took a beating" from his mentors when performing a surgery.

Later, he summarized his experience and published it in a journal in an attempt to find other surgeons that "suffer from the same fate". Surprisingly, after his article was published, many surgeons e-mailed him, asking him how left-handed doctors should undergo surgical training, and so on. Then he met Professor Tristan D. Yan, the editor-in-chief of Annals of Cardiothoracic Surgery, who happens to be a left-handed doctor. Tristan encouraged him to become a heart surgeon because there are steps in cardiac surgery that require the use of the left hand to complete the suture threading technique. Tristan's view was that it was better if surgeons were trained to use both their left and right hands.

A few days ago, on my daughter's first day of kindergarten, I chatted with her teacher for a while; finally, she asked me if there was anything about my daughter that she should take note of . "Please do not correct my daughter's left-handedness," I said, "Just let it be." "Why?" the teacher asked in wonder.

On December 7, 2013, we held the second AME Academic Salon in the Hospital Affiliated to Nantong University. After dinner, Dr. Shen Yaxing from the Department of Thoracic Surgery of Shanghai Zhongshan Hospital invited several attendees to have tea in his room. The elevator was in the middle of the hotel. After we walked out of the elevator, he led us to the left, then to the left, then to the left, then to the left, and finally to the door of his room. Although we were somehow confused and disoriented, some of us did find out that the door was just diagonally across the elevator. We all burst into laughter. Yaxing shared that he took this route the first time he entered his room, and so he decided to bring us on the same route on the second time. Yaxing then said that this was the behavior of a 'typical' surgeon!

During the training to be a surgeon, each step and each action are done under the strict direction and supervision of a senior surgeon. Thus, many surgeons like to affectionately address their mentors as their "masters".

How, then, can you become a master of surgery? In addition to your own intelligence and diligence, the expertise and mentorship offered by a "master" is also very important. Just like in the world of martial arts, there are many different schools that are independent from each other and have their own strength and weakness, and the surgical world is very much the same.

Therefore, it is important for a young surgeon to gain knowledge and skills from different masters by taking in only the essence and discarding the dregs. Therefore, we have planned to publish the AME Surgery series, in an attempt to share with our readers the surgical skills of some prominent surgical teams in China and abroad, as well as their philosophical thinking and some interesting stories. We sincerely hope that our colleagues in the surgical departments find these books insightful and helpful.

Stephen D. Wang
Founder and CEO,
AME Publishing Company

The first laparoscopic colorectal surgery was performed in the United States in 1990. In its 28 years of evolution this technology has constantly been optimized and experienced particularly rapid advances in recent years, with the introduction of many new emerging techniques and concepts. For instance, the conventional transabdominal approach has been replaced by the transanal approach, and the traditional multi-port surgery has been developed into single-port surgery and NOSES procedure without any incision in the abdomen. Colorectal surgeons have to face challenges from changing technologies and new ideas and move toward rebuilding their skills.

Is “minimally invasive” the core value and the only advantage of laparoscopic colorectal surgery? For me, the core advantage of laparoscopic surgery is that it enables the delivery of sophisticated surgeries in high-definition field of view, which is more conducive to high-level lymph node dissection, nerve identification, and precise separation of surgical planes. The core advantages of laparoscopic surgery are reflected in the proceduralization of the surgical steps and the transparency of the surgical process, which shorten the learning curve and help young doctors to master new technologies quickly.

How can laparoscopic technology perfectly implement the concepts of tumor surgery? In our center, the laparoscopic radical resection of rectal cancer is performed by following the idea of “vessels first, followed by planes; veins first, followed by arteries”, with vessels as the central approach, which is just based on the principles of traditional tumor surgery. In addition to treatment effectiveness, we also pay attention to the safety and functionalization of surgery. Based on the above understandings, we also pioneered the laparoscopic transanal pull-through without angled double stapling and advocated the radical surgery of rectal cancer with the preservation of left colonic artery. With these innovations, we are pursuing more minimally invasive or even non-invasive techniques.

This book was contributed by many colorectal surgeons at home and abroad. All of them are top experts in minimally invasive surgery and have their unique technologies and ideas. I believe our readers will benefit much from the insights and perspectives of these outstanding authors.

Finally, I would like to thank three of my tutors: Professor Dongpo Xu, who instructed me when I was a master candidate with his words and deeds, helping me to master solid knowledge on surgical oncology; Professor Chengzhu Zheng, my doctoral tutor, who trained me on the skills of minimally invasive surgery and the innovative way of thinking; and Professor Sanjun Cai, my professional tutor, who guided me to enter the professional hall of colorectal surgery. Their professionalism, visions, and lofty personality have been most motivating for me in my education and career.

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Preface

It gives me a great pleasure to write an introduction to this book which bridges the gap between surgeons and endoscopists across the world and the surgical innovators, and it provides a foundation for all classic, newer and emerging techniques in minimally invasive colorectal surgery.

Colorectal surgery has shown substantial changes during the last several decades after the introduction of minimally invasive surgery. Challenges about early minimally invasive surgery in colorectal surgery are recognized and newer techniques and robotic devices have been developed to overcome some of the drawbacks of early laparoscopic surgery. Further improvements with technology improvements and flexible scopes that ease the operations are introduced which are all discussed in this book.

Colorectal surgery has been benefiting the ample opportunities that robotic system offer, yet, unavailability of the platform in every medical center, prolonged operative time, cost and the steep learning curve pose obstacles for the globalization of the robotics. Debates keep climbing toward whether the purported advantages of the robotic systems will actually translate into clinical effectiveness over conventional laparoscopy. This book discusses the current role of laparoscopic surgery as well as alternative robotic approaches in colorectal surgery settings and future directions of the robotic surgery. It provides tips and tricks that allow the user to move up the learning curve, overcome challenges, increase the utilization of minimal invasive techniques even for the management of metastatic colorectal diseases.

Lastly, this book addresses emerging approaches such as advanced endoscopic procedures in the management of difficult colorectal lesions as well as EndoLuminal Surgery which will be a huge leap forward in the near future. Thus this book is also an inspirational guide for the innovator of the future since many cutting edge and newer techniques are discussed. It allows surgeons to better adapt to inevitable changes in future operative techniques.

Written by experts in the field of Open, laparoscopic, robotic colorectal surgery, and endoluminal surgery, *Minimally Invasive Approach to Colorectal Diseases* is a valuable resource for general and colorectal surgeons of all levels including residents, fellows and surgeons already in practice.

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Minimal invasive surgery as a surgical approach is becoming more and more popular among surgeons all over the World.

While laparoscopic approach has become Gold Standard for colonic surgery, its role in rectal pathologies treatment is still controversial. Probably due to its technical challenge and its longer learning curve laparoscopic colorectal surgery it is not yet widespread as it should be among surgeons, but in expert hands it has proven to be safe and effective.

The aim of this manual is to discuss in detail minimal invasive surgery for colorectal pathology treatment, especially surgical indications and procedures techniques, in order to help its practical learning and its international diffusion.

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More and more patients with colorectal diseases are treated by minimally invasive approach worldwide. I'd like to congratulate the AME Publishing Company for publishing the book "Minimally Invasive Approach to Colorectal Diseases"; it's a collection of related articles from journals of AME written by the leading surgeons or endoscopists in the field of minimally invasive approach to colorectal diseases, and the readers can learn the updated progress and technique from this book. I hope the reader will enjoy these papers.

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I want to acknowledge the privilege that *ALES* offered to me to write the preface for this book. *ALES* is doing an enormous effort looking for an strong place in the world of scientific publishing, and this book is a palpable sample of the imaginative and creative way of understanding new ways of publishing and managing scientific knowledge.

The book that you have on your hands is a compilation of papers published recently by ALES, grouped by a common theme that is the minimally invasive approach to colorectal diseases. These contributions have the common denominator of a high quality because they are the results of a peer reviewed process of evaluation. These papers have been sorted in 7 chapters that include most of the hot topics on this area of MIS. Surgical approach to colorectal disease has evolved in a significant way during last decades. Probably, the most seminal advance was the definition and understanding of the concept of total mesorectal excision for rectal cancer, following the ideas from Heald, and becoming a standard of care nowadays. Just as an extension of this concept, during last years we have also seen the raise of the concept of total mesocolon excision, conceptual and technical aspects well covered in this book. But the most important advances in the surgery of colon and rectum are technologically related as it has been the widespread development of minimally invasive approach. Minimally invasive approach does not mean only laparoscopic surgery. As a heritage of NOTES, flexible endoscopic endosurgery with the new concepts of ESD and EMR will be an important alternative of surgery for large benign or initial colon or rectal cancer. Minimally invasive colorectal surgery, in spite of its higher technical difficulty has become the standard of care in many centers around the world. This book covers the development of hese techniques when applied to colon or rectum. Technical description includes multiport as well single port, reduced port and the last invited TaTme. The reader will find in the bunch of papers devoted to these topics a clear description of surgical concepts, as well technical pearls, tricks and tips.

The future of MIS surgery is without doubt robotic. Robotic surgery is as well covered in a chapter of this book giving and idea of its advantages, pitfalls and controversies.

I am convinced that the reader will found in these pages clear and useful knowledge, that will improve their daily practice. By other hand, the curious surgeon would also found a number of controversial issues around this topic, and may induce to new trials challenging the current established knowledge. I hope that the reader will appreciate the care that ALES has had when compiling all these papers to create this useful new issue.

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Minimally Invasive Colorectal Surgery (MICS) underwent to a radical evolution in the last 30 years, thanks to the fundamental results of the randomized trials comparing laparoscopy and open surgery, to the development of cameras, telescopes and instruments, with a consequent increased number of the MICS techniques. All these aspects contributed to an improved quality of surgery and patient's care.

Nowadays, centers with experience in MICS perform the different procedures through various techniques, each one adopted patient by patient with the reference to the presented disease and to the single patient's anatomy. The procedures can be performed through the abdomen, as well as through the anus and, most of the time, joining these two approaches.

All the colic segments, as well as the rectum, are resected following the appropriate plane of dissection and, in front of oncologic cases, achieving the adequate lymphadenectomy. This strategy allows the specimen's removal with a minimal blood loss and acceptable operative time, with the maximum number of lymph nodes, and with a general improved patient's comfort. Oncologic outcomes completely changed in favor of better outcomes thanks to the advances in multimodality therapies and strategies. Lymphadenectomy radically improved in terms of number of nodes achieved, following the correct mesocolic/mesorectal dissection and also researching the sentinel lymph node.

Furthermore, this improved quality of resection is performed using the latest evolved techniques, with an extra-magnified quality of image, precision and accuracy of dissection thanks to the elaborated cameras, optics, and instruments for dissection and coagulation. Both laparoscopic and robotic methods benefit of these technical improvements, leaving the final choice to adopt one of them to the surgeon's experience and to the hospital's material availability.

In this *Minimally Invasive Approach to Colorectal Diseases* book, the reader can get an overview of the different MICSs described by referenced pioneers in each of these techniques. A description of MICSs with reported feasibility and results can stimulate the reader to reproduce the surgical procedure and to achieve compared data in order to select the adequate procedure for each single patient.

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Current surgical considerations for colorectal cancer

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Background

Colorectal cancer is the second leading cause of cancer-related deaths in the United States each year. Among men and women, it is the third most common cancer following lung cancer, prostate and breast cancers, respectively. In recent years, It has been estimated that in 2012 there were more than 100,000 new cases of colon cancer and more than 40,000 cases of rectal cancer (1,2). Fortunately, both the incidence and mortality of colorectal cancer have declined steadily in the past three decades. This has been largely attributed to more effective screening programs and improvements in treatment modalities (1,2). Surgical resection offers the best chance of achieving cure, but the management of colorectal cancer often requires a multidisciplinary approach, which has been pivotal in achieving better patient satisfaction and outcomes.

Surgery for colon cancer

Overview

The diagnosis of an invasive colon cancer requires a complete staging work up that includes endoscopic evaluation of the entire colon, baseline imaging of the abdomen and chest to rule out distant spread, and routine labs including a baseline carcinoembryonic antigen (CEA) level (1). Colectomy should be offered to those patients with resectable tumors that have no evidence of distant metastasis. The extent of the colectomy is primarily determined by the location of the tumor and the blood supply to that segment of bowel. Adequate margins (≥5 cm) should be gained proximal and distal to the primary tumor and should include the associated mesentery containing regional lymph nodes. Tumors that are adherent to adjacent structures should be resected *en bloc* to ensure complete removal of the cancer. Adjuvant chemotherapy is offered to patients with evidence of lymph node metastasis.

Laparoscopy for colon cancer resections

Traditionally, colectomies have been approached via a laparotomy with good clinical outcomes. However, the advent of laparoscopy has revolutionized surgery and, in appropriate patients, is now a popular alternative for the surgical management of colorectal disorders. This has been primarily due to the substantial short-term benefits, which include less postoperative pain, earlier return of bowel function, and shorter hospital stays (3,4). While laparoscopy has been shown to be consistently safe and feasible for a variety of gastrointestinal pathology, initial enthusiasm about employing a minimally invasive approach for colorectal cancer was tempered by a steep learning curve as well as reports of wound and trocar site recurrences (4). Therefore, the steady implementation of this approach has required balance of the potential short-terms benefits with preservation of oncologic outcomes. These criticisms were addressed with initial data reported in retrospective studies and later confirmed by larger, randomized clinical trials, which demonstrated that laparoscopy does not compromise oncologic outcomes or increase perioperative complications (3,5-8).

The Barcelona trial was among the first randomized, prospective, single-institution trials, which compared laparoscopic colectomy to the conventional open approach. From 1993 to 1998, 206 patients were enrolled (105 patients in the laparoscopic arm) with cancer-related survival as the primary endpoint. The authors found that laparoscopy was more effective than open surgery with respect to morbidity, hospital stay, tumor recurrence, and cancer-related survival. A follow up to this study with longer follow up data (median 95 months) comparing laparoscopic and open colectomies demonstrated that the overall survival and recurrence rates favored the laparoscopic group, but did not reach statistical significance (5,6).

A larger prospective, randomized, multicenter trial by the Clinical Outcomes of Surgical Therapy (COST) Study Group showed similar long-term results. Between 1994 and 2001, 872 patients (435 patients in the laparoscopic arm) were randomized. The median follow-up time was 52 months and the primary endpoint was time to tumor recurrence. Analysis at three years demonstrated similar recurrence rates in the laparoscopic and open groups, 16% and 18%, respectively. Additionally, there was no difference in overall survival (86% in the laparoscopic group *vs*. 85% in the open group). The authors have also recently published 5-year data from this original cohort demonstrating that overall and disease-free survival were similar between the two treatment groups. Additionally, overall recurrence rates remain similar (19.4% laparoscopic group; 21.8% open group) (7,9). These survival data have been confirmed in the slightly larger European multicenter Colon cancer Laparoscopic or Open Resection (COLOR) trial that was designed to evaluate disease-free survival and overall survival 3 years after laparoscopic or open resection for colon cancer. For all stages, the 3-year overall and disease-free survival rates were not significantly different between groups. Local and distant recurrence rates were also similar (8). It should be noted that lymph node harvest is also similar between open and laparoscopic groups. The main criticisms of these trials center on the probability of selection bias when offering a laparoscopic approach to those with cancer.

In fact, those with smaller tumors (amenable to smaller incisions) and those with tumors that involve only the colon (T3 and below) are most likely still the best candidates for laparoscopy.

Postoperative complications and quality of life (QOL)

While the short-term benefits of laparoscopy have been well documented and reproducible across practices, many also postulate that laparoscopy also facilitates fewer complications than traditional open surgery. While the primary endpoints of the aforementioned clinical trials were tumor recurrence and survival, these initial data also offer some information on intraoperative and perioperative complications. The Barcelona Trial found that the patients in the laparoscopic group had significantly less intraoperative blood loss and postoperative morbidity (5). However, the COST study and the COLOR trial did not demonstrate any significant difference in postoperative morbidity or 30-day mortality. The rates of intraoperative complications, rates or severity of postoperative complications, rates of readmission, and the rates of reoperation were similar between groups (7,8). Tjandra *et al.* recently published a systematic review of 17 randomized trails of laparoscopic resections for colon cancer, which analyzed 4,013 patients. The authors found that there were no significant differences in the overall complication rate. However, laparoscopic surgery had significantly lower perioperative mortality as well as lower wound complications (infection and dehiscence) (10).

Overall quality of life parameters after colorectal cancer resection have also been fertile ground for study and there is significant data to suggest that patients undergoing laparoscopic colectomies have modest improvements in these parameters. Analysis of the responders from the COST study (428 patients) showed short-term benefits according to the global rating scale score at 2 weeks after surgery. No difference was found between the groups using the other instruments or at other time points (2 days and 2 months) (11). Long-term follow up of the patients in this study found that at 18 months after surgery, patients who underwent laparoscopic resections had significantly greater improvement from baseline in the global QOL rating and total QOL index (QLI) (12).

The role of surgery in metastatic colon cancer

Up to 25% of patients with colon cancer will present with synchronous colorectal cancer metastasis and of these, only approximately 10-20% will have lesions that are ultimately resectable (1,13). More commonly, patients will develop metastasis in the interval after resection of the primary colon tumor with the liver being the most commonly involved organ.

Patients with colorectal liver metastasis (CLM) should have a complete evaluation with the coordinated care of a multidisciplinary team—including oncologists, radiologists, colorectal and hepatobiliary surgeons in order to assess resectability. Surgical resection of these metastatic lesions should only be considered in medically fit patients with good performance status, if obtaining negative margins is feasible and adequate functional liver reserve (>20%) can be maintained. While surgery is the gold standard for resectable disease, other potential treatment adjuncts, including radiofrequency ablation (RFA) and hepatic artery infusion (HAI) of chemotherapy, have been employed. Neither of these other modalities alone has been shown to be as effective as chemotherapy and surgical resection, which have reported 5-year survival rates up to 40% (1,14-16).

While the benefit of surgery and chemotherapy are clear, considerable controversy still remains in the optimal sequence of these treatments. Proponents for a surgery-first approach cite the potential for progression of disease and chemotherapy-associated liver injury as reasons to forego neoadjuvant chemotherapy; however, there is limited data that supports that this approach confers an advantage in overall survival (17). Contradictory data has been presented in the EORTC 40983 trial, which compared perioperative chemotherapy (pre- and postoperative) with surgery alone. The authors found that there was an 8.1% improvement in the 3-year progression-free survival with perioperative chemotherapy. However, postoperative complications were more frequent in the chemotherapy group (18).

The management of patients with synchronous, resectable CLM has also been subject to controversy. The traditional approach has been resection of the primary colon tumor followed by adjuvant chemotherapy and staged hepatic resection; however, more recent studies have shown that simultaneous colon and liver resections are safe in specialized centers and appropriately selected patients (19). This combined approach is advantageous in sparing the patient the morbidity of additional surgery and eliminating potential progression of liver disease during recovery from primary colorectal surgery. More recently, a reverse strategy, or liver-first approach, has been proposed for early management of metastatic liver disease, which proponents assert optimizes the potential for cure (20). While the data related to this approach is not as robust, the greater body of study on the management of synchronous CLM suggests that the approach should be individualized. The patient's functional status and burden of disease must be assessed in order to balance surgical risk and oncological benefit (21).

In patients with asymptomatic primary colon tumors and unresectable minimally symptomatic metastatic disease, chemotherapy is the mainstay of treatment. The available data supports that there is little benefit in resection of the primary tumor. Doing so risks delaying necessary chemotherapy and offers no survival advantage. In 2009, Poultsides *et al*. reported a series of 233 patients with unresected primary tumors and synchronous metastasis receiving chemotherapy. They found that 93% of patients did not require any surgical palliation of their primary tumor (22). Clearly, if the patient is exhibiting signs and symptoms of obstruction, which cannot be controlled with dietary changes alone, then palliation with resection is required. This seems to be the minority of cases.

Surgery for rectal cancer

Overview

The surgical decision-making process for rectal cancer is complex and often requires a multidisciplinary approach. While the pathophysiology of rectal cancers is believed to be identical to that of colon cancers, the anatomic location within the bony pelvis offers unique surgical challenges. Over the past century, an improved understanding of the histopathology as well as patterns of recurrence has afforded significant strides in the treatment of rectal cancer (23).

The initial management of rectal cancer requires complete evaluation of the local extension as well as distant spread. Unlike colon cancers, rectal tumors are more easily accessible by physical examination, which can provide added information on size, the degree of fixation, and location (2). Ultimately, the choice of treatment hinges primarily on the location of the tumor in the rectum and the depth of local invasion. Therefore, modalities such as endorectal ultrasound (ERUS) and pelvic MRI are often used for local staging of tumor depth and nodal involvement (24,25). Patients with evidence of locally advanced cancers in the distal and mid rectum (defined as Stage IIA and beyond) are now routinely referred for neoadjuvant chemoradiation, which has been shown to decrease rates of local recurrence (23,26). This paradigm has been challenged and the Alliance for Clinical Trials in Oncology is currently accruing patients for a phase II/III trial of neoadjuvant chemotherapy with the selective use of radiation in locally advanced rectal cancer. Treatment of upper rectal cancers (those above the peritoneal reflection or at the rectosigmoid junction are more controversial. Data suggests that a more individualized approach may be needed for these patients, with bulky large tumors getting neoadjuvant and smaller ones getting treated primarily with surgery.

Total mesorectal excision

Historically, local and radical resections for rectal cancers have been plagued by significant patient morbidity and high local failure rates (25). In 1982, Heald *et al*. named the concept of total mesorectal excision (TME), which has drastically changed the surgical approach to proctectomy. An appropriate TME requires sharp dissection in the areolar, presacral plane between the mesorectal envelope (fascia propria) and the adjacent pelvic structures (27). For distal rectal cancers, TME is performed circumferentially down to the pelvic floor muscles incorporating the entire mesorectum. This allows complete removal of the rectal tumor and the regional lymph nodes while ensuring a negative radial margin and preserving the autonomic nerves (23,24,27). This has been shown to be an integral part of achieving lower local recurrence. A prospective, randomized trial, organized by the Dutch Colorectal Cancer Group, which was among the first to include surgical quality control for TME, reported a local recurrence rate of 8.2% at 2 years (10.9% at 6-year follow-up) in patients who underwent complete rectal cancer resection alone (28,29). Proximal rectal tumors, as mentioned, often do not require a total mesorectal excision since lymphatic spread is generally limited to within a few centimeters of the tumor. In these cases a partial mesorectal excision can be performed after ensuring an adequate distal margin. Bulky large proximal tumors may, however, benefit from preoperative chemotherapy and radiation in selected patients.

Radial and distal margins

Achieving the appropriate distal and radial margins is often not problematic in segmental colon cancer resection, but these are critical concepts in the surgical management of rectal cancer. A high-quality TME has improved our ability to achieve negative radial or circumferential resection margins (CRM), which has been shown to be an important predictor of local recurrence, distant metastasis, and survival (27,30,31). A positive CRM is defined as tumor extension to within 1 mm of the radial tissue edge and can occur due to direct tumor extension, mesorectal tumor deposits, involved mesorectal lymph nodes, or inadequate surgical dissection. In 2002, Wibe *et al.* reported a series of 686 patients who underwent proctectomy without adjuvant radiation, which underscored the significance of the circumferential margin. After a median follow up of 29 months, they found that the overall local recurrence rate for those with a positive CRM was 22% as compared to 5% for those with a negative margin (>1 mm). The CRM was also an independent risk factor for distant metastasis (hazard ratio 4.7) and mortality (hazard ratio 3.7) (32).

The ideal distal margin in rectal cancer surgery remains relatively controversial, especially in this era of sphincter-preserving procedures. A 5-cm distal margin had been previously advocated; however, this has been largely refuted based on pathology data demonstrating limited intramural spread of low rectal cancers (33,34). The degree of intramural and extramural spread is crucial in determining the ideal distal resection margin. In one of the larger retrospective review on the subject, Shirouzu *et al*. reported a series of 610 patients who underwent rectal cancer resections and found that only 10% had distal intramural spread. Moreover, the majority of these cases were within 2 cm of the distal border of the primary tumor. As a result, the authors postulated that a distal margin of 1 cm would be appropriate for most rectal cancers (34). Based on the available data, current recommendations suggest that a 2-cm distal margin is adequate for most rectal cancers. Smaller tumors that are low in the rectum may be resected with an acceptable margin of 1 cm (35,36).

Sphincter-preserving surgical procedures for rectal cancer

The extent of surgical resection for rectal cancer largely depends on the location of the mass in the rectum, the degree of local invasion, and the patient's baseline sphincter function and medical co-morbidities (23,26,35). For tumors in the mid and upper rectum a low anterior resection (LAR) is generally the ideal approach. During the procedure, a TME dissection is carried out after the sigmoid colon and upper rectum are dissected free from the peritoneal attachments. The inferior mesenteric artery, which is the principal feeding vessel, is ligated and divided proximally. The distal rectum is left in place after ensuring a margin 4-5 cm distal to the inferior edge of the tumor. A colorectal anastomosis is then created using a circular stapler; however, a hand-sewn anastomosis is also possible. Tumors in the lower rectum can also be considered for LAR as long as a 1-2 cm distal margin can be obtained adequately. Intestinal continuity is then restored with a stapled or hand-sewn coloanal anastomosis. The potential for pelvic sepsis due to anastomosis leak can be mitigated by a temporary loop ileostomy in those patients with low pelvic anastomoses and those that have required preoperative radiation.

Many patients experience disordered bowel function after LAR, typically characterized by increased stool frequency, bowel fragmentation, fecal urgency, and incontinence, which has been termed "low anterior resection syndrome" (37). The incidence is variable, as there are no validated tools for diagnosis, and the etiology is likely multifactorial. Reported rates range from 20-50% and possible causes include sphincter injury, decreased rectal compliance, or neuropathy (37). Alternative reconstructive techniques to the straight end-to-end anastomosis following TME with coloanal anastomosis including colonic J-pouch and transverse coloplasty have been explored in attempt to improve postoperative function. In these cases, randomized trials have shown that the colonic J-pouch results in superior postoperative bowel function for at least 18 months after surgery, after which function becomes similar to the end-to-end anastomosis (38). The ability to do this from a technical standpoint, however, is quite dependent upon the patient's body habitus with a narrow pelvis often precluding the safe formation of a colonic pouch.

Abdominoperineal resection

Patients with pre-existing fecal incontinence or with very low rectal cancers will ultimately require an abdominoperineal resection (APR). During the abdominal phase of the procedure, the TME dissection is carried out down to the pelvic floor muscles and a permanent colostomy is created using the descending colon. During the perineal dissection, the anus and the sphincter complex are excised widely in continuity with the proximal specimen. High rates of bowel perforation, positive circumferential margins, and subsequently local recurrence have been reported with conventional APR (39-41). Therefore, much emphasis has been placed recently on achieving a cylindrical resection, which avoids narrowing of the resected specimen at the level of the levator ani muscles. This approach has been shown to reduce the risk of local recurrence without increasing local complications (42).

The primary closure of the perineal wound has been plagued with significant complications, especially in the setting of preoperative radiation. Infection and wound dehiscence are among the most frequent complications with incidences that range from 10-40% in the existing literature (43). As a result, efforts to mitigate these complications with the routine use of rotational myocutaneous flaps have been proposed with variable success (43,44). Currently, there is no standard recommendation for the use of myocutaneous flaps in the reconstruction of the perineal wound. Individualizing treatment is required—those at higher risk of perineal wound complications (obese, diabetic, malnourished) may be selective candidates for flap closure.

Minimally invasive surgery for rectal cancer resections

Laparoscopy for rectal cancer resection has been approached with as much enthusiasm as initial studies for colon cancer; however, the available data is not as mature. While a minimally invasive approach to proctectomy with laparoscopy, or even robotically, is more challenging and costly, the available technology offers the added benefit of better visualization and more precision than traditional open surgery. Initial nonrandomized studies demonstrated that laparoscopic proctectomy was safe and feasible with similar short-term benefits and oncologic outcomes (45). This has been confirmed in subsequent small, randomized trials; however, sufficient long-term data is lacking. The American College of Surgeons Oncology Group (ACOSOG) is nearing completion of a large phase III prospective randomized trial comparing laparoscopic-assisted resection versus open resection for rectal cancer which should further illuminate this subject. However, recent meta-analyses of the available randomized clinical trials comparing laparoscopic to open rectal cancer resections conclude that laparoscopy is associated with significantly lower rates of intraoperative bleeding and postoperative blood transfusion, quicker return of bowel function and shorter hospital admission (46,47). Additionally, when compared with open TME, there is no difference in the number of lymph nodes harvested, involvement of CRM, local recurrence, 3-year overall survival, and disease-free survival for rectal cancer (48). The results of larger multicenter, randomized clinical trials are pending. Complicating adoption of this technology is the large learning curve needed to implement these techniques in practice. Often "hybrid" open/laparoscopic approaches are utilized with some success to keep incision sizes small and mimic the advantages of a total laparoscopic approach in less time.

Local excision for early rectal cancers

In carefully selected patients, local excision has generally been considered as an acceptable treatment option for small, early (T1 and T2) cancers in the mid to distal rectum that have favorable histologic features (well-differentiated, absence of lymphovascular invasion, superficial submucosal invasion) (49,50). It has also been proposed in patients that are unsuitable for radical surgery as the resection of these lesions with traditional transanal surgery, or transanal endoscopic microsurgery (TEM) for more proximal tumors, is associated with lower patient morbidity.

Traditional transanal excision (TAE) is reserved for small tumors within 8 cm of the anal verge that are readily accessible. A full-thickness resection through the bowel wall into the perirectal fat is carried out with a minimum of

1-cm margins. In some cases, prominent lymph nodes can be resected but generally a thorough lymphadenectomy is not feasible, which is a major concern in more advanced tumors; therefore, preoperative patient selection and accurate staging is critical. The mucosal defect is then closed primarily. More proximal tumors can be accessed using TEM, which was introduced in the early 1980s as a minimally invasive alternative. The operating platform consists of an operating proctoscope and specialized microsurgical instruments that allow dissection in the upper rectum for lesions that previously could only managed with abdominal surgery (50).

The initial studies of local excision for early rectal cancers demonstrated that this procedure was associated with high local failure rates (17% for T1 tumors and up to 46% for T2 tumors) (51,52). In 2000, Mellgren *et al*. reported a retrospective study comparing 108 patients T1 and T2 rectal cancers excised locally with 153 patients who underwent radical resection. They found that local recurrence was significantly higher after local excision for both T1 and T2 cancers as compared with standard resection (T1: 18% *vs*. 0%, T2: 47% *vs*. 6%). Additionally, overall 5-year survival decreased significantly after local excision of T2 cancers as compared with standard resection (81% *vs*. 65%) (51). These findings were confirmed in a larger, retrospective study using the National Cancer Database. In this report, local recurrence after local excision was 12.5% for T1 cancers and 22.1% for T2 cancers. These were both statistically higher than rates for standard resection. Interestingly, despite these data, the authors also found that the use of local excision had increased significantly from 1989 to 2003 (53).

Salvage surgery may be possible for local recurrence after local excision but often not without significant morbidity. It often involves multimodality treatment including preoperative chemoradiation and extensive surgery (multivisceral resection or pelvic exenteration). Sphincter preservation is not always possible and overall 5-year survival is relatively poor (54).

These data suggest that in appropriately selected patients with T1 rectal cancers, local excision has similar acceptable overall survival rates as compared with standard resection. However, patients should be counseled that the reduced short-term morbidity of local excision is also associated with significantly higher rates of local and overall recurrence. Local excision of T2 rectal cancers has not been routinely recommended outside of clinical trials. The preliminary results of the ACOSOG Z6041 trial of neoadjuvant chemoradiation followed by local excision of T2 cancers have just been reported. The authors found that this strategy resulted in high rates of complete response (44%) and 64% of patients had their tumors downstaged. Negative resection margins were achieved in 99% of the included patients; however, the chemoradiation toxicity and postoperative complications were not insignificant. Sixty-two patients (72%) were able to complete chemoradiation per protocol and 39% of patients developed grade 3 adverse events or higher. Perioperative complications occurred in 58% of study patients and the most common grade 3 adverse events included rectal pain, bleeding, infection, urinary retention, and anal incontinence (55).

Management of locally recurrent rectal cancer

Despite the advances in chemoradiation therapy and surgical technique, local recurrence occurs in up to 10% of cases (56,57). The prognosis is generally poor and is only slightly improved with additional adjuvant treatment alone; therefore, radical surgical resection offers the only possibility for cure. The patterns of local recurrence are variable but may occur at the anastomosis or within the pelvis with attachments to the pelvic sidewall(s), bony structures, or adjacent pelvic organs. There is currently no accepted universal classification to define local rectal cancer recurrence; however, important features include patient symptoms, anatomic location, and the degree of fixation (57).

Patients who are suspected to have locally recurrent disease require a thorough endoscopic and radiographic evaluation to rule out distant metastasis and to define the degree of local involvement. Suspicious lesions should be biopsied with the help of useful diagnostic modalities including pelvic MRI, CT scan, or PET scan. Urologic and gynecologic exams should be performed as indicated.

Surgical resection is often complex and requires careful preoperative planning incorporating a multidisciplinary team (colorectal surgery, urology, gynecology, orthopaedics, and oncology). Patients that have not previously received chemoradiation should have neoadjuvant treatment followed by the anticipated resection, while those that have had previous radiation should proceed to surgery, if medically fit. Intraoperative radiation therapy (IORT) or brachytherapy may be indicated based on the degree of residual disease after resection. Extended resection should be performed *en bloc* with any contiguous organ to ensure no residual disease remains (57).

A recent series of 304 patients with locally recurrent rectal cancer undergoing subsequent curative resection found an overall 5-year survival rate of 25%. Preoperative external beam radiation was given in 244 patients (80%) and IORT in 131 patients (43%). Negative resection margins were achieved in only 138 patients and 5-year survival was significantly improved in these patients as compared with those that had residual gross or microscopic disease (32% *vs*. 16%). Extended resections (involving at least one surrounding organ) were performed in 130 patients and were associated with a higher complication rate; however, survival was not significantly different from those that underwent limited resections. Symptomatic pain and fixation in more than one location were associated with a poor prognosis (58).

Conclusions

Colorectal cancer remains a significant cause of morbidity and mortality worldwide. Surgery is the mainstay of treatment for cure in these patients but the overall management of these cancers often requires a multidisciplinary approach. The advent of laparoscopy, robotic and other surgical technology, as well as an increased awareness of the importance of operative technique, have revolutionized the surgical management of this disease. Likewise, innovation in newer chemotherapy regimens and radiation therapy have increased median survival and decreased local recurrence in advanced disease. Despite these advances, there is ample room for further improvement.

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Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

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Current status of minimally invasive surgery in colorectum

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Colorectal cancer (CRC) is the third most common cancers in men and second most common in women with incidence rates of 15–21 per 10,000 worldwide (1). Surgery is the only curative therapy for CRC, with the advancement in surgical technology and understanding the concepts of anatomy and pathology impelled to increase in survival. Technology and experience had transformed the field of colorectal surgery in diverse aspect, as there are no standardization of surgical technique and minimally invasive surgery (MIS) still it is in evolving process, whether to adopt with the new perspective depends on the experience and available evidence which this article brings forth the current practice of MIS in colorectal surgery.

Present state of MIS in colon surgery

Laparoscopic colorectal surgery follows the same oncological principles as open surgery with adequate lymphadenectomy, high ligation of vessel, adequate bowel margins. Since first reported laparoscopic colectomy by Jacob it has become standard surgical procedure in majority of centres. During initial period of MIS there were concern of port site metastasis and long term outcome in laparoscopic colon surgery, but last 2 decades have shown level one evidence suggesting that laparoscopy has good short and long term benefits as compared to open surgery. There are randomised control trials (RCTs) (1-9) (*Table 1*) and meta-analysis (10) suggesting the laparoscopy has better outcome compared to open colectomy showing benefits in terms of decreased intraoperative complications, decreased transfusions, early recovery of bowel function, decreased analgesic, short hospital stay, smaller incision, CRM margins and cost. However, laproscopy did not jeopardise the oncological outcome (2-6).

In large data base of over 3,00,000 cases from ACS NSQIP (national surgical quality improvement programme, 2006–2013) the number of laparoscopic colorectal cases performed are 36–49% (11). The context of the studies and the practical applicability differs with the experience of the surgeon, high volume centres and the standardised technique practised which finally gives better outcomes.

Concepts and controversies of complete mesocolic excision (CME)

In rectal cancer adoption of total mesocolic excision principles of surgery has reduced the local recurrence (LR) rates and improved the survival. The anatomical and embryological planes continue from rectosigmoid, descending colon, and run posteriorly behind the pancreas to include duodenum, cecum, ascending colon and the mesenteric root. Removal of tumour along the mesocolic plane increases survival benefits, concept of CME raised from this anatomical basis. The 10-year outcomes of CLASSIC trial (6) concluded in subgroup analysis that laparoscopic right hemicolectomy has increased propensity for LR than left hemicolectomy. Whether the long term outcomes of surgery based on the CME principles results could transform in better outcome is the matter of debate.

CME involves three principles: (I) removal of central envelop in mesocolic plane; (II) high vascular tie; (III) sufficient length of bowel both proximally and distally (12). Proponents of CME put forward that there are high number of lymph node harvested and eradicating the lymphatic's better achieves local control of cancer,

Table 1 RCT of MIS in colon cancer

Trial	Period	No. of patients	Lap/open	Follow up	Primary outcome	Short term outcomes (laparoscopy *vs.* open)	Long term outcomes (laparoscopy *vs.* open)
COST (2,3) [2004, 2007]	1994–2001	872	435/428	4.4 y	Time of tumour recurrence	Laparoscopy had faster recovery, short hospital stay, decreased parenteral and analgesic use, with similar 30 day mortality, morbidity, readmissions, reoperations compared to open	3 y RR similar (lap 16% *vs.* 18%open), RR at wound sites similar (1% *vs.* 1%), OS is similar (lap 86% *vs.* 85% open)
CLASSIC (4,5) [2007]	1996–2002	794 (52% colon)	2:1 ratio	62 m	3 y OS/DFS/LR	No difference in OS (78.3% *vs.* 82.7%); DFS (89% *vs.* 77%), RR. Conversion rates 16–38%	Conversion to open has worse OS
CLASSIC (6) [2013]	1996–2002	794	526/268	10 y	SR/RR		Laparoscopy has similar long term outcomes. Right colon cancers has increased LR than left colon (14% *vs.* 5%)
COLOR 1 (7) [2005]	1997–2003	1,248	536/546	3 y	3 y cancer free survival	Laparoscopy has less blood loss, early bowel function, less analgesic requirement, short stay. No difference in number of lymph node retrieval, mortality and morbidity. Conversion rates 17%	
COLOR (8) [2009]	1997–2003	1,076	627/621	3 y	3 y DFS		No difference in DFS (76% *vs.* 74%), OS (84% *vs.* 81%)
ALCCaS (9)	1998–2005	601	294/298		Operative, perioperative and HPE details	Laparoscopy had short stay, early recovery of GIT. Significant haemorrhage in laparoscopy group (10% *vs.* 3%). Conversion rates 14%. Laparoscopy showed shorter distal margin in right hemicolectomy	

Lap, laparoscopy; open, open surgery; DFS ,disease free survival; OS, overall survival; LR, local recurrence; RR, recurrence rates; y, years; m, months; GIT, gastrointestinal tract; HPE, histopathological examination; COST, Clinical Outcomes of Surgical Therapy Study Group; CLASICC, Conventional versus Laparoscopic-Assisted Surgery in Colorectal Cancer; COLOR I, Colon Cancer Laparoscopic or Open Resection; ALCCaS, Australasian Randomized Clinical Study Comparing Laparoscopic and Conventional Open Surgical Treatments for Colon Cancer Trial.

high lymph node ratio, identify the skip metastasis, stage migration, identification of micrometastasis, high quality of surgical specimen, and sufficient length of bowel. Opponents argued that the theoretical benefit of removing mesocolic lymph node is minimal as there are other confounding factors for the survival, there is no difference in survival if more than 12 lymph nodes are removed, incidence of D3 lymph node involvement is less and CME leads to over treatment of disease and there are no RCT to support the evidence. There are scepticisms regarding implementation of CME technique in terms of feasibility, and safety in clinical practice.

CME involves sharp dissection under embryological planes between visceral and parietal fascia which was first described by Hohenberger *et al.* (13), he achieved improvement in 5-year survival from 82% to 89% and reduction in 5-year LR from 6.5% to 3.6%. West *et al.* (14) demonstrated 15% survival advantage, increase plane of resection in CME specimens (92% *vs.* 40%) and increase LN retrieval (30 *vs.* 18). The study concluded that CME produced good quality specimens, this was further validated by number of studies (15-22). Storli *et al.* (23) supported the CME with high 3-year SR 88% and increase in DFS (82% *vs.* 75%) compared to non CME patients. Bertelsen *et al.* (24) in a population based study demonstrated that CME has a predictor of better survival with 4-year SR (85% *vs.* 75%) and low RR (11% *vs.* 16 %). Kanemitsu *et al.* study concluded that CME produced better long term survival in right colon cancers (25). Laparoscopic CME offers the similar oncological outcome with advantages of MIS (*Table 2*). JCOG 0404 (15) is the first RCT comparing laparoscopy verses open D3 dissection, this study concluded that laparoscopy has better short term safety and clinical benefits.

Current role of MIS in rectum

Laparoscopic techniques has gained promising role in rectal surgery as it provides precise pelvic dissection , better identification of pelvic structure in narrow pelvis, improved magnification and visual angles. Sphincter preserving surgery has been recent trend made achievable with adequate pelvic dissection and adequate distal margins feasible by endostapling. Laparoscopic surgery has technical advantage in male pelvis, morbid obese and in prior chemordiotherapy and bulky distal tumours.

Meta-analysis and RCT comparing laparoscopy verses open in rectal cancers have shown the feasibility and safety and better short term advantages of laparoscopic surgery in rectal cancers (4-6,26-30). The difference in the operating time and conversion depends on the experience of the surgeon as COREAN, COLOR, ACOSOG Z6051, ALACaRT trials recorded 1%, 16%, 11%, 9% conversion rates respectively.

The CLASSIC trial (4-6) which included 48% rectal cancer cases concluded the there is no difference in OS (lap 78% *vs.* 82% open), DFS (lap 89% *vs.* 77% open), LR (lap 9% *vs.* 10% open) in 10-year follow up. This study analysis raised concern about a potentially higher positive CRM (laparoscopy 12% *vs.* 6% open, P<0.14) in laparoscopic anterior resection (LAR) group but is not significant. In APR the CRM positivity is higher in laparoscopy (16% *vs.* 14%) but did not reach statistical significance and there is no survival difference in 5-year follow up. There is no difference in mortality and morbidity between laparoscopic and open rectal surgery. Laparoscopy has shorter stay than open in rectal surgery. The COREAN trial (28) observed no difference between CRM, macroscopic quality of the total mesorectal excision (TME), number of harvested lymph nodes or perioperative morbidity between the two groups. COLOR 2 trial included 29% low rectal cancers, the CRM positivity in laparoscopy 9% *vs.* 22% in open and LR 3% in laparoscopy *vs.* 12% in open which was less compared to CLASSIC trial which showed more CRM positivity in laparoscopy (16%), with high LR of 9% in lap *vs.* 10% in open. CLASSIC trial (4-6) had 16% CRM positive after laparoscopic surgery (AR group 12% *vs.* 9%). Higher CRM positivity in COLOR ll (26,27) trial is due to the fact that margin involvement is taken as within 2 mm from the lateral surface of the mesorectum, whereas the COREAN (28) study used a 1-mm margin. COREAN (28) study concluded that laparoscopy had better advantages than open in low rectal cancers with low CRM positivity and low recurrence rates. ACOSOG Z6051, ALACaRT multi centric RCT showed non-inferiority of laparoscopic surgery compared with open surgery determined by histopathological evidence (29,30).

After the introduction of TME there is significant reduction in complication of Urinary dysfunction and sexual dysfunction due to preservation of autonomic nerves. With open TME the urinary dysfunction has been 0% to 12% and sexual dysfunction in 10% to 30%. The CLASSIC trial (4-6) reported no difference in bladder dysfunction between laparoscopy and open TME. Hur *et al.* showed that laparoscopy had decrease sexual dysfunction compared to open TME (31).

Table 2 Trials on laparoscopic CME

Trial	Type	No. of patients	Laparoscopy/ open	Stage of disease	Primary end point	Short term outcome (laparoscopy *vs.* open)	Long term outcome (laproscopy *vs.* open)
Japan JCOG 0404 [2014] (15)	RCT	1,057	533/524	Stage 2/3	Efficacy, safety	Lap had less blood loss, short time to pass flatus, decrease use of analgesics, short stay, decreased morbidity	99% underwent D3 dissection in both groups
Republic of Korea 2014 (16)	Prospective	168	168 lap	Stage 2/3	Short and long term outcomes	Morbidity: 17%; leak: 5%; no mortality; mean LN retrival: 27	5 y DFS: 95% in stage 1, 80% in stage 2
Republic of Korea 2016 (17)	Prospective	215 right colon	99/116		Short term	Lap retrieved more LN (31 *vs.* 27), no difference in length of specimen and distal and proximal margin, similar operating time, OS and DFS. Open had more 30 day complication (36% *vs.* 23%)	
Taiwan 2014 (18)	Prospective	244 right colon	244 lap		5-year follow up RR, OS, DFS	LN retrieved: 34; skip metastasis: 19%; upstaging: 4.5%	5 y cumulative RR: N0, 16%; N1, 21%; N2, 43%; N3, 52%
Denmark 2014 (19)	Prospective 2008–2011	244	244 lap		Quality of specimen	Lap has better quality of specimen, increase mesocolic resection, increase in distance between tumour and artery tie, bowel and artery tie	
Italy 2015 (20)	Retrospective 2008–2013	Right colon	115 lap		Short term and long term	Lap R0: 97%; CRM <1 mm: 2.6%	Better OS in lap in stage II/IIIa and b, apical node negative IIIC
Taiwan 2006 (21)	Prospective	Recto sigmoid	98 lap	Stage 3	Time of recurrence, 5 y recurrence	Time of recurrence: N0, 56 m; N1, 46 m; N2, 43 m	5 y recurrence: N0, 20%; N1, 23%; N2, 33%; N3, 42%

JCOG, Japan Clinical Oncology Group; Lap, laparascopy; RR, recurrence rates; OS, overall survival; DFS, disease free survival; CRM, circumferential rectal margins; N, nodal stations; LN, lymph nodes; y, years; m, months.

Emerging trend of robotic colorectal surgery

Advance imaging and technology has made major leap through with use of robotic in CRCs surgery. With difficult pelvic dissection due to narrow pelvis and anatomical complexity in dissection by laparoscopy, adoption of robotic has added advantage of 3D binocular vision, 7 degrees of motion, high resolution, improved dexterity, tremor reduction, improves pelvic dissection, surgeon controlled camera, stable traction and surgeon comfort.

Since the adoption of robotic in colorectal surgery from 2001 there has been increase studies to validate the outcomes comparing robotic and laparoscopic colorectal surgery. Kang *et al.* (32) concluded that robotic is better in terms of faster recovery, short stay, early recover of bowel, decrease wound infection sand decrease complication rate (20% *vs.* 27%) (P<0.034). This has been similar in other studies published by Saklani *et al.* (33) supporting decrease morbidity (16% *vs.* 26%), Park *et al.* reported no difference in complication in robotic compared to laparoscopy (34).

The CLASSIC trial (4-6) showed conversion rates of 16% in laparoscopic rectal surgery. After the adoption of robotic the data showed conversion rates of 0–8% (33-35). In Saklani *et al.*'s series of 74 robotic low rectal cases, the conversion rate is 1% (33). Surgical outcomes in rectal cancer depend on the quality of the specimen, and with the implementation of robotics yielded high quality TME specimen. Kang *et al.* (32) reported low CRM positivity in robotic (4.2% *vs.* 10% lap, P<0.034), Yoo *et al.* 2015 (35) also supported low CME positivity in robotic 9% *vs.* 19%. The drawbacks of robotics are the increase in operating time and cost. Patriti *et al.* demonstrated shorter operating time (165 min) (36).

There are few studies (37,38) to show the long term outcome in robotic surgery, Park *et al.* (37) compared 133 cases of robotic LAR with 5-year follow up showed no difference in OS, DFS, LR. The ROLARR (39) multicentre RCT concluded that there is no difference in conversion rates (8% *vs.* 12%), CRM positivity (5% *vs.* 6%), but robotic surgery showed benefits in males, in low tumour and obese patients.

Contention in management of transverse colon (T-colon) cancers

T-colon deserves special mention as T-colectomy surgeries are quite challenging. Laparoscopy has better benefits in T-colon as better visualization of mesentery base, identification of middle colic vessels, better dissection of mesentery from pancreas. T-colon has special anatomical and embryological status and surgery in T-colon is not standardised, because of an embryological fusion of mesenteric fascia, metastatic nodes incidence is 5% in subpyloric and 4% in right gastroepiploic nodal station (40). Most of the randomised trials like CLASSIC, COST, COLOR, ALCCas, have not included T-colon cancer.

Agarwal *et al.* (41) showed that laparoscopy retrieved more LN yield (22 *vs.* 18) and laparoscopy is feasible with conversion of 10% cases, further laparoscopy had decreased stay and similar 5-year OS and DFS, RR. Chong *et al.* published largest series of 1,060 patients comparing outcomes of T-colectomy verses extended colectomy which showed no difference in 5-year DFS/OS (42).

Distinction of combined endoscopic and laparoscopic surgery (CELS) in colorectal surgery

CELS is a recent development for removal of colonic polys when endoscopically difficult for excision when polyp is large, broad base, difficult visualization between the folds of mucosa, torturous colon. The advantages of CELS is the real time visualization of full thickness injury, avoids bowel resection, suture repair laparoscopic, invagination and mobilization of intestine. In recent review complication of CELS is coagulopathy (0–18%), and cancer risk of 2–10% (43). CELS has advantage of short stay and less operating time, the success rate of CELS is 75%. The long term outcome of CELS is safe and effective (44). Additional surgery is not necessary if the tumour is early stage and margins are clear, but CELS need dedicated OR room, two skilled doctors, endoscopic suturing, preoperative preparation, frozen section and learning curve.

Application of fluorescence imaging in colorectal surgery

Anastomotic leak in colorectal surgery is major concern in terms of mortality and morbidity and long term outcomes. Most of the anastomotic leak occurs due to the inadequate perfusion at the anastomosis, there is no reliable tool to confirm the micro perfusion at time of anastomosis. Fluorescence angiography is a new tool introduced in laparoscopic MIS to assess the adequate perfusion at the time of anastomosis. PILLAR II multi-institutional trial of 139 patients on use of fluorescence angiography showed that the success rate of angiography is 99% and by performing a fluorescence angiography study changed the planned proximal margin of transection in 7.9% of patients, with resulting leak rates of 0% (45). This is new technique and studies have showed safety and feasibility of this technique. This technique can be useful mainly where there is high risk anastomosis, and extended resections and re-resections of CRC where there is risk of precarious blood supply.

Natural orifice translumenal endoscopic surgery (NOTES) in rectal surgery

The leading edge of minimal invasive surgery is NOTES. Organ preserving surgery has been the recent trend in rectal surgery which has less pelvic complications and no anastomotic leak when compared to radical surgery. Since the introduction of Transanal endoscopic surgery platform in 1980 by Dr. Gerhart Buess there has been many modification, in 2009 the technique of transanal minimally invasive surgery (TAMIS) was introduced by Dr. Mathew Albert. Transanal surgery is mainly performed for benign rectal lesions and T1 lesions. The advantage of NOTES is that it avoids stoma, and complications of anastomic leak, and prevents neurovascular injury to bladder and preserves sexual function. Advantages of TEM is it has stable platform, specific insufflation, and dedicated suction and more proximal rectal lesions up to 20 cm can be resected, 3D vision. TAMIS has short learning curve as it has the similar instrumentation and techniques of SILS, decrease set up time for platform, flexibility of instruments use and better working angle for instruments. There is robust data on safety and feasibility of TEM/TAMIS, meta-analysis (46) compared three RCT concluded that TEM showed oncological outcomes equivalent to TME in early rectal cancer (cT1–2N0M0). TEM is also associated with a significantly shorter operative time, decreased intraoperative blood loss, decreased need for stoma and analgesia, and shorter hospital stay. TEM and TME were similar in terms of perioperative mortality and complete tumour resection. There are further CARTS, TESAR trial awaited to show whether there is advantage of transanal surgery in rectal cancer.

Trans anal total mesorectal excision (TaTME) is a new extension of MIS in treatment of rectal cancers. It can be performed as pure Transanal or hybrid procedure. The advantage of TaTME is in narrow pelvis, obese patients, large rectal tumours, irradiated patients, reoperative surgery. It is a bottom up approach which helps in clear visualization or rectum and mesorectum. Till now less than 500 cases have been reported which showed safety and feasibility of the procedure, recent systematic review (47) showed TaTME has good quality specimens with CRM clear in 98% and 1% LR in 14-month follow up, long term outcomes are still awaited. Further on-going COLOR III trial is awaited to know the long term outcomes.

Summary

Minimal invasive surgery in colorectal cancer results in good short term benefits with equivalent long term outcomes compared to open surgery. CME produces better quality specimen and showing promising long term outcomes, further studies need to address the long term benefit of CME. Robotic rectal surgery is an emerging technique with advantage in low rectal cancer, male pelvis and in obese patients. Trans anal surgery is a new platform in management of rectal cancer.

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Footnote

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Improving preoperative endoscopic localization of colon and rectal tumours

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Provenance: This is a Guest Commentary commissioned by Editor-in-Chief Minhua Zheng (Department of General Surgery, Ruijin Hospital, Shanghai Jiaotong University School of Medicine, Shanghai Minimal Invasive Surgery, Shanghai, China).

Comment on: Yap R, Ianno D, Burgess A. Colonoscopic localization accuracy for colorectal resections in the laparoscopic era. Am J Surg 2016;212:258-63.

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We read with great interest the article published in *The American Journal of Surgery* by Yap *et al.* entitled "*Colonoscopic localization accuracy for colorectal resections in the laparoscopic era*" (1). The authors should be commended on their interesting study addressing an important aspect of preoperative planning in the increasingly established era of laparoscopic colorectal surgery.

The benefits of a laparoscopic approach to colon and rectal surgery have been well demonstrated, and this approach is used with escalating frequency with comparable oncologic results to open surgery (2). However, in contrast to open surgery which affords the surgeon the ability to palpate and confirm the location of masses intraoperatively, a laparoscopic approach is more dependent on accurate preoperative localization of the lesion. Efforts to understand and minimize errors in preoperative localization of colorectal lesions are therefore of relevance and importance to reduce the frequency of intraoperative changes to the surgical plan.

In their study, Yap *et al.* found that of the 221 colon and rectal masses retrospectively reviewed over a six-year period, only 175 (79.2%) had been accurately localized when intraoperative findings were compared with preoperative endoscopy reports. Of the 46 incorrectly localized lesions, 17 (37%) required an intraoperative change in the surgical plan, with three requiring ileostomy creation due to unexpected rectal lesions, and one requiring conversion from laparoscopy to open for palpation of the tumour (1).

Of the 46 lesions which were incorrectly localized preoperatively, the correct location was ultimately determined intraoperatively by tumour visualization in 26.1%, by visualization of endoscopic tattoo in 26.1%, and by CT scan in another 21.7%. Of the remaining lesions, 19.6% were identified by means not specified in the operative report (1). In light of these findings, and given that all patients in this study underwent preoperative colonoscopy for diagnosis, it is notable that only 110 lesions (49.7%) were tattooed, and just 196 lesions (88.7%) had a documented staging CT to complete the patient's preoperative work up (1).

On univariate and multivariate analysis, Yap *et al.* (1) found that two factors influencing the likelihood of an incorrectly localized tumour remained statistically significant: (I) incomplete colonoscopy (P=0.026 on multivariate analysis); and (II) colonoscopy performed by an endoscopist with a gastroenterology (as opposed to surgical) background (P=0.028 on multivariate analysis).

Szura *et al.* (3) in their 2016 RCT found colonoscopic localization was accurate in 83.2% of the 129 patients in the study's endoscopy arm, although this number has been reported to be as high as 96–99% for studies examining single surgeon-endoscopists (4,5). While there has been recent discussion in the literature about endoscopy as the domain, preferentially, of the gastroenterologist, we feel that this study and the three referenced above (3-5) are reminders of the importance of a strong surgical presence within the endoscopy community. This ensures that the focus on preoperative planning and associated endoscopic considerations brought to bear by the operating surgeon can be shared and incorporated into future standards of practice to help minimize the risk of intraoperative localization errors, especially in the era of laparoscopy.

Yap *et al.* (1) also indirectly reinforce the importance of a complete diagnostic and staging work up for all colorectal tumours, as well as a multidisciplinary team review of a patient's management plan. It is important to note that approximately three-quarters of incorrectly localized tumours could be correctly identified intraoperatively by systematic examination of the colon, aided by the presence of an endoscopic tattoo and a staging CT scan (1). The interdisciplinary review of a patient's work up prior to finalization of the management plan serves to improve communication between the endoscopist, surgeon, and radiologist with regards to localization and evidence of nodal or metastatic disease. In addition, this provides an opportunity to discuss the timing and order of surgery with medical and radiation oncologists, whose roles are essential in the management of colorectal cancers.

Finally, and perhaps most fundamentally, our group is not aware of any standardized definitions for the endoscopically determined location of colonic lesions. This lack of a shared endoscopic nomenclature creates inherent ambiguity in the subjective assessment of tumours described as being located within the hepatic or splenic flexures, or within the descending, sigmoid, or rectosigmoid colon. Even the definition of a rectal cancer has been debated, with no agreed upon standard to guide reporting. Given the importance of clear communication about tumour location between the endoscopist and surgeon for accurate preoperative planning and informed consent, the establishment of a standardized set of definitions for localizing colorectal tumours is an essential starting point.

Yap *et al.* (1) highlight an important topic in the surgical management of colon and rectal cancers, and reinforce the importance of interdisciplinary communication and collaboration to improve patient outcomes. The establishment of a shared endoscopic nomenclature defining tumour location, as well as the adoption of complete diagnostic and staging work ups as institutionally prioritized quality indicators are crucial steps toward minimizing incorrect preoperative localization of colon and rectal cancers in the era of laparoscopic surgery.

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None.

Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

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Laparoscopic rectal resection—the road to safety surgery

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Abstract: Total mesorectal excision (TME) indicates a surgical technique for the removal of the rectum and mesorectum during an anterior resection for rectal cancer. The concept of complete TME was first described by Heald in 1979. In the past ten years laparoscopic total mesorectal excision (LTME) has been introduced as an alternative to the open technique and proved to be equivalent by many studies. Anyhow, the laparoscopic approach is technically more challenging than the open one, and its learning curve is often longer. The purpose of this study is to suggest a standardization of the procedure by suggesting a critical view of safety for laparoscopic rectal resection, advising some tips and tricks which could benefit its learning and its performance.

Keywords: Rectal; cancer; laparoscopy; operative technique

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Introduction

Total mesorectal excision (TME) indicates a surgical technique for the removal of the rectum and mesorectum during an anterior resection for rectal cancer. The concept of complete TME was first described by Heald in 1979 (1). The mesorectum is the fat tissue that surrounds the rectum, it contains blood vessels, lymph vessels and lymph nodes and autonomic nerves. Rectal cancer, in most cases, is confined to the mesorectum, therefore, to obtain definitive cure of the disease the complete removal of this package is necessary. In fact, being associated with low local recurrence rates, this technique became the gold standard for rectal cancer (2). To fully understand the surgical technique described by Heald, it is important to define what in literature is called the 'holy plane'. In the pelvis, the visceral compartment is enveloped in the visceral fascia, which posteriorly covers the mesorectum. This fascia is connected with a layer of loose tissue which can be divided, opening the space of the Retzius anteriorly and the retrorectal space posteriorly. This dissection plane is called 'holy plane' or TME plane, described by Heald in 1988 (3).

In the last decade laparoscopic total mesorectal excision (LTME) has been introduced as an alternative to open TME (OTME) and proved to be equivalent by many multicentric trials (4-6). Anyhow, the laparoscopic approach is technically more challenging than the open one, and its learning curve is often longer. Moreover, TME is proven to be the hardest task to learn to perform, among the various phases of the anterior resection (7).

To facilitate the learning of this technique and, therefore, to improve its safety, many Authors all over the world have tried to standardize it. For an example Miskovic *et al.* in their recent work tried to establish a structured international consensus on a detailed technical description of laparoscopic TME. At the moment most of the phases of the operation have been internationally standardized, but a few controversies are still open. In fact, a debate is still going on about the height of section of the inferior mesenteric artery (IMA) and the routine mobilization of the splenic flexure.

To better understand the implications of the ligation of the IMA it is necessary to understand its anatomical features. The IMA, originates from the abdominal aorta and supplies the splenic flexure, the descending colon, the sigmoid colon and the upper part of the rectum. IMA's branches are the left colic artery, the sigmoid branches and the superior rectal artery. Proximally, its territory of distribution overlaps with the middle colic artery, a branch of the superior mesenteric artery (SMA). In fact, the SMA and IMA anastomose at two levels: the artery of Drummond and the Riolan's arcade. These anastomotic sites are essential to the correct vascularization of the colon. It is worth mentioning the existence of a vascular site particularly susceptible to ischemia in case of insufficiency or deficiency of these anastomotic branches, resulting particularly interesting in rectal surgery: Griffith's critical point. It is defined as the site of communication of the ascending left colic artery with the marginal artery of Drummond and anastomotic bridging between the right and left terminal branches of the ascending left colic artery at the splenic flexure of the colon (8). Therefore, splenic flexure vascularization results dependent from the collateral circulation between the SMA and the marginal artery branch of the IMA, supplying the descending colon.

This critical point described become even more critical when associated to vascular arteriopathy, in particular in the elderly.

Considering the anterior resection of the rectum, the ligation of the IMA at its origin is preferred by many surgeons (9). Anyway, the high-tie section of the IMA leads to the sacrifice of the left colic artery, leaving the Drummond artery supplying blood for the splenic flexure.

Splenic flexure mobilization is usually performed to prevent tension on the anastomosis. When the proximal colon stump can reach the pubic symphysis, the anastomosis will be tension-free.

It is worth mentioning that, as demonstrated by Buunen *et al.*, only in 20% of cases the descending branch of the left colic artery represents a limitation factor for the creation of a tension-free anastomosis, so in 80% of cases low-tie ligation can be performed.

It is important to underline how IMA ligation and splenic flexure mobilization are interconnected and if badly managed can lead to complications, such as the anastomotic leakage, which is due to the combination of low perfusion and tension on the anastomosis.

In our opinion, if the operator decides to go for high-tie ligation of the IMA, the splenic flexure should be always mobilized to prevent ischaemic complications at Griffith's critical point. While if the operator decides to perform a low-tie ligation, the splenic flexure can be spared or mobilized, in case of short rectal stump, to prevent anastomotic tension.

All considered, laparoscopic rectal resection represents a challenging operation characterized by a long learning curve that must be performed by expert operators.

The main purpose of this study is to suggest a standardization of the procedure. As Strasberg (10,11) did for colecistectomia procedure, we suggested a critical view of safety for laparoscopic rectal resection, advising some tips and tricks which could benefit its learning and its performance.

Operative technique

Equipe positioning

Operator (surgeon) on the right side of the patient; 1st Assistant on the right side of the patient, at left of the operator; 2nd Assistant between the legs of the patient; nurse on the left side of the patient.

Port placement

T1: 10 mm port placed 2 cm above the umbilicus along the midline.

T2: 10 mm port placed in the right flank, 1 cm above the transverse umbilical line, along the longitudinal emiclavear line.

T3: 5 mm port in the left flank, 1 cm above the transverse umbilical line, along the longitudinal emiclavear line.

T4: 12 mm port placed in right iliac region, at least 2 cm far from the hipbone.

T5: 12 mm port placed in the sovrapubic region, along the midline, on the Pfannenstiel incision line.

Splenic flexure mobilization

T1 camera (1st assistant) T2 operator's left hand T3 operator's right hand T4 2nd assistant's left hand

The operator with his left hand in T2 grabs the omentum, pulling it up and keeping it in traction. The colon is pulled downwards by the 2nd assistant in T4, by grasping epiploic appendix. The dissection line is highlighted by the operator's traction and assistant's counter traction (*Figure 1*). Surgeon's right hand performs the coloepiploic detachment, opening the omental bursa. Dissection proceeds from medial to lateral, up to reach the splenocolic ligament, which gets resected to complete the mobilization of the splenic flexure (*Figure 2*).

Critical view of safety

The main landmarks of the dissection line are: superiorly the limit of the omentum flipped upwards and inferiorly the

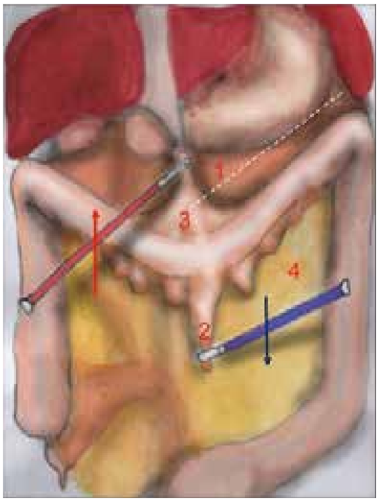

Figure 1 Coloepiploic detachment. The discontinuous line indicates the dissection direction that must be followed until the complete mobilization of the splenic flexure. Blue clamp, assistant; red clamp, operator; 1, coloepiploic ligament; 2, epiploic appendix; 3, omentum; 4, mesentery.

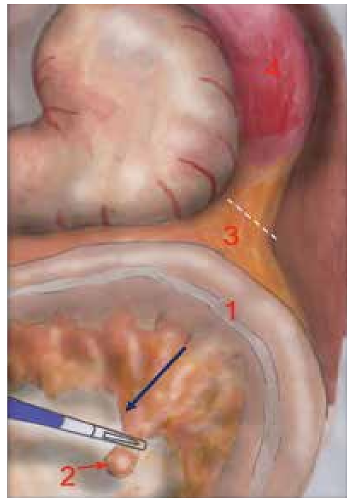

Figure 2 Splenic flexure mobilization. The discontinuous line indicates the direction of dissection of the splenic-colic ligament. Blue clamp, assistant; 1, splenic flessure; 2, epiploic appendix; 3, splenocolic ligament; 4, spleen.

colon profile counter-tractioned downwards.

The identification of the posterior gastric wall confirms the right opening of the lasser sack. The detachment of splenic flexure is considered complete when the colon can be moved completely (*'like the page of a book'*) and if it results completely detached from the omentum. It must be reminded that, sometimes, the omentum can lay on the antimesenteric side of the colon, strongly adhering to it. In these cases it is important to perform a careful detachment of the two.

Tricks: the instruments of both the operator and the assistant must proceed gradually in the direction of the dissection, as it moves on. The continuous traction and counter traction of gastrocolic and splenocolic ligaments allow an easier dissection, additionally facilitated by the intra-bdominal pressure created by the pneumoperitoneum.

Vascular dissection

T2 camera (1st assistant) T1 operator's left hand T4 operator's right hand T3 1st assistant's left hand

The peritoneum is opened from the Treitz to the pelvic cavity, following the descending path of the aorta.

Vascular dissection is based on the identification of the embryological plane which divides Toldt's fascia from Gerota's fascia.

The plane is dissected at first under the inferior mesenteric vein. Thereafter the dissection proceeds under the IMA at its origin, 2 cm from the aorta (high-tie vascular dissection). Eventually, the two planes are joined and the colon detachment is complete.

The operator pulls the mesenteric vein up to create an arch-shaped space underneath which he can divide the Toldt's fascia from the Gerota's fascia. The dissection begins right next to the Treitz ligament, where the identification of the vein is easier (*Figure 3*).

The dissection moves towards the plane already dissected during splenic mobilization. The pancreatic margin can be clearly identified on the left. The dissection of the vein ends with the detachment of the mesocolon from the pancreatic margin, after which the mobilization of the colon is completed.

Thereafter, the operator, with his left hand grabs the IMA with a clamp and keeps it suspended. By doing so, all the retroperitoneal structures, like gonadal vessels, ureter, sympathetic nervous plexus are left behind the meso of the colon. This is made possible also by the assistant who pulls up and left the sigmoid and, consequently, the vascular axes (*Figure 4*).

The surgeon opens the visceral peritoneum and proceeds with the identification of the hypogastric nervous plexus, the abdominal aorta, the iliac vessels and the left ureter. This phase of identification of the anatomic landmarks is done by

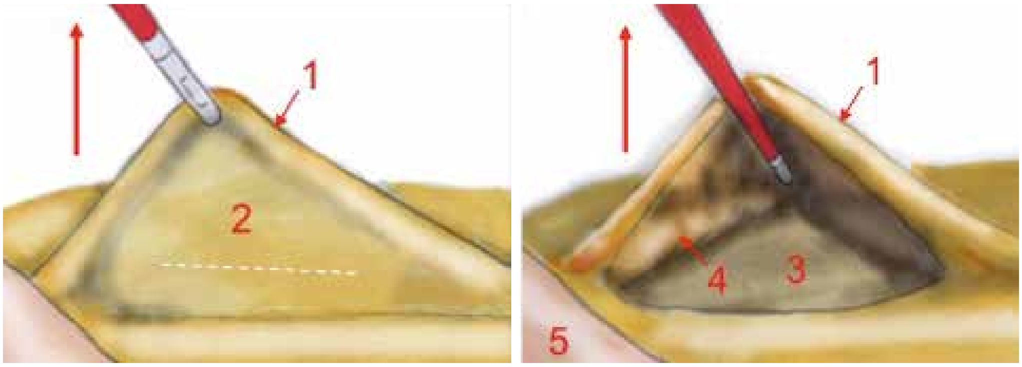

Figure 3 Identification of inferior mesenteric vein and exposure of Toldt's fascia. Red clamp, operator; 1, inferior mesenteric vein; 2 & 3, Toldt's fascia; 4, pancreas; 5, Treitz ligament.

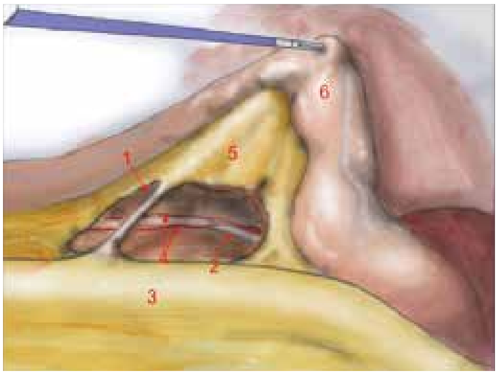

Figure 4 Dissected aortic plane. Identification of inferior mesenteric artery and left ureter. Blue clamp, assistant; 1, inferior mesenteric artery; 2, left ureter; 3, aortic artery; 4, gonadal vessels; 5, mesentery; 6, descending colon.

a dissection that goes from medial to lateral and upwards, inside the peritoneal widow just created. The dissection moves upwards, until the origin of the IMA, and laterally until the posterior muscular plane. After identifying the left ureter, always pulling up the mesosigmoid, the inferior mesenteric axis is put in tension, isolated and dissected at its origin.

The operation goes on by pulling up the vascular axis and the meso of the sigmoid and of the descending colon, and sticking the laparoscope and the laparoscopic tools under these structures. By doing so, the dissection can proceed from medially to laterally and upwards. Laparoscopic magnification and pressure caused by pneumoperitoneum allow the precise identification of the posterior side of the mesocolon, always kept in tension.

Critical view of safety

The anatomical landmarks that must be identified during mesenteric vein dissection are: the mesenteric vein tractioned upwards, creating a vascular arch superiorly and the Treitz ligament inferiorly. The floor of the plane is represented by the retroperitoneal space. The pancreatic margin must be identified on the left and is slightly elevated compared to the retroperitoneal plane created by the surgeon.

The anatomical landmarks that must be identified during mesenteric artery dissection are: the vascular axis perpendicular to the plane, the sigmoid superiorly and the aorta inferiorly. The floor of the plane is represented by the plane of the ureter that should be identified before artery dissection.

Tricks: to facilitate the dissection it is essential to create the right amount of tension on the tissues. This is made possible by a continuous gentle traction of the mesenteric vein before and of the sigmoid and vascular axis thereafter.

Sharp dissection must not be performed. The division line between the Toldt's fascia and Gerota's fascia has to be found with gentle dissection movements. The operator's tools move gently up and down between the two fascial tissues, in order to gently separate them (*'just like opening a plastic grocery bag'*). The identification of the correct plane is guaranteed by the avascularity of the dissection. If you meet any bleeding during dissection, you may got lost.

Paracolic gut detachment

The parietal peritoneum is dissected alongside the lateral margin of the colon, beginning from the proximal sigma up to the splenic flexure. The first assistant grabs the colon

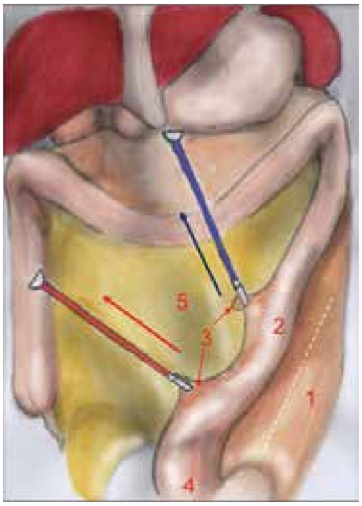

Figure 5 Left paracolic gutter dissection. The discontinuous line indicates the dissection line on the left paracolic gutter that must be followed to complete colon mobilization. Blue clamp, assistant; red clamp, operator; 1, left paracolic gutter; 2, descending colon; 3, epiploic appendices; 4, rectum; 5, mesentery.

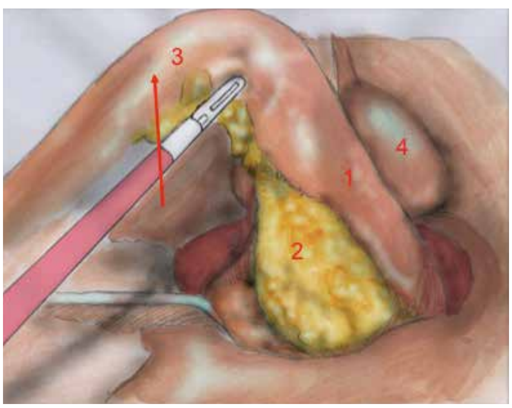

Figure 6 Mesorectum dissection. Red clamp, operator; 1, rectum; 2, mesorectum; 3, sigmoid colon; 4, uterus.

from T1, keeping a few cm from the grab of the operator, and suspends it promoting the separation from the parietal peritoneum (*Figure 5*).

Mesorectal dissection

T2 camera (1st assistant) T1 operator's left hand T4 operator's right hand T3 1st assistant's left hand T5 2nd assistant

The first assistant (T3) holds rectosigmoid and retracts it cranially, so that the operator can start circular dissection of pelvic peritoneum. The assistant moves the rectosigmoid laterally, anteriorly or posteriorly synchronously with the operator's position, in order to facilitate surgeon's circular dissection (*Figure 6*).

Also in laparoscopy, times of operation are the same described by Heald, starting from the posterior dissection moving down the pelvis, while the rectum is held high by the assistant (a laparoscopic retractor can be inserted is inserted in T5). Posterior dissection gets deeper and deeper, keeping on the sacral plane, paying attention to keep the mesorectal fascia intact. The posterior plane proceeds vertically down until the tip of the coccyx where, after the dissection of rectal-sacral ligament, it turns horizontal at the level of the elevator of the anus. It is advisable to go down as far as possible with the posterior dissection before starting the lateral and the anterior dissection. Once the posterior part is completely dissected, the dissection moves laterally (left and right). The operator is helped by the assistant, who performs countertraction. The retractor holds up the uterus in women and the bladder in both sexes. Laterally the 'rectal wings' are dissected. In this plane the vascularization is minimum but attention must be paid to the nervous system. Anteriorly the peritoneum is incised at 1 cm from the Douglas reflection so that the Douglas pouch can be entirely removed. The dissection moves in front of the Denonvilliers' fascia where, in men, seminal vesicles can be identified while in women the vaginal wall.

A laparoscopic retractor in inserted in T5 during the dissection of the anterior side of the rectum. Its main function is to place a retractor to lift uterus and vagina in women and prostate and seminal vesicles in men.

Critical view of safety

The anatomical landmarks are: superiorly the rectum retracted upwards, inferiorly the sacrum, laterally pelvic walls and nervous plexus and anteriorly the vaginal wall, in women, and the seminal vesicles, in men.

Tricks: mesorectal dissection occurs in a total avascular plane that, once identified, can be easily dissected, exposing 'the white side of the yellow' as Heald first described in 1979. As the posterior dissection continues downward, the mesorectum looks more and more bilobate (indicating a good quality of the dissection) until it thins out and disappears.

Once again traction and counter traction are essential in lateral and anterior resection to identify the dissection plane. Working in the right dissection plane means to protect the nervous structures laterally and the seminal vesicles/vagina anteriorly. Moreover, the identification of the nervous structures at this level is facilitated by laparoscopic magnification.

Rectal dissection

Upwards continuous traction (left and right), counter traction obtained by the laparoscopic retractor and, sometimes, pushing the pelvic floor up for a few centimeters, associated with laparoscopic vision, allow an extremely precise dissection. Distal rectum gets dissected using a laparoscopic linear stapler, inserted from T5.

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Footnote

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Review: endoscopic submucosal dissection (ESD) and endoscopic mucosal resection (EMR)

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Abstract: Endoscopic resection within the gastrointestinal tract has changed the disease management paradigm for multiple premalignant conditions. Recently indications have expanded to include several types of early cancers as well. Unified by submucosal injections and a submucosal dissection plane, endoscopic resection techniques are generally divided into endoscopic mucosal resection (EMR) and endoscopic submucosal dissection (ESD). EMR is a natural extension of polypectomy, applied to a flat lesion after a submucosal injection. ESD is a technically more difficult technique that involves tunneling the endoscope into the submucosal plane, but may allow curative, *en bloc*, resections of early stage malignancies. This review evaluates an array of current evidence for pathologies within the gastrointestinal tract, appropriate preoperative evaluation, preparation and procedural techniques.

Keywords: Endoscopic submucosal dissection (ESD); endoscopic mucosal resection (EMR)

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Introduction

Endoscopic mucosal resection (EMR) and endoscopic submucosal dissection (ESD) represent the progression of endoscopy from a diagnostic modality, to a useful therapeutic tool for curative intent to treat mucosal lesions and early cancers of the gastrointestinal tract. EMR is an extension of polypectomy techniques that were developed for pedunculated polyps, but applied to sessile and laterally spreading lesions. The differentiating step in EMR and ESD the procedure is submucosal injection to create a neo-polyp, or pseudopolyp, which increases tissue purchase by the hot snare. Submucosal injection as a technique was introduced in 1955 and 1973 for rigid and flexible colonoscopy (1,2). Since that time, development of EMR technique has resulted in distinct methods, categorized as injection assisted, suction cap and ligation techniques, detailed below. Piecemeal resection is possible to achieve complete resection.

To distinguish EMR from ESD, an understanding of a subtle division in layers of the gastrointestinal wall is essential. The mucosa, derived from the embryonic endoderm, and muscle arising from the embryonic mesoderm, are the two principal layers existing in the wall of the gastrointestinal tract, and are attached by a loose connective tissue submucosa (1). Both EMR and ESD involve separation of these layers at their junction in the submucosa. Histological evaluation of specimens reveals that maximal tissue depth resected is slightly greater for ESD, when compared to EMR, meaning ESD accomplishes a slightly deeper division in the submucosa (3). From a pathological standpoint, ESD then facilitates a better oncologic resection, and allows for *en bloc* endoscopic resections. However, the secondary implication is a higher rate of intra-procedural bleeding, as intramural blood vessels travel in this deeper layer of the submucosa. The development of ESD has, by necessity paralleled the development of electrosurgical instruments and generators to achieve coagulation, a more recent development.

Rapid adoption of ESD occurred in Asia, where incidence of gastric cancers is 8–10 fold higher than Europe and the United States. This was buoyed by national screening programs in some counties, which resulted in detection of a large number of precancerous lesions and early gastric cancers. Application of ESD then progressed to esophageal neoplasms, where early lymph node metastases are common, but where surgical resection of early cancers was excessively morbid. ESD was later applied to the colon and rectum, and this was the major driver of the introduction of ESD to Europe and the Americas.

Literature evidence for EMR and ESD is stratified anatomic location of target lesions and suspected underlying etiology (see *Figure 1*). While there are some indications for treatment of benign lesions, the vast majority of accumulated evidence exists for premalignant and early malignant conditions. There is application for EMR and/or ESD with curative intent for metaplasia and dysplasia in of the esophagus (Barrett's), certain early gastric cancers, and some superficial duodenal lesions that do not involve the ampulla. Few small bowel lesions beyond the duodenum can be successfully managed with endoscopic resection. Colon and rectal polyps and early cancers are also amenable to EMR and/or ESD.

Patient selection and workup

Prudent patient selection is warranted prior to attempting EMR or ESD, and is largely based on the superficial appearance of lesions within the gastrointestinal tract. The consequence of attempting EMR or ESD on an inappropriate lesion may result in incomplete oncologic resection and necessitate surgical intervention with a poorer overall prognosis. Generally EMR is indicated for nearly any benign or precancerous lesion located throughout the gastrointestinal tract. Indications for ESD are more nuanced, and are briefly reviewed below.

Esophagus

In the esophagus, where lymphatics penetrate the muscularis mucosa, earlier lymph node metastases are more common in esophageal cancer compared to other gastrointestinal malignancies. Since esophagectomy introduces a high rate of morbidity and mortality, endoscopic resection for pre-malignant and early malignant lesions is attractive, and often spares the patient an esophagectomy. For Barrett's associated metaplasia and dysplasia, EMR is considered part of a multimodal treatment platform aimed at eradication. While complete resection of Barrett's lesions is possible with EMR, most endoscopists use EMR techniques to remove distinct nodular areas in a background of Barrett's. This strategy, in combination with thermal or radiofrequency ablative therapies has been shown to be safe and effective to eradicate Barrett's lesions (4). EMR can be additionally attempted for curative intent for early moderately and well differentiated squamous cell esophageal cancer confined to the mucosa or lamina propria (5). Generally the upper limit of size for lesions amenable to EMR is at most 2–3 cm diameter and less than 1/3 the circumference of the esophageal lumen (3,4). Beyond that size, the risk of perforation, incomplete resection, and later stricture are unacceptably high. ESD is indicated for lesions of a similar size, and occupying less than 2/3 of the esophageal lumen. There is a relative indication to attempt ESD for cancers with less than 200 μm depth of invasion, as assessed by endoscopic ultrasound (6). While lesions amenable to successful R0 resection of early esophageal cancer by EMR or ESD likely differ based on the underlying phenotype (squamous cell *vs.* adenocarcinoma), no consensus statements that make such a distinction (7,8).

Stomach

EMR and ESD have become the mainstay of treatment for early gastric cancers in Japan, where the incidence is highest. More than 50% of gastric cancers are diagnosed at an early stage, potentially amenable to endoscopic management (6). Both ESD and EMR are safe and effective. EMR is associated with a recurrence rate of 6–10% in the reported literature, and is higher with piecemeal resection. ESD has a recurrence rate of ~1%, and is generally the preferred endoscopic technique used in Asia. ESD offers the additional advantage of clearly defining margin status and a greater chance for *en bloc* resection. However, the longer procedure times associated with gastric ESD compared to EMR make the latter more attractive for patients with significant co-morbid conditions. Generally accepted criteria for lesions appropriate for EMR or ESD are moderately

Superficial lesion of the gastrointestinal tract identified on screening or surveillance endoscopy

Planning endoscopy Paris Classification ± saline lifting characteristics
Size estimation
Mucosal pattern

Lesion location	Esophagus: Squamous cell cancer	Esophagus: Barrett's dysplasia and adenocarcinoma	Stomach	Duodenum	Colon	Recutm
Endoscopic adjuncts	EUS to evaluate submucosal invasion and node status	Chromoendoscopy			Determination of granular/non granular/ depressed pattern EUS to evaluate submucosal invasion and node status	Determination of granular/non granular/ depressed pattern EUS to evaluate submucosal invasion and node status
R0 resection possible with EMR EMR indicated	❖ <10 mm ❖ Flat lesion (Paris 0–II), AND ❖ m1–m2 invasion, AND ❖ < 2/3 circumference, AND ❖ *en bloc* resection reasonably assured	❖ <15 mm, AND ❖ <500 µm invasion May be used with ablative techniques	❖ <10–15 mm ❖ Paris 0–IIa ❖ Difficult anatomic location for ESD	❖ Adenomatous polyp not involving ampulla	❖ Pedunculated ❖ <20 mm in diameter ❖ Non granular, non depressed	❖ Pedunculated ❖ <20 mm in diameter ❖ Non granular, non depressed
R0 resection possible with ESD ESD indicated	❖ Up to 30 mm, AND ❖ Flat lesion (Paris 0–II), AND ❖ m1–m2 invasion	❖ High grade dysplasia, or intramucosal adenocarcinoma ❖ >15 mm, or poor lifting, AND ❖ <500 µm invasion, AND ❖ <2/3 circumference	Classic: Generally first option ❖ Differentiated early gastric cancer ❖ Elevated lesions <20 mm ❖ Depressed lesions, with no ulcer <10 mm Expanded: Intramucosal cancer with no lymphovascular invasion, AND ❖ without ulcer, regardless of size ❖ with or without ulcer, <30 mm in size	Not recommended	Sessile or laterally spreading lesion >20 mm Non granular, non depressed	Sessile or laterally spreading lesion >20 mm Non granular, non depressed

Figure 1 Generally accepted guidelines for EMR and ESD for premalignant and malignant conditions based on anatomic location and size. EMR, endoscopic mucosal resection; ESD, endoscopic submucosal dissection.

or well differentiated adenocarcinoma and papillary carcinoma, without ulcer and less than 2 cm in diameter. Expanded criteria specify that the upper diameter limit for flat or depressed gastric lesions (Paris class IIb and IIc) is 1 cm. Because poorly differentiated adenocarcinoma and signet-ring cell carcinoma are associated with earlier lymph node involvement, these are generally not considered for EMR or ESD.

Duodenum

Duodenal adenomas occurring sporadically and not involving the ampulla can be successfully treated with EMR in some cases, with the large caveat that almost all literature for EMR in this region comes from high volume centers (9,10). Inspection with a duodenoscope is essential to adequately assess non-involvement of the ampulla. A slightly higher risk of bleeding from EMR in this region and risk of perforation likely warrants overnight observation of these patients.

Colon and rectum

EMR has its widest application in the colon and rectum, and can successfully achieve curative resection for relatively large, sessile lesions. EMR is indicated for sessile polyps 20 mm diameter or larger, with some attempting EMR up to 40mm diameter lesions. Piecemeal resection, prior intervention in the same location and difficult anatomic location are predictors of EMR failure (4). ESD generally has the same indications, but should be pursued with curative intent and careful attention to the margin status. If there is any question, referral for surgical resection is warranted.

Pre-operative preparation

Most providers support the use of a planning endoscopy prior to attempting EMR or ESD. In addition to careful inspection, it allows the provider to adequately discuss options for management as part of the informed consent process. Visual inspection of the target lesions should occur, and be characterized by the Paris classification (11). Lesions with depressed areas and ulceration are more likely to be associated with submucosal invasion, and should be biopsied, tattooed and referred for surgical resection. A caveat exists for lesions with prior intervention, since scarring and fibrosis may be present and lesions may appear depressed. If initial visual inspection is unclear, most endoscopists evaluate saline lift characteristics (see *Figure 2*). Non-lifting lesions are associated with deeper invasion and should be referred for surgical resection. Magnified views of surface architecture and pattern of crypts, both with and without augmentation with topical dyes are commonplace in Asia, but are not in wide use in the West, mostly due to the unavailability of magnifying endoscopes. Other adjuncts such as endoscopic ultrasound may further aid in determining appropriate lesions for endoscopic resection. Tattooing can be helpful, but should not be placed within the target lesion, as it can cause tissue fibrosis.

Planning for the approach to sedation and anesthesia and management of co-morbid conditions is beneficial. In the United States, most endoscopic procedures are performed using a combination of benzodiazepine and narcotic, such as midazolam and fentanyl, to achieve moderate sedation. Propofol may also be appropriate, though we qualify that statement with the reality that it is not available to non-anesthesiologists in all practice areas, and does require additional training and patient monitoring devices (12). Either technique is likely appropriate for EMR; however, long procedure times sometimes associated with ESD often make general anesthesia a better option. Cardiac and respiratory comorbidities should be evaluated prior to pursing EMR or ESD, especially if a patient is to undergo general anesthesia. Bleeding is one of the major complications of EMR and ESD, and patients on chronic anticoagulation and antiplatelet agents may be at higher risk. Standard protocols for peri-procedural management of anticoagulation and antiplatelet agents should be followed (13).

Adequate bowel preparation is essential for lesion detection and visualization during resection. For esophageal and gastric lesions, a clear liquid diet for 1 day prior to the procedure and then *nil per os* for 6 hours prior to the procedure is typically sufficient, barring a functional disorder of the esophagus or stomach. For colon and rectal lesions, polyethylene glycol preparation is preferred. If inadequate preparation is encountered, EMR or ESD should not be attempted. A secondary preparation should be administered and the patient rescheduled for the following day.

In addition to patient evaluation, preparation and optimization, consideration must be made to the preparation of the provider. ESD has been slowly adopted in the West, and a relative paucity of advanced endoscopists have the requisite skills or experience. Lastly, reflecting the multidisciplinary management paradigm surrounding treatment of most malignant conditions, relationships with thoracic, general and colorectal surgeons and medical oncologists should be well established.

Equipment preference card

(I) Therapeutic panendoscope with video monitor and

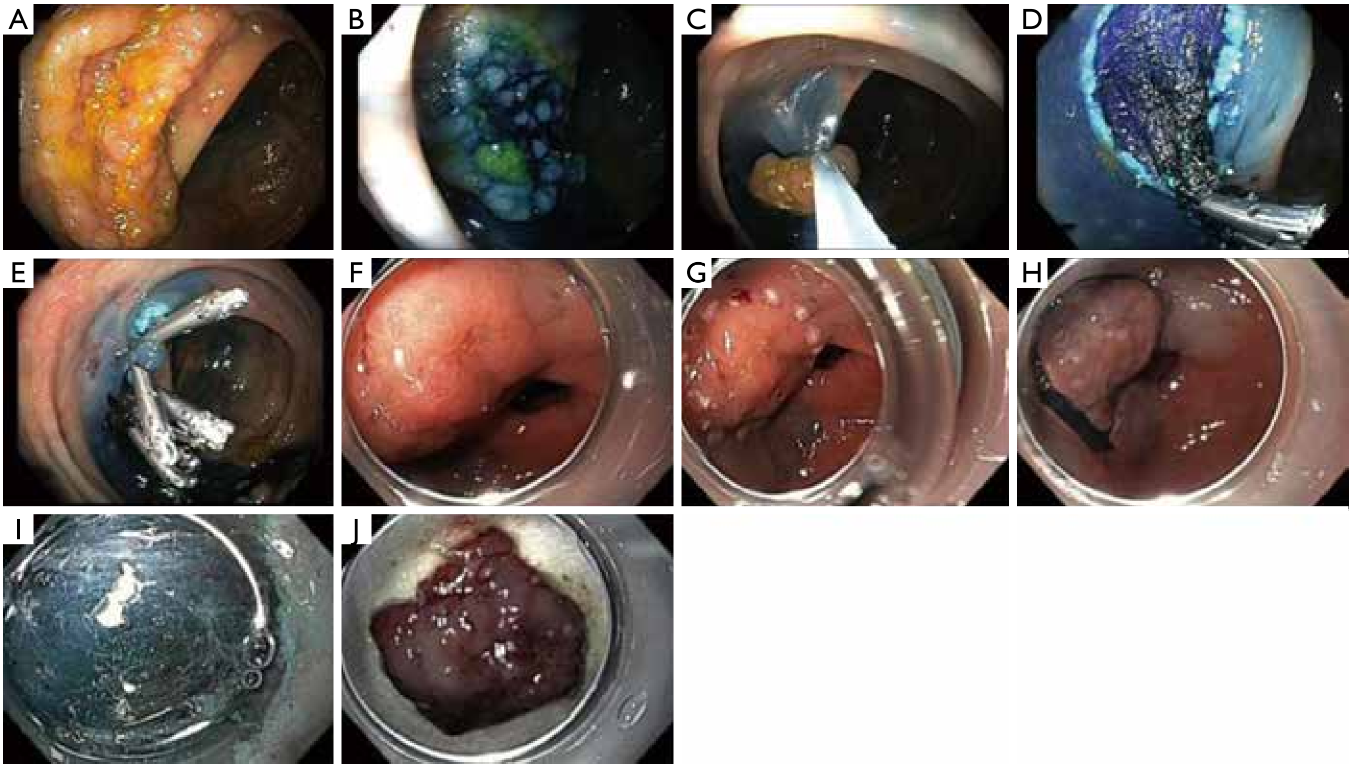

Figure 2 Intraprocedural images of ESD and EMR. Images (A-E) depict EMR of a cecal mass in a septuagenarian, initially discovered during a screening colonoscopy; images (F-J) depict ESD of a mass of the gastric antrum with high grade dysplasia but no invasive carcinoma in a sexagenarian, discovered during endoscopic evaluation of anemia. (A) Initial appearance of cecal mass; (B) after injection with normal saline containing methylene blue dye, demonstrating adequate lifting characteristics; (C) neo-polyp grasped with snare prior to application of electrocautery; (D) ulcer left following resection with stepwise clipping of mucosal defect begun; (E) final appearance of ulcer. EMR images courtesy of Dr. Jeffrey Ponsky, Cleveland Clinic Foundation; (F) initial appearance of antral mass; (G) marking of lesion with argon plasma coagulator (APC); (H) circumferential mucosal incision; (I) submucosal tunnel mid-dissection. Note the blue coloration and the areolar nature of the submucosal tissue; (J) ulcer remaining following resection. ESD images courtesy of Dr. Madhusudhan Sanaka, Cleveland Clinic Foundation. EMR, endoscopic mucosal resection; ESD, endoscopic submucosal dissection.

lavage system. Video recording capabilities are useful when learning EMR or ESD.

(II) Electrosurgical generator capable of implementing customized settings for EMR and ESD. Our institution uses Erbe Vio® 300D (Erbe USA, Marietta, Georgia, USA) equipped with both water jet and argon plasma coagulator (APC) modules and a foot pedal.

(III) Carbon dioxide insufflation system.

(IV) For EMR.
- (i) iSnare System® (US Endoscopy, Mentor, Ohio, USA).
- (ii) For the esophagus, Duette® multi band mucosectomy kit is used (Cook Medical, Bloomington, Indiana, USA).
- (iii) Roth Net® (US Endoscopy, Mentor, Ohio, USA).
- (iv) A variety of hemoclips are used.

(V) For ESD.
- (i) A variety of injection needles and injection solutions are used.
- (ii) Both straight and oblique caps may be used.
- (iii) APC™ 2 (Erbe USA, Marietta, Georgia, USA).
- (iv) DualKnife™ (Olympus Endoscopy, Central Valley, Pennsylvania, USA).
- (v) ITknife nano™ (Olympus Endoscopy, Central Valley, Pennsylvania, USA).
- (vi) A variety of hemoclips are used.

Procedure

EMR or ESD may take place in a dedicated endoscopy suite. While EMR can often be performed under moderate sedation with benzodiazepine with narcotic sedation, longer procedure times associated with ESD often make general anesthesia a better option. There is a low incidence of bacteremia after EMR, and thus most providers do not administer perioperative antibiotics (14). Once a lesion is located, stable access and visualization is paramount. There has been considerable work done regarding settings and pulse wave patterns of electrosurgical units in combination with various electrosurgical generators, and is outside the scope of this review (15).

EMR

Regardless of the specific technique, the first two steps for EMR are to locate the lesion, and perform a submucosal injection. Injection is accomplished with a 21–25 G needle to create a neo-polyp (see *Figure 2*). Multiple injections may be necessary to achieve a relatively uniform lift. There are numerous injection solutions available depending upon practice location. Small case control studies of head to head comparisons exist, but choice of solution is largely based on individual preference (10,16). Generally more viscous solutions produce more durable lifts. Addition of indigo carmine or methylene blue can aid in the identification of the submucosal layer, and more importantly the lateral margin of target lesions. Resection of the lesion can often be accomplished with a single resection, but piecemeal resection is possible if lesions are larger. Resection occurs by one of the following techniques:

Snare

A hot snare that is sized to be slightly larger than the target lesion is introduced through the working channel of the endoscope. The submucosal injection generally allows for greater tissue purchase on the far edge of the lesions. The lesion is encircled, and the snare is set, ensuring that there is not too much bunching of the tissue. Application of the electrocautery frees the lesion. This can be serially repeated if necessary for piecemeal resection.

Suction or cap assisted EMR

If this technique is to be used, a clear plastic cap is applied to the end of the endoscope. The submucosal injection is performed with the cap in place. Apposing the cap to the tissue, while applying suction creates a neo-polyp within the cap. A hot snare is then introduced, and generally falls along the circumference of the cap. Following application of electrocautery, the lesion can often be removed with the scope if the suction is maintained. For small lesions a trap should be placed in the suction tubing. The suction cap technique is most useful in the stomach and esophagus.

Band ligation

If this technique is to be used, a clear plastic cap with a band ligation system is applied to the end of the endoscope. The submucosal injection is performed with the cap in place. Application of suction again elevates tissue into the cap. The band is then deployed. A hot snare is then introduced through the instrument port, and used to resect the neo-polyp. The snare may be applied below, across, or above the band. There are some providers who do not perform a submucosal injection prior to application of this technique.

ESD

ESD begins similarly to EMR, with lesion location. It is also important to ensure that visualization of the lesion is adequate prior to embarking on the next steps. In certain situations, lesions are more accessible in a retroflexed view, in which case a pediatric diameter endoscope can be useful, however, the decreased rigidity of a narrow caliber endoscope can make resection challenging in other ways. Defining the lateral margin of lesions is perhaps the most important step, as ESD is typically undertaken for curative intent (see *Figure 2*). Use of surface dyes, chromoendoscopy, narrow band imaging, magnification or other adjuncts cannot be understated, but is outside the scope of this review. Circumferential mucosal marking is the next step, and accomplished with a needle knife or APC. Marks are made roughly 5 mm outside the lateral margin of a gastric lesion. For esophageal adenocarcinoma marking is 5–10 mm outside, or at the margin for squamous cell carcinoma. In the colon, lesion borders are often more obvious, and marking may not be necessary. A circumferential mucosal incision is made just outside the mucosal markings. A submucosal injection is then performed with a 21–25 G needle to lift the lesion. Submucosal dissection is then performed with the assistance of a cap and an ESD specific knife. The distal tip of the cap elevates the lesion and an electrosurgical knife dissects parallel to the muscular layer. Any bleeding encountered should be controlled expeditiously, as blood can quickly and easily obscure the dissection plane. Submucosal dissection is continued until the lesion is completely free. Small lesions can often be extracted within the application of suction through the cap, while a Roth net may be necessary to retrieve larger lesions. Generally orienting the lesions to the 5 o'clock position is advantageous, and allows the best combination of scope maneuverability and visualization. If possible, positioning the patient such that lesions is in an anti-dependent position allows gravity to aid in retraction (3).

Post-operative management

As with most endoscopic procedures, most patients are able to return home after the procedure. Hospitalization is the exception rather than the rule. Nearly all EMR procedures can be performed as ambulatory procedures. ESD carries a higher risk of bleeding complications compared to EMR, and as such, may warrant overnight observation. This is especially true for providers that are embarking to establish a new ESD practice.

In the immediate post-operative period, monitoring focuses on detecting early complications with either EMR or ESD. Bleeding is the most common complication. Bleeding occurring after EMR is rare in the esophagus, but occurs in an estimated 0–11% of gastric lesions and 2–22% of colonic lesions (10). Most bleeding events occur during the index procedure, and the vast majority of post-procedural bleeding presents within 24 hours; however delayed bleeding may occur up to 5% of the time (10). Prophylactic coagulation of visible non bleeding vessels has not been shown to decrease bleeding after EMR. Bleeding after ESD is also common, occurring in 4.5–15.6% of cases, and this risk increases with lesion size (17). Judicious intraprocedural hemostasis is thus encouraged. For gastric and duodenal lesions, proton pump inhibitor and mucosal protectant medications are associated with decreased bleeding rates. Perforation after EMR and ESD is thankfully uncommon. EMR associated perforations occur 0.5–1% of the time, with some variation based on location, reflecting differences in thickness of the gastrointestinal wall. ESD has higher perforation rate of 2–4%. ESD-related perforations do tend to be smaller, due to the small size of the knives used. EMR related perforations can be quite large, as they result from the muscularis mucosa being gathered into the snare. Management of perforation can range from endoscopic management with clips and suturing if recognized during the index procedure, to percutaneous drainage, or surgical exploration of the abdominal or thoracic cavity.

Following EMR or ESD, surveillance endoscopies are warranted to monitor for recurrence, *de novo* lesions, and to evaluate for strictures. There is no consensus on the time interval for surveillance endoscopy, but an initial diagnostic endoscopy at 3–6 months post resection is reasonable in most cases. EMR and ESD related strictures are most common in the esophagus, affecting 12–17% of patients (10,17). These can often be palliated with pneumatic balloon dilation. Unfortunately, recalcitrant strictures may require operative intervention.

Tips, tricks and pitfalls

The learning curve for ESD is substantial, though it does depend on the background of the individual endoscopist. In Asian training paradigms, independent proficiency for ESD has been shown after 30–40 ESD procedures. Procedural outcomes become similar to experts after >80 procedures (18-20). For this reason, training is likely best performed in tertiary centers, where a concentration of patients with amenable lesions are likely to exist.

Several authors have proposed training paradigms for endoscopists outside of Asia to obtain the requisite skills to be credentialed to safely perform ESD (6,21). These authors advocate for travel to high volume Asian centers for initial observation and training. This should be followed by dedicated training time in both *ex vivo* and *in vivo* animal models, which are typically pigs or dogs. Initial attempts at ESD should be proctored by an endoscopist experienced in ESD. While capabilities for video-based mentoring are increasing internationally, this is likely not appropriate for the initial ESD attempts, and is better delayed until the endoscopist has completed at least a few ESD procedures with an immediately present proctor (22).

Authors have also noted that ability to performed ESD varies by anatomic location. Distal gastric lesions are technically easier, followed by proximal gastric lesions. The decreased incidence of these lesions in the West, but commonality of colonic lesion makes the latter the most attractive entry point for Western providers to perform ESD (6).

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Footnote

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The role of endoscopic submucosal dissection for Tis/T1 rectal cancer

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Background: Colorectal endoscopic submucosal dissection (ESD) is widely used as a minimally invasive treatment for neoplasms in the colon and rectum. Rectal ESD is generally thought to be less complex than ESD in other segments of the colon, however difficult time-consuming lesions can be encountered. Here we investigated the short-term outcomes of ESD for lesions in the upper rectum, lower rectum and anal canal.

Methods: From February 1998 to January 2017, 404 consecutive patients with 414 lesions of upper rectum (Ra), lower rectum (Rb) and anal canal (P), that underwent ESD at our hospital were analyzed. Age, gender, macroscopic feature, lesion size, location of the lesion, procedure time, histological diagnosis, depth of invasion and adverse effect such as intra-procedural perforation, delayed perforation and delayed bleeding, were evaluated as short-term outcomes. Univariate analysis between the lesions with depth of Tis/T1a and T1b was performed.

Results: The number of the lesions located at Ra, Rb and P was 104, 292, and 12, respectively. Mean procedure time was 109.2 minutes (SD ±77.5) and *en bloc* resection ratio was 95.2%. The overall ratio of curative resection was 80.9%. The ratio of intra-procedural perforation, delayed perforation and delayed bleeding was 1.0%, 0% and 3.9%, respectively. When comparing T1b lesions to Tis/T1a lesions, there is no difference in lesion size, procedure time, intra-procedural or delayed perforation ratio and delayed bleeding ratio between the two groups. Positive margins were encountered more frequently in the T1b group compared to the Tis/T1a group (21.0% *vs.* 5.5%).

Conclusions: ESD is feasible for Tis and T1a rectal cancers from the aspect of short-term outcomes and quality of life (QOL) for patients. Incomplete resection was still a problem for T1b cancers and collaboration between endoscopists who perform ESD and surgery has potential in the future.

Keywords: Colorectal endoscopic submucosal dissection (colorectal ESD); rectal cancer; Tis and T1 rectal cancer

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Introduction

Colorectal endoscopic submucosal dissection (ESD) is widely used as a minimally invasive treatment for neoplasms of the colon and rectum. Colorectal ESD plays an important role because surgical treatment sometimes impairs patient's quality of life (QOL) especially for rectal lesions. Transanal resection (TAR) and transanal endoscopic microsurgery (TEM) are options for rectal neoplasms, however, several studies reported relatively high local recurrence rates with these techniques (8% to 33%) (1-4). On the other hand, colorectal ESD is associated with low recurrence rates. ESD is technically difficult, time-consuming and the procedure requires longer time for training for manipulation of endoscope and management of adverse effects such as bleeding and intra-procedural perforation. Intra-procedural perforation seems to be decreasing according to advancement of ESD technique and improvement in equipment. Recent studies also have reported that patients with colon perforation could be managed conservatively after endoscopic clipping of the defect (5). For rectal neoplasms, surgery is associated with decreased patient's QOL and rectal perforation rarely causes peritonitis due to anatomical reasons. Compared with the proximal colon, endoscope manipulation is easy in the rectum, therefore even less-expert endoscopists can perform ESD relatively with ease for rectal lesion (6).

Here we investigated the short-term outcome of ESD for lesions in the upper rectum (Ra), lower rectum (Rb) and anal canal (P).

Our experience

From February 1998 to January 2017, 1,610 consecutive patients with 1,688 colorectal lesions underwent ESD at the National Cancer Center Hospital, Tokyo, Japan. Among these patients, 404 patients with 414 lesions located at upper rectum, lower rectum and anal canal are analyzed (*Figure 1*). Data from these procedures were entered into a prospective database [NEXUS endoscopic database from Sep 2007 and Japan Endoscopy Database (JED) from Jan 2015]. Age, gender, macroscopic feature, lesion size, location of the lesion, procedure time, histological diagnosis, depth of invasion and complication (intra-procedural perforation/delayed perforation/delayed bleeding) were all entered into the database prospectively. If delayed perforation or delayed bleeding occurred, these were also prospectively added to the database. Then, univariate analysis of the lesions with depth of Tis/T1a and T1b was performed. These lesions were histologically evaluated as adenocarcinoma. All histological evaluation was based on guideline by the Japanese Society for Cancer of the Colon and Rectum (JSCCR) (7). All ESD procedures were performed by one of 11 expert staff endoscopists or 29 trainee endoscopists under the direct supervision of an expert. All 11 endoscopists are certified endoscopists by Japan Gastroenterological Endoscopy Society (JGES) and considered experts in ESD.

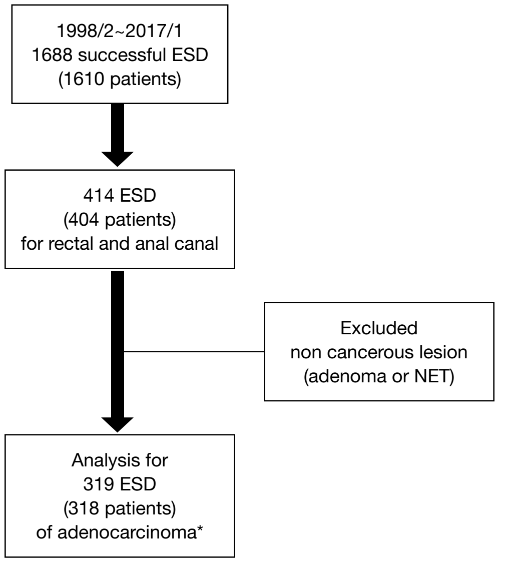

Figure 1 Patients flow. *, according to guideline of Japanese Society for Cancer of the Colon and Rectum. ESD, endoscopic submucosal dissection.

R0 resection was defined as one-piece resection of an entire lesion with carcinoma-free lateral and vertical resection margins. Curative resection was defined when the resection was R0 or Rx without deep submucosal (SM) invasion (>1,000 μm) or lymphovascular invasion or poorly differentiated adenocarcinoma component. We defined colonic perforation as a full thickness defect of the muscular layer with recognition of connective tissue, the abdominal cavity, or serosa. Delayed perforation was defined as perforation occurring after completion of the ESD procedure without any intra-procedural perforation (8).

Results were expressed as mean ± SD or median and range. Continuous variables were compared using a Student's *t*-test in two groups. Categorical variables were compared between the two groups using the chi-squared test or Fisher's exact test, as appropriate. A two-tailed P value <0.05 was considered to be statistically significant.

Table 1 Clinical characteristics of the patients and lesions

Characteristics	N=414
Gender (M/F) (n=404)	231/173
Age (mean ± SD)	63.6±11.5
Lesion size (mean ± SD) (mm)	37.3±23.4
Macroscopic feature	
Protruded (Ip/Is/Is + IIa)	260
Flat/elevated (Is + IIc/IIa/IIa + IIc/IIb/IIc)	106
Recurrence	39
Others (SMT etc.)	9
Location of the lesion	
Ra (upper rectum)	104
Rb (lower rectum)	298
P (anal canal)	12

M, man; F, female; SD, standard deviation; SMT, submucosal tumor.

Table 2 Short term outcome of all lesions

Variables	N=414
Histological diagnosis	
Adenocarcinoma	319
Adenoma	74
Others	21
Procedure time (mean ± SD) (min)	109.2±77.5
En bloc resection† [n (%)]	394 (95.2)
Depth of invasion	
Tis	225
T1a	29
T1b	61
T2	4
Others (including adenoma)	95
Curative resection‡ [n (%)]	335 (80.9)
Intraoperative perforation [n (%)]	4 (1.0)
Delayed perforation [n (%)]	0 (0)
Delayed bleeding [n (%)]	15 (3.9)

†, *en bloc* resection is defined as 1-piece resection of an entire lesion; ‡, curative resection is defined as R0 or Rx without deep submucosal (SM) invasion (>1,000 μm)/lymphovascular invasion/poorly differentiated adenocarcinoma component. SD, standard deviation.

Statistical analysis was performed using the JMP SAS version 12.0.1 (SAS Institute, Cary, NC, USA).

This study was approved by the internal review board in our institution, and informed written consent was obtained from all patients for each specific endoscopic treatment.

Table 1 shows clinical features of the patients and lesions. The mean age of patients was 63.6 years (SD ±11.5), 235 of 404 (58.1%) patients were male. The mean size of the lesions was 37.3 mm (SD ±23.4) and number of the lesions located at upper rectum (Ra), lower rectum (Rb) and anal canal (P) were 104, 292 and 12, respectively. Most of the lesions (260 lesions, 63%) showed protruded features (Is and Is + IIa). *Table 2* shows the short-term outcome of rectal ESDs. Mean procedure time was 109.2 minutes (SD ±77.5) and *en bloc* resection was performed in 95.2% of lesions. Sixty-five (15.7%) lesions were evaluated as T1b or T2 in depth diagnosis. These lesions were diagnosed as non-curative resection. Overall ratio of curative resection was 80.9%. The ratio of intra-procedural perforation, delayed perforation and delayed bleeding were 1.0%, 0% and 3.9%, respectively.

Next, we compared the short-term outcome of the T1b lesions to Tis/T1a lesions (*Table 3*). There was no difference in size of the lesions, procedure time, intra-procedural or delayed perforation, and delayed bleeding between Tis/T1a and T1b groups. In the T1b group, R1 resection was higher than Tis/T1a group (21.0% *vs.* 5.5%).

State of Art

The technique of colorectal ESD has been previously described in detail (9,10). Briefly, we used an endoscope (PCF-Q260JI or GIF-Q260J; Olympus Medical Systems Co., Tokyo, Japan) with a water-jet pump system (OFP; Olympus Medical Systems Co.). A carbon dioxide (CO_2) gas supply system (Olympus Medical Systems Co.) (11) was introduced in 2004. Glycerol® (10% glycerin and 5% fructose) with a small amount of indigo carmine dye and epinephrine (1 mL of 0.1%) solution was injected into the submucosal (SM) layer first to confirm appropriate SM elevation. Next, hyaluronic acid solution MucoUp® (Seikagaku Co., Tokyo, Japan) was injected into the properly elevated SM layer (12). Washing the lesion with the water jet was very important process of colorectal ESD.

Additionally, the patient was positioned appropriately for gravity to provide downward traction on the lesion, which both facilitates SM dissection. Basically, an initial incision

Table 3 Comparison of the short-term outcome between Tis, T1a and T1b lesions

Variables	Tis/T1a (n=254)	T1b (n=61)	P value
Lesion size (mean ± SD) (mm)	40.9±24.0	39.0±23.7	0.584
Procedure time (mean ± SD) (min)	111.9±78.4	127.5±84.8	0.180
Resection†			<0.001
R0 (complete) [n (%)]	219 (86.2)	44 (71.0)	
R1 [n (%)]	14 (5.5)	13 (21.0)	
Rx [n (%)]	21 (8.3)	5 (8.1)	
Curative resection‡ [n (%)]	228 (89.7)	0 (0)	<0.001
Intraoperative perforation [n (%)]	3 (1.3)	0 (0)	1.000
Delayed perforation ratio [n (%)]	0 (0)	0 (0)	–
Delayed bleeding [n (%)]	8 (3.8)	3 (5.5)	0.432

†, R0 resection is defined as 1-piece resection of an entire lesion with carcinoma-free lateral and vertical resection margins; ‡, curative resection is defined as R0 or Rx without deep submucosal (SM) invasion (>1,000 μm)/lymphovascular invasion/poorly differentiated adenocarcinoma component; SD, standard deviation.

and marginal resection of the oral side was made with the bipolar knife (Jet B knife®, XEMEX Co., Tokyo, Japan) using the retroflex view, except for the patients with lesions that were close to the dentate line. After the lesion was partially dissected, a monopolar ESD knife (IT knife nano®, Olympus Medical Systems Co., Tokyo, Japan) was used to complete the dissection of the SM layer quickly and safely (10).

West *vs.* East

In the West, piecemeal endoscopic mucosal resection (EMR) is performed even if the lesions are more than 20 mm. The ESGE guideline states that the majority of colonic and rectal superficial lesions can be removed by standard EMR (13). ESD can be considered for colonic and rectal lesions with high suspicion of limited SM invasion. This is based endoscopic visualization of depressed morphology and irregular or nongranular surface pattern, particularly if the lesions are larger than 20 mm. As preoperative examinations, endoscopic ultrasound (EUS) is mainly used for assessment of depth of invasion and presence of lymph node metastasis. Early invasive superficial neoplasia such as T1a and T1b are indication for surgical resection. If the lesions are located near to the dentate line, TEM may be considered, especially in Europe. Resected lesions that showed evidence of deep SM invasion (T1b) or lymphovascular invasion are better served by additional surgery or chemo-radio therapy (CRT).

In Japan, on the other hand, ESD is recommended for lesions more than 20 mm or T1a invasive lesions when *en bloc* EMR is considered difficult (14). While magnified chromo-endoscopy (MCE) is not yet available in the West, MCE is generally used as a detailed preoperative examination to assess depth of invasion in Japan (15). Surgery is highly recommended for T1b lesions (14). Currently in Japan, patients with histologically high-risk lesions such as deep SM invasion (T1b) or lymphovascular invasion, only additional surgery is the standard option while CRT is now chosen as a clinical trial.

In the West, most large benign rectal lesions are removed by piecemeal EMR due to not widely available ESD. Data have shown that piecemeal EMR is associated with increased recurrence risk (odds ratio, 4.14) (16). These differences of practical approach to rectal lesions between the West and the East are partially due to the difference of histological definition of cancer. Tis (intra-mucosal) lesions are considered as cancer in Japan, whereas it is recognized as a non-cancer but high-grade dysplasia in most Western countries. However, local recurrences with invasive cancer after piecemeal EMR have been reported, although the rate of such recurrences are quite low. From this standpoint, we believe *en bloc* resection should be recommended when the intra-mucosal lesions are detected as far as cost-effectiveness permits it.

Fu *et al.* reported that MCE is at least accurate as EUS for preoperative staging of early colorectal cancers (17). As

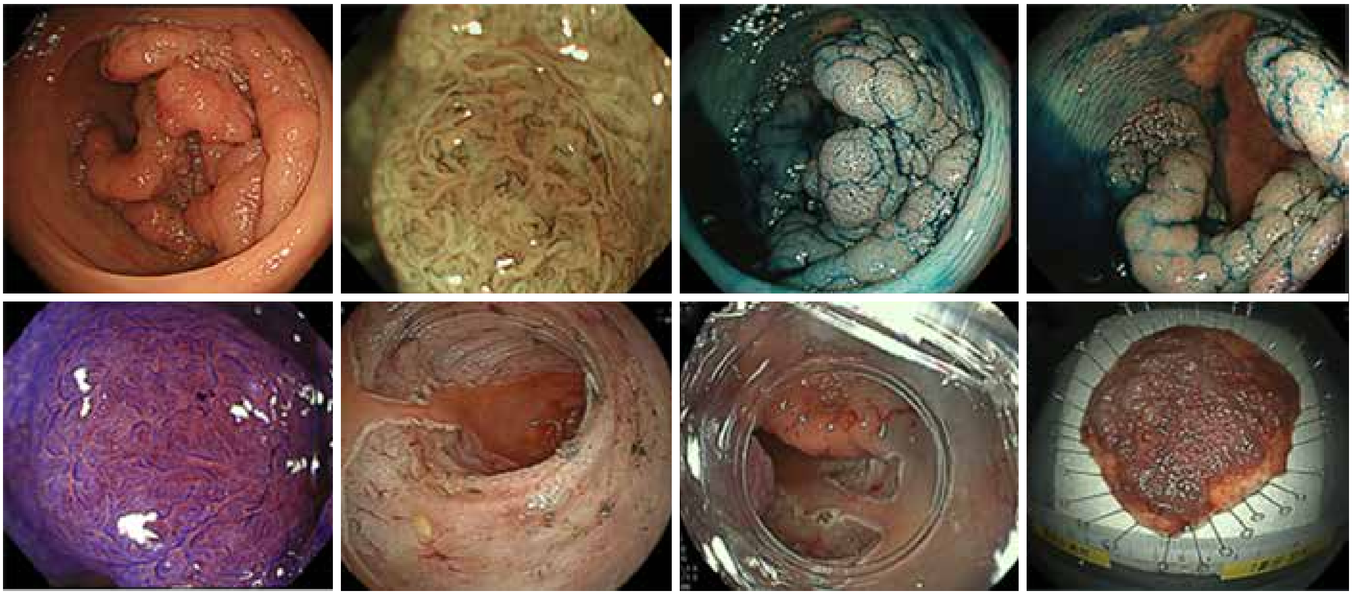

Figure 2 Case of rectal lesion. A 70-year-old man with large rectal tumor is treated. The 0-Is + IIa (LST-G) lesion is seen upper to lower rectum semi-circumferentially. ESD was performed with negative margin (R0 resection) and evaluated as curative resection. LST, laterally spreading tumor; ESD, endoscopic submucosal resection.

the examination tools of detailed depth of invasion, MCE has been developed by repeated conference and discussion between endoscopists and pathologists, especially in Japan. Generally, Japanese pathologists make histological section of endoscopically resected specimen every 2 mm apart in order to evaluate precisely for high risk features such as lymphovascular invasion. Furthermore, this contributes to the detailed discussion of comparison between MCE and histological findings.

Another difference between the West and the East is the reimbursement provided by the insurance companies for ESD procedures. In the US, for example, currently ESD doesn't have a current procedural terminology (CPT) code and medical insurance doesn't cover colorectal ESD.

Colorectal ESD is a minimally invasive therapy compared with open or laparoscopic assisted surgery for superficial SM invasive rectal lesions and thus provide a better QOL for patients (15,18). Due to the technical difficulty and longer learning curve for ESD as well as limitation of reimbursement, ESD is not widely available in the West. Several studies have reported that rectal ESD is an effective training for Western endoscopists who want to learn about ESD (19). Currently, a few Western endoscopists are now performing colorectal ESD with high *en bloc* resection and low complication rate. Therefore, rectal ESD may be feasible and safe if appropriate training is taken and in the right selected patients. Therefore, we believe optimized indication for rectal ESD is very important.

Discussion

To our knowledge, this study is the largest retrospective study investigating the short-term outcomes of rectal ESD. Ikematsu *et al.* (20) had reported that the local recurrence rate for patients with SM invasive rectal cancer were worse than patients with SM colon cancer when treated by endoscopic resection alone and no additional surgery. According to Japanese guidelines (7), SM invasive colorectal cancer with negative vertical margins, well-differentiated or moderately differentiated adenocarcinomas, no evidence of vascular or lymphatic invasions, and invasion depths of less than 1,000 µm are classified as low risk for lymph node metastasis and local recurrence. SM invasive colorectal cancer that is positive for any of these risk factors are classified as high-risk lesions. Therefore, it is thought that additional surgical treatment with lymph node dissection is needed when the lesion is histologically evaluated as a high-risk lesion. On the other hand, endoscopic resection is sufficient treatment for low-risk SM invasive cancers. Therefore, ESD has an important role because it allows precise histological evaluation by *en bloc* resection. *Figure 2* showed that we could achieve *en bloc* resection for semi-circumferential rectal lesions by ESD, so it is thought that there is no limitation in size of the lesion. The prevalence of cancer in rectal lesions was 79.0%, no statistically significant differences compared with the prevalence of cancer in colon lesions (77.3%) in our institution (*Table S1*). This indicates that rectal and colon lesions should be treated according to endoscopic findings.

In this study, R0 resection and curative resection for rectal cancers with depth of Tis or T1a was 86.2% and 89.7%, respectively. It is notable that non-curative resections due to lymphovascular infiltration was high (24.1%, 7/29 lesions) among these T1a cancers. This illustrates the importance of *en bloc* resection by ESD for accurate histopathological diagnosis. Among rectal cancers histologically diagnosed as T1b, 47 lesions (78.3%) were difficult to distinguish T1a from T1b by pre-operative endoscopic examination, while 13 lesions (21.7%) were diagnosed correctly but resected considering patients' high mortality. The R1 resection rate of the lesions of histologically T1b was significantly higher than Tis or T1a. To consider additional surgery, precise histological evaluation is required. The lesions should be resected *en bloc* with R0 when endoscopic resection was chosen.

Next, we compared the group of Tis/T1a lesions and group of T1b lesions. There is no significant difference in procedure time and adverse events between two groups. However, the ratio of positive vertical margin is significantly higher in T1b group than Tis/T1a group (13.1% *vs.* 0.8%, P <0.001). It is important to improve the R0 resection ratio, especially negative vertical margin for T1b lesions in the future.

In summary, endoscopic resection is feasible for Tis and T1a rectal cancers. Additionally, *en bloc* resection by ESD is desirable for lesions that are suspected T1a or T1b in endoscopic depth diagnosis for precise histological evaluation. Concerning rectal T1b cancer, the problem of positive vertical margin, lymph node metastasis and local recurrence is still remaining. Collaboration with surgical local resection should be considered and endoscopic resection is an appropriate treatment options for lesions spreading to anal canal. Abdominoperineal resection (APR) is sometime chosen as surgical method for cancer located in the lower rectum. In such cases, CRT with *en bloc* ESD may be also one of the options for patients who are not suitable for surgery due to patient risk factors, or patients who refuse a radical rectal excision with APR. We are now preparing a clinical trial for ESD following CRT for rectal cancer.

This study has several limitations. First, it is a retrospective analysis from clinical records. The second limitation is that this study has a possible selection bias.

In conclusion, ESD for Tis or T1a rectal cancers is thought to be feasible from the aspect of good short-term outcomes and less adverse events, while higher R1 resection ratio was still problem of ESD for T1b lesions. Collaboration between ESD and surgery, and ESD following CRT are potential future treatment options.

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Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

Ethical Statement: This study was approved by our institutional ethics committee (approval number 2016-447). Informed written consent was obtained from all patients for each specific endoscopic treatment.

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Colorectal endoscopic submucosal dissection (ESD) could reduce the need for surgery of colonic polyps in the West

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Provenance: This is a Guest Editorial commissioned by Editor-in-Chief Minhua Zheng (Department of General Surgery, Ruijin Hospital, Shanghai Jiaotong University School of Medicine, Shanghai Minimal Invasive Surgery, Shanghai, China).

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This is an original article written by Gorgun *et al.* who are colorectal surgeons at a large tertiary referral hospital in USA. I read this paper with great interest because I thought most surgeons would believe that colectomy is simple and does not reduce QOL for patients except in rectal tumors.

A tincture of time

It is important to point out that the interval over which this study collected cases encompasses 16 years between 1997 and 2012. In our opinion, it is safe to assume that techniques such as wide-field endoscopic mucosal resection (WF-EMR) and endoscopic submucosal dissection (ESD) were not prevalent during this time and hence may have affected the referral patterns for surgery. Most academic centers now have faculty that perform WF-EMR and as such many of these polyps maybe now be managed endoscopically. It would be interesting with the current study design to determine the percentage of patients with large polyps that are now referred for surgical resection as a function of time.

ESD could reduce over-surgery

Colorectal ESD was developed in Japan and is now widely accepted there as first-line treatment for early colorectal cancers, large laterally spreading tumors (LSTs), and adenomatous polyps not amenable to complete resection by polypectomy or EMR (1,2). However, there is limited practice of colorectal ESD in the West, because of the technical challenge of performing the procedure, and as a result colectomy is commonly performed for large colorectal LSTs although there is no need for lymph-node dissection.

Before the introduction of ESD at the National Cancer Center Hospital, Tokyo, Japan, approximately 20% of surgeries for colonic polyps had only intramucosal neoplasia, however after introduction of ESD this number has dramatically decreased to 1%, and thus "over-surgery" was largely avoided (3). As we conduct challenging ESD on massive LSTs or submucosal cancer (T1a or T1b), about 10% of all ESD cases result in non-curative resections (3), but these patients could easily go on to have surgery with lymph node dissection without additional harm. In this way, patients are given the best opportunity to avoid surgery, and maintain their quality of life. The authors reported that "*cancer was identified on the operative specimen in 37 patients (8.4%)*", the other 402 patients (91.6%) could have potentially avoided surgery if ESD was an available option.

Clinical impact of pathological diagnosis of cancer by biopsy

The diagnostic criteria of cancer on biopsy samples should be discussed in this paper. The authors reported that "*Of the 439 patients, 346 (79%) underwent preoperative colonoscopy in our institution for all polyps preoperative biopsy was benign.*" and "*All patients who had cancer in the final pathology had preoperative biopsies and results were as follows: tubular (n=6, 16.2%), tubulovillous (n=22, 59.5%), villous (n=8, 21.6%) and SSA/P (n=1, 2.7%). Preoperative HGD rate was found to be significantly higher in patients who had cancer in the final pathology compared to benign polyps [n=18 (48.0%) vs. n=70 (17.4%) P<0.001].*"

The consensus criteria for the pathologic diagnosis of intramucosal cancer in the West is only when dysplastic epithelial cells breach the basement membrane to invade the lamina propria or muscularis mucosae (MM); therefore, it might be difficult to diagnose a cancer by pre-operative biopsies.

In Japan, where there are consensus criteria for the pathologic diagnosis of intramucosal cancer without the invasion to lamina propria or MM, expert pathologists are able to diagnose intramucosal cancer on EMR, ESD and biopsy specimens. We believe it is important to establish the diagnosis of intramucosal cancer as we have had several cases of invasive and metastatic recurrence after piecemeal EMR of lesions with intramucosal cancer (4,5).

While small local adenomatous recurrences can easily be treated with follow up EMR, invasive and metastatic recurrences can have a much more devastating outcome (4). Due to these experiences, we no longer perform piecemeal EMR for LSTs-non-granular type >20 mm in diameter and LST-granular type >30 mm in diameter considering the risk of submucosal invasion and difficulty of predicting the area of SM invasion (6,7).

The differences of intramucosal cancer diagnosis between East and West, might help explain why the authors found that high grade dysplasia was associated with malignancy even if the endoscopic appearance of the polyp was benign. Within Japan many of these patient's biopsies might have been diagnosed with intramucosal cancer.

Clinical importance of endoscopic diagnosis using pit pattern

The authors reported "*An endoscopic diagnosis of a malignancy in a polyp is based on the appearance (irregular, ulcerated suggest cancer), feel (hard polyp suggests cancer), fragility (malignant polyps bleed easily) and fixity (a malignant polyp and surrounding colon wall move together).*" But "*None of the cancers in our series were like this. Preoperative biopsy may confirm or suggest cancer but did not here, reflecting an error rate of biopsies compared to examination of the entire lesion. Factors associated with malignancy among unresectable colonic polyps include left sided location, villous architecture, HGD, and advanced patient age. We found that polyp size and HGD were associated with malignancy. Our data establish the importance of high grade dysplasia as a clue that the polyp may be malignant even though it doesn't look it.*" In addition, 37.9% of patients believed to have a benign polyp endoscopically had stage IIa or higher colon cancer on resection.

In Japan, we routinely use magnified endoscopic evaluation to differentiate non-neoplastic from neoplastic lesions and estimate depth of invasion with a high degree of accuracy (8). While magnifying endoscopes are not commonly used in the West, near-focus systems are, that are able to deliver 50× magnification and similar results to optical zoom magnification (from 80× to 100×) may be obtained.

We do recommend, therefore, that use of pit pattern diagnosis with a near focus system be further explored and validated in the West. From our retrospective analysis, pit pattern diagnosis showed the highest accuracy and was an independent factor on multivariate analysis for estimation of early cancer depth of invasion (9).

Safety and QOL of ESD compared to surgery

The authors reported in this article that "*The complication rate after colorectal surgery was nearly 20% in our series*" and "*Many of these complications could be avoided by using advanced endoscopic techniques. Based on the results of the current study we pushed advanced endoscopic techniques for the management of benign polyps not amenable to conventional colonoscopic removal. The algorithm we follow for the different colorectal lesions are summarized in Figure 3.*"

We have published several papers comparing clinical results and patient's QOL between ESD and surgery including laparoscopic colectomy (LAC) (10,11). LAC showed lower QOL and increased post-procedure complications compared to ESD with similar clinical results (12). Accurate pre-operative diagnosis using pit pattern is essential for performing ESD technique for larger colorectal LSTs to ensure proper case selection (8,9). In addition, we do not perform any biopsies before endoscopic treatment because biopsies may cause fibrosis and that could cause non-lifting sign even for intramucosal neoplasm, and make subsequent resection more difficult. We believe that use of colonic pit pattern analysis (8,9) can help triage colonic polyps to the most appropriate treatment while avoiding the fibrosis that can be induced by endoscopic biopsies, and have adopted its use in all colonoscopies including screening.

Conclusions

In the West, patients with colonic polyps are not amenable to complete endoscopic resection with polypectomy or EMR traditionally undergo surgical resection. The article by Gorgun *et al.* suggests the majority of these lesions are benign and do not require lymph node dissection. Colorectal ESD would allow many of these patients to avoid the complications of surgery and maintain their quality of life, but due to the technical challenge of performing ESD there has been limited practice of ESD in the West. But that might be changing soon, there are now Western endoscopists who have been well trained in ESD under expert Japanese guidance that are performing ESD with high en-bloc resection and low complication rates, and we are optimistic they can move forward colorectal ESD in the West (12-15).

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Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

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Endoscopic versus surgical resection for early colorectal cancer—a systematic review and meta-analysis

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Background: To investigate the available data on the treatment of early colorectal cancer (CRC), either endoscopically or surgically.

Methods: Two independent reviewers searched MEDLINE, EMBASE, CENTRAL COCHRANE, LILACS and EBSCO for articles published up to August 2015. No language or dates filters were applied. Inclusion criteria were studies with published data about patients with early colonic or rectal cancer undergoing either endoscopic resection (i.e., mucosectomy or submucosal dissection) or surgical resection (i.e., open or laparoscopic). Extracted data items undergoing meta-analysis were en bloc resection rate, curative resection rate, and complications. A complementary analysis was performed on procedure time. The risk of bias among studies was evaluated with funnel-plot expressions, and sensitivity analyses were carried out whenever a high heterogeneity was found. The risk of bias within studies was assessed with the Newcastle score.

Results: A total of 12,819 articles were identified in the preliminary search. After applying inclusion and exclusion criteria, three cohort studies with a total of 768 patients undergoing endoscopic resection and 552 patients undergoing surgical resection were included. The en bloc resection rate risk difference was −11% [−13%, −8% confidence interval (CI)], demonstrating worse outcome results for the endoscopic resection group as compared to the surgical resection group [number need to harm (NNH) =10]. The curative resection rate risk difference was −9% [(−12%, 6% CI)] after a sensitivity analysis was performed, which also demonstrated worse outcomes in the intervention group (NNH =12). The complications rate exhibited a −7% risk difference [(−11%, −4% CI)], denoting a lesser number of complications in the endoscopic group [Number Need to Treat (NNT =15). A complementary analysis of procedure time with two of the selected studies demonstrated a mean difference of −118.32 min [(−127.77, −108.87 CI)], in favor of endoscopic resection, even though such data lacks homogeneity across studies, and could be heavily influenced by local expertise. Long-term results were found in only one study and therefore were not included in the final analysis.

Conclusions: According to the current available data, the treatment of early CRC by surgical resection is associated with higher curative resection rates and higher en bloc resection rates, despite of higher complications rates, as compared to endoscopic resection. Shorter procedure times are associated with the endoscopic methods of treatment, however high heterogeneity levels limit this conclusion.

Keywords: Colorectal neoplasms; sigmoid neoplasms; colonic neoplasms; colectomy; colonic surgery; hemicolectomy; sigmoidectomy; rectosigmoidectomy; endoscopic resection; endoscopic treatment; endoscopic submucosal dissection (ESD); endoscopy; endoscopic submucosal resection

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Introduction

Colorectal cancer (CRC) is the second most commonly diagnosed cancer in females and the third in males. A total of 1.2 million new cases and 608,700 deaths are estimated to have occurred in 2008 alone (1). Higher mortality rates are associated with more advanced disease progression (2). As CRC screening continues to gain importance as a prevention tool against advanced disease diagnosis, with direct impact on mortality (3), early disease detection rates rise. Early CRC is defined as invasive neoplasia that does not involve the colonic wall beyond the mucosal and submucosal layers (4) [T_{is} or T_1 according to current American Joint Committee on Cancer TNM classification (2)]. The risk of lymph node metastasis is low following neoplastic invasion of the mucosa, lamina propria, muscularis mucosa, and superficial submucosa of the colorectum, due to the regional absence of a rich lymph vascular network (2,4). Surgical resection has historically been recognized as the gold-standard treatment (either open or laparoscopic assisted), but less invasive techniques [i.e., trans anal endoscopic microsurgery (TEMS), endoscopic mucosectomy resection (EMR), or endoscopic submucosal dissection (ESD)] are emerging as important and safe treatment options (5-7). Nonetheless, there is little data available in the literature concerning the short and long-term outcomes of these new, less invasive treatments, as compared to traditional surgical outcomes. Local expertise of both endoscopic and surgical teams is mainly what determines treatment choice, and the results are often published in the literature with no comparison between techniques (5-7).

The aim of the present study is to acquire and analyze the available data regarding the short- and long-term results of EMR or ESD, when compared with the gold standard surgical (open or laparoscopic) treatment, for the treatment of patients diagnosed with early CRC.

Methods

Registration

This review is registered on PROSPERO international database (from University of York Centre for Reviews and dissemination—www.crd.york.ac.uk/prospero/) under number CRD42014015630.

Eligibility criteria and PICO (Patients, Intervention, Control, and Outcomes)

The search was directed towards comparative studies. No language or publication date filters were applied. The inclusion criteria were:

- Studies including patients with early CRC, defined via post-procedure pathological assessment as malignant adenocarcinoma invading up to the submucosa;
- Studies with the experimental intervention defined as purely endoscopic resections, either EMR or ESD (studies regarding TEMS procedures were not included);
- Studies with the control intervention being surgical treatment, either open or laparoscopic assisted;
- Studies with short and/or long-term results (curative resection rates, *en bloc* resection rates, procedure times, complications, long-term survival rates).

Abstracts or full texts with data that could not be retrieved were excluded, as well as those with available data that did not discriminate between patients with early or advanced CRC or between those in the control intervention group undergoing colorectal surgery or TEMS.

Data search

Two independent authors performed a systematic review of articles published up to August 2015 in any language, in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (8). The searched databases were MEDLINE, EMBASE, LILACS, CENTRAL COCHRANE, and EBSCO. Additional searches were performed on selected studies references, and used the MESH terms reported in the selected studies.

- The MEDLINE search strategy was {(colorectal neoplasms or sigmoid neoplasms or colonic neoplasms) and [(colectomy or colonic surgery or hemicolectomy or sigmoidectomy or rectosigmoidectomy) and (endoscopic resection or endoscopic treatment or ESD or endoscopy or endoscopic submucosal resection)]};
- EMBASE and other databases were searched using the terms 'Colon cancer' and 'surgery' and 'endoscopy'.

Study selection

The two reviewers independently assessed eligibility of all screened abstracts according to the inclusion and exclusion criteria discriminated above. Disagreements between the reviewers were resolved by consensus.

Data collection process and outcomes

Only published, available, and comparable data regarding the stated outcomes (i.e., short and long-term results of early CRC treatments) was extracted. The two reviewers independently extracted data directly from the results of each article. The following outcomes were included for data extraction:

- Primary outcomes:
  - *En bloc* resection: specimen resection and retrieval as a single fragment;
  - Curative (R0) resection: when resection margins were assessed as disease-free on pathological analysis of the surgical specimen, an R0 resection was achieved.
- Secondary outcomes:
  - Complications: all the included studies compared the frequency of complications in absolute numbers for each intervention group. The nature of these complications naturally differed between the two groups: endoscopic complications reported were perforation and post-esd bleeding; surgical complications reported were: wound infection, pelvic abscess, anastomosis leakage, anastomosis bleeding, ileus, peritonitis, diverting stoma, surgical wound dehiscence, surgical wound infection, subcutaneous hematoma, pneumonitis, cholecystitis, abdominal incisional hernia, hives, paroxysmal atrial fibrillation, and delirium;
  - Procedure time: mean duration of the procedures, expressed as means and standard deviations.

Risk of bias in individual studies

The risk of bias in individual studies was assessed using the Newcastle—Ottawa Quality Assessment Scale for Cohort Studies (9). The methods of individual studies were analyzed to search for other possible bias sources.

Summary measures

Individual patient data (expressed as absolute values) were collected for each outcome on each group (endoscopic or surgical treatment) so that the risk difference of that particular outcome between the two groups could be calculated for comparison. 95% confidence intervals (95% CIs) for statistical significance were expressed. NNT and number need to harm (NNH) values were also expressed, whenever statistically significant. Continuous variables had to be stated as means and standard deviations in order to be included in the final analysis. Forest plot graphical expressions were used to demonstrate the relation between sample size and effect size.

Planned methods of analysis

The analysis was performed using the software Review Manager (RevMan) 5.3. (10), obtained from the website Cochrane Informatics & Knowledge Management Department. Risk differences of dichotomous variables were calculated using a fixed effects model, resulting in forest and funnel plots. Mantel-Haenszel tests were employed to calculate a 95% CI for each outcome risk difference; a value of p below 0.05 (95% CI) was considered statistically significant. Consistency levels across studies were obtained and reported in chi-squared (Chi^2) and in I^2. Based on the Higgins concept (11), a value of I^2 above 50% was considered excessively non-homogeneous.

Risk of bias across studies

Funnel plot graphical expressions were chosen to search and identify publication bias.

Additional analyses

As stated by Higgins, categorization of values for I^2 as low (i.e., 25%), moderate (i.e., 50%) or high (i.e., 75%) is not appropriate for all circumstances (11); however, homogeneity strengthens the results obtained in any meta-analysis, therefore a cut-off value of 50% was determined suitable in our analysis. A sensitivity analysis and subsequent assay was performed over every outcome analysis considered of high heterogeneity (I^2>50%), after exclusions of outliers detected on funnel plot expressions; that assay generated new forest and funnel plots. When no outliers could be found, the hypothesis was that true heterogeneity had occurred.

Results

Study selection

A total of 11,637 records were identified through the MEDLINE search and 12,819 records were identified through EMBASE and other databases searching. After applying inclusion criteria and removing duplicates, nine records were found. Four (12-15) were excluded since they were abstract-only records and had no extractable data. Of the five full-text articles assessed for eligibility, two were

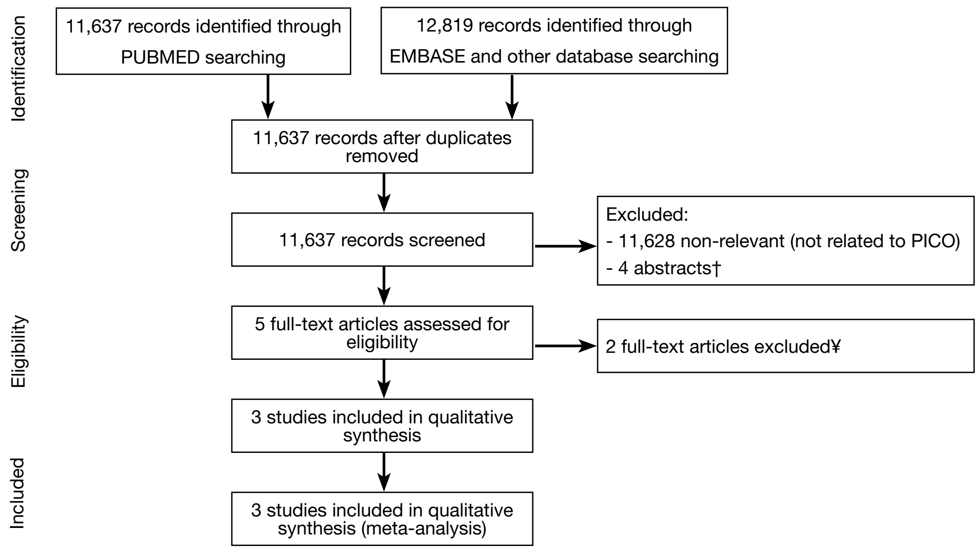


Figure 1 Studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage. †, references (12-15); ¥, reference (16)—compares ESD and TEMS, not surgical resection, reference (17)—impossible to perform separate analysis on early colorectal cancer alone. PICO, Patients, Intervention, Control, and Outcomes; ESD, endoscopic submucosal dissection; TEMS, trans anal endoscopic microsurgery.

excluded. One compared ESD and TEMS and not surgical resection (16), and one did not allow for separate analysis on patients with early-only CRC (17). Three studies were included in the final qualitative analysis and meta-analysis (*Figure 1*).

Study characteristics

No randomized studies were found within the screened records. All three studies were either prospective or retrospective cohorts, and all three were published in English. Across all three studies, 768 subjects in the experimental intervention (i.e., endoscopic resection) and 552 on the control or comparison group (i.e., surgical resection) were included. Patients with early-only colorectal neoplasia were included in each group. Experimental intervention was either ESD and EMR, or ESD alone. Control intervention was either laparoscopic and open surgery, or laparoscopic surgery alone. The primary outcomes assessed were *en bloc* resection and curative resection. The Kiriyama study also published 3-year survival data, and was the only one to publish long term follow-up data. The secondary outcomes were procedure duration, hospitalization duration, and complications. Two of the studies also recorded the time needed before dietary intake was restored. Studies characteristics are summarized (see *Table 1*).

Risk of bias within studies

Using the inclusion criteria mentioned above, all three studies scored at least a six on the Newcastle-Ottawa Quality Assessment Scale for Cohort Studies (8). However, when the methods of each study were analyzed, other possible sources of bias were identified, regarding the comparability between the interventional and control groups. In the Kiriyama (18) study and the Nakamura (20) study, whenever deeper, submucosal invasion was suspected on magnified narrow band imaging (NBI) examination, the patient was referred to surgical intervention; when deeper invasion signs were not found, the patient underwent endoscopic resection. Additionally, lesion location and median size in the experimental and control groups varied across studies (*Tables 2,3*).

Results of individual studies

Below we list the characteristics and the available data of the included studies. The number of patients on each group, the age of the patients, the location of the neoplasia (i.e., colonic or rectal), and lesion size were the data available concerning the characteristics of the populations. *En bloc* resection, curative resection, procedure time, resection time, fasting time, and complications were the outcomes reported on all studies; however, the only comparable outcomes throughout all three studies were

Table 1 Characteristics of studies included in meta-analysis

Studies	Patients	Experimental	Control	Outcomes
Kyriyama *et al.* 2012 (18) (Cohort, retrospective)	297 patients with colorectal intramucosal or slightly submucosal invasive cancers, undergoing ESD 292 patients with T1 colorectal cancers undergoing LAP	ESD	Lap	Curative resection, *en bloc* resection, survival, procedure time, hospitalization time, fasting time, complications
Heo *et al.* 2014 (19) (Cohort, retrospective)	168 lesions with mucosal/superficial submucosal invasion were treated by endoscopic resection 70 lesions with mucosal/superficial submucosal invasion were treated by colorectal surgery	ESD or EMR	Open surgery	Curative resection, *en bloc* resection, procedure time, hospitalization time, complications
Nakamura *et al.* 2014 (20) (Cohort, prospective)	300 patients with colorectal intramucosal or slightly submucosal invasive cancers, undergoing ESD 190 patients with T1 colorectal cancers undergoing LAP	ESD	Lap	Curative resection, *en bloc* resection, procedure time, hospitalization time, fasting time, complications

ESD, endoscopic submucosal resection; EMR, endoscopic mucosectomy; Lap, laparoscopic assisted colectomy.

Table 2 Available data

Studies	Bias within studies	Newcastle score
Kiriyama *et al.* 2012 (18)	Retrospective, possible differences in patient selection for each group	6
Heo *et al.* 2014 (19)	Retrospective	7
Nakamura *et al.* 2014 (20)	Non-randomized prospective cohort; possible differences in patient selection for each group	6

Individual Newcastle scale scores and indicators of bias within studies; a Newcastle score equal or above 6 is considered adequate for cohort studies.

en bloc resection, curative resection, and complications. Procedure time was the only continuous outcome variable expressed in mean and standard deviation in two of the selected studies [Kiriyama *et al.* (18) and Heo *et al.* (19)]. Survival and follow-up data were only published in one article, Kiriyama *et al.* (18) (*Tables 3,4*).

Note about survival rate: no mortality data was available for comparison across studies (only the Kiriyama study reported 3-year mortality rate); therefore, long-term results assessment was not possible.

Synthesis of results

The following figures represent the estimates for risk difference, based on calculated CIs, for each outcome. Risk of bias across studies and additional analysis are also reported.

(I) *En bloc* resection rate: a risk difference of −0.11 (−0.13, −0.08 95% CI, P<0.00001) was observed, favoring the surgical group, with an acceptable heterogeneity of 44% expressed by the I^2 (*Figures 2,3*);

(II) Curative resection rate: a risk difference of −0.14 (−0.17, −0.11 95% CI, P<0.0001) was observed, favoring the surgical group, with a high heterogeneity level of 89% expressed by the I^2 (*Figure 4*).

An additional sensitivity analysis was performed after identification and exclusion of one outlier (*Figure 5*—Kiryiama *et al.*); a more homogeneous result was then obtained. The adjusted risk difference for curative resection was −0.09 (−0.12, −0.06 95% CI, P<0.00001), with an I^2= 0%, favoring the surgical group (*Figures 6,7*).

(I) Complications: a risk difference of −0.07 (−0.11, −0.04 95% CI, P<0.0001) favoring the endoscopic group was observed, with an heterogeneity of 0% expressed by the I^2 (*Figures 8,9*);

Table 3 Data extracted for comparison

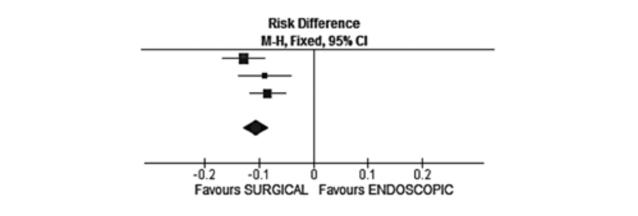
Studies	*En bloc* resection (%)		Curative resection (%)		3-year survival (%)		Procedure time [min]		Hospital stay time [days]		Fasting time [days]		Complications (%)	
	E	C	E	C	E	C	E	C	E	C	E	C	E	C
Kiriyama *et al.* 2012 (18)	87.2	100	80.4	100	99.2	99.5	106±77	206 ±62	4 [1–13]	13 [7–30]	2 [0–9]	5 [2–8]	6.39	13.69
Heo *et al.* 2014 (19)	91.1	100	91.1	100	–	–	34.7±16.1	196.1±73.1	2 [2–29]	10 [7–37]	–	–	5.4	5.7
Nakamura *et al.* 2014 (20)	91.7	100	91.0	100	–	–	90 [15–540]	185 [48–449]	5 [4–17]	10 [6–41]	2 [1–16]	3 [1–21]	7	14.7

Extracted data. E, experimental (endoscopic resection); C, control (surgery).

Table 4 Populations characteristics

Studies	Age		Location			Size, mm	
	E	C		E	C	E	C
Kiriyama *et al.* 2012 (18)	65±10	62±10	Co	185	243	37±19	20±12
			Re	112	49		
Heo *et al.* 2014 (19)	62±10	63±9.5	Co	125	42	19.8±121	26.1±13.4
			Re	43	28		
Nakamura *et al.* 2014 (20)	68 [36–98]	65 [20–86]	Co	83	33	30 [8–110]	20 [8–150]

E, experimental group (endoscopic resection); C, control group (surgery); Co, colon; Re, rectum.



Study or Subgroup	ENDOSCOPIC RESECTION Events	ENDOSCOPIC RESECTION Total	COLORECTAL SURGERY Events	COLORECTAL SURGERY Total	Weight	Risk Difference M-H, Fixed, 95% CI	Year
KIRYIAMA 2012	259	297	292	292	47.0%	-0.13 [-0.17, -0.09]	2012
HEO 2014	153	168	70	70	15.8%	-0.09 [-0.14, -0.04]	2014
NAKAMURA 2014	275	300	190	190	37.2%	-0.08 [-0.12, -0.05]	2014
Total (95% CI)		**765**		**552**	**100.0%**	**-0.11 [-0.13, -0.08]**	
Total events	687		552				

Heterogeneity: $Chi^2 = 3.55$, df = 2 (P = 0.17); $I^2 = 44\%$
Test for overall effect: Z = 8.95 (P < 0.00001)

Figure 2 *En bloc* resection rate—sample size and weight.

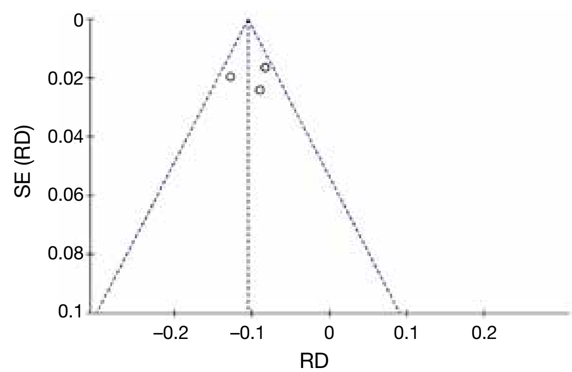


Figure 3 *En bloc* resection rate—distribution of studies. SE, standard error; RD, risk difference.

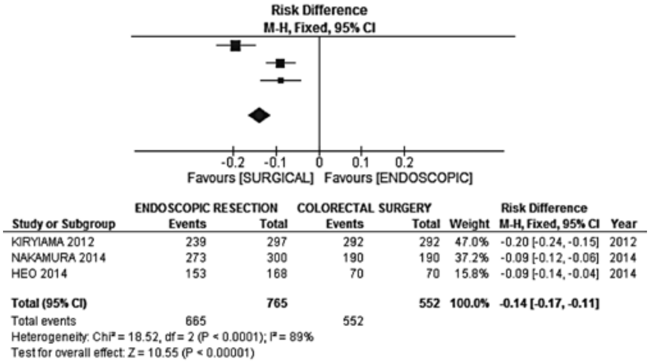
(II) Procedure time: an analysis of the two studies that reported comparable information on procedure time (i.e., measured in minutes) was performed. A mean difference of −118.32 min (−127.77, −108.87 95% CI) was observed (*Figure 10*), the longer mean procedure time being found in the surgical group. However, that result was accompanied by true high heterogeneity (I^2=97%) across the two studies (*Figure 11*).

Discussion

Summary of evidence

Interpretations of the above findings are listed below.

(I) *En bloc* resection: a statistically significant difference was observed in the analysis [risk difference of −0.11 (−0.13, −0.08 CI), P<0.00001], favoring the surgical group, with an acceptable level of



Study or Subgroup	ENDOSCOPIC RESECTION Events	Total	COLORECTAL SURGERY Events	Total	Weight	Risk Difference M-H, Fixed, 95% CI	Year
KIRYIAMA 2012	239	297	292	292	47.0%	-0.20 [-0.24, -0.15]	2012
NAKAMURA 2014	273	300	190	190	37.2%	-0.09 [-0.12, -0.06]	2014
HEO 2014	153	168	70	70	15.8%	-0.09 [-0.14, -0.04]	2014
Total (95% CI)		**765**		**552**	**100.0%**	**-0.14 [-0.17, -0.11]**	
Total events	665		552				

Heterogeneity: Chi² = 18.52, df = 2 (P < 0.0001); I² = 89%
Test for overall effect: Z = 10.55 (P < 0.00001)

Figure 4 Curative resection rate—sample size and weight.

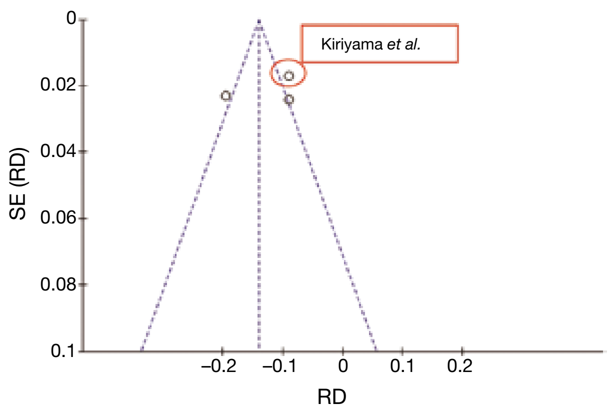
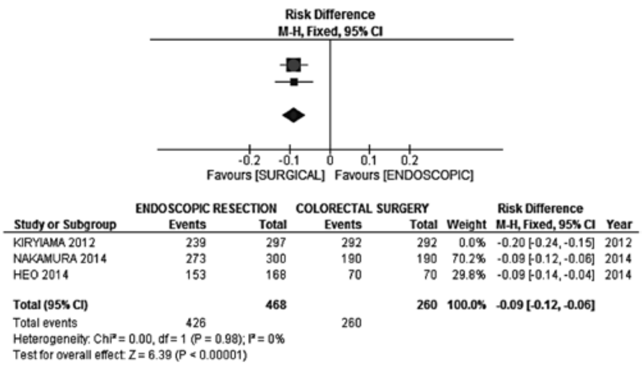


Figure 5 Identification of an outlier in the funnel-plot graphic. SE, standard error; RD, risk difference.



Study or Subgroup	ENDOSCOPIC RESECTION Events	Total	COLORECTAL SURGERY Events	Total	Weight	Risk Difference M-H, Fixed, 95% CI	Year
KIRYIAMA 2012	239	297	292	292	0.0%	-0.20 [-0.24, -0.15]	2012
NAKAMURA 2014	273	300	190	190	70.2%	-0.09 [-0.12, -0.06]	2014
HEO 2014	153	168	70	70	29.8%	-0.09 [-0.14, -0.04]	2014
Total (95% CI)		**468**		**260**	**100.0%**	**-0.09 [-0.12, -0.06]**	
Total events	426		260				

Heterogeneity: Chi² = 0.00, df = 1 (P = 0.98); I² = 0%
Test for overall effect: Z = 6.39 (P < 0.00001)

Figure 6 Curative resection rate—sample size and weight after removal of outlier.

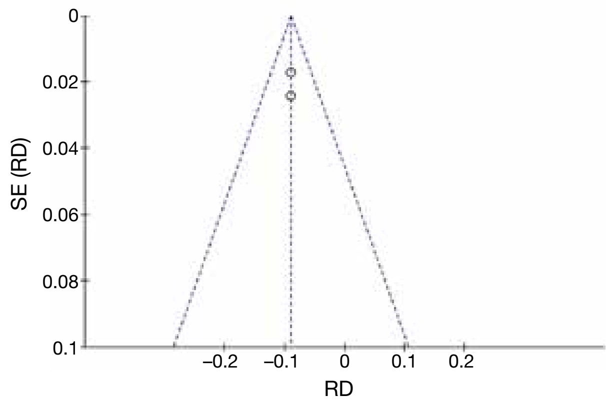
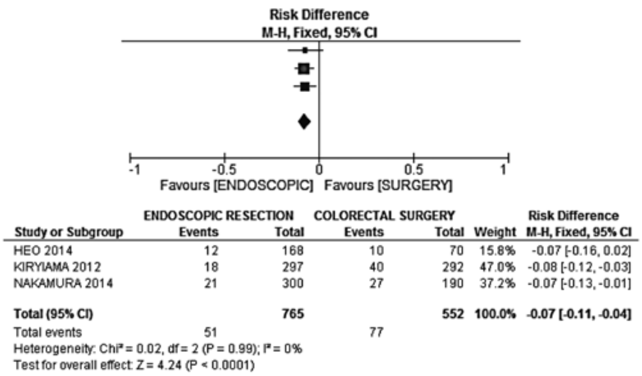


Figure 7 Curative resection rate—distribution after removal of outlier. SE, standard error; RD, risk difference.



Study or Subgroup	ENDOSCOPIC RESECTION Events	Total	COLORECTAL SURGERY Events	Total	Weight	Risk Difference M-H, Fixed, 95% CI
HEO 2014	12	168	10	70	15.8%	-0.07 [-0.16, 0.02]
KIRYIAMA 2012	18	297	40	292	47.0%	-0.08 [-0.12, -0.03]
NAKAMURA 2014	21	300	27	190	37.2%	-0.07 [-0.13, -0.01]
Total (95% CI)		**765**		**552**	**100.0%**	**-0.07 [-0.11, -0.04]**
Total events	51		77			

Heterogeneity: Chi² = 0.02, df = 2 (P = 0.99); I² = 0%
Test for overall effect: Z = 4.24 (P < 0.0001)

Figure 8 Complications—sample size and weight.

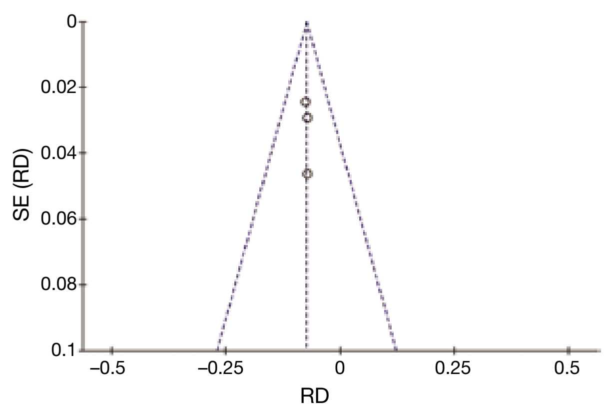
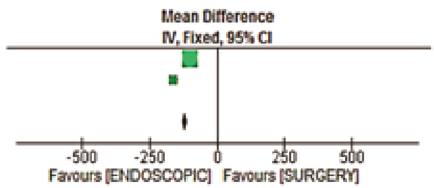


Figure 9 Complications—distribution of studies. SE, standard error; RD, risk difference.



Study or Subgroup	ENDOSCOPIC Mean	SD	Total	SURGERY Mean	SD	Total	Weight	Mean Difference IV, Fixed, 95% CI	Year
KIRYIAMA 2012	106	77	297	206	62	292	70.2%	-100.00 [-111.28, -88.72]	2012
HEO 2014	34.7	16.1	168	196.1	73.1	70	29.8%	-161.40 [-178.70, -144.10]	2014
Total (95% CI)			465			362	100.0%	-118.32 [-127.77, -108.87]	

Heterogeneity: Chi² = 33.96, df = 1 (P < 0.00001); I² = 97%
Test for overall effect: Z = 24.54 (P < 0.00001)

Figure 10 Procedure time—sample size and weight.

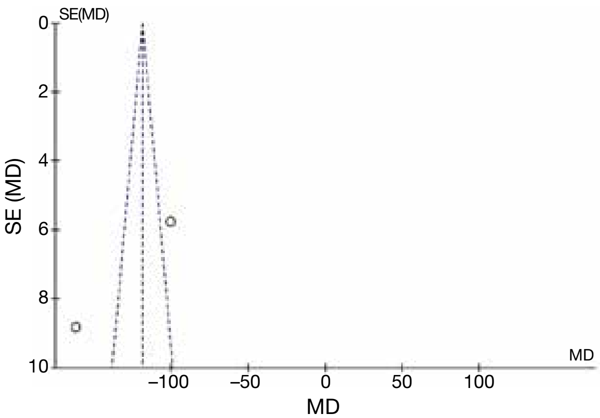


Figure 11 Procedure time—distribution of studies. SE, standard error; MD, mean difference.

heterogeneity across studies. The NNH calculated is 10 (interpretation: after every 10 endoscopic resections of early CRC, one piece-meal resection is performed, when compared with surgical resection).

(II) Curative (R0) resection: after a sensitivity analysis was performed due to high heterogeneity, a statistically significant difference favoring the surgical group was observed [risk difference of −0.09 (−0.12, −0.06 CI), P<0.00001], with a level of heterogeneity across studies equal to 0%. The NNH calculated is 12 (interpretation: after every 12 endoscopic resections of early CRC, one incomplete resection (e.g., R1) is performed, when compared with surgical resection).

(III) Complications: a statistically significant difference, favoring the endoscopic group, was observed in the analysis [risk difference of −0.07 (−0.11, −0.04 CI)], with a level of heterogeneity across studies equal or below 0%. The NNT calculated is 15 (interpretation: after every 15 endoscopic resections of early CRC, one complication is avoided, when compared with surgical resection).

(IV) Procedure time: a statistically significant difference was observed in the complementary analysis for procedure time (mean difference of −118.32 minutes (−127.77, −108.87 95% CI, P<0.00001). However, this information should be carefully analyzed, since the heterogeneity across the two studies included is very high (I^2=97%). Using a cut-off target value of 60 minutes, the interpretation of the NNT associated with this mean difference is that for every two endoscopically treated patients, 60 minutes can be spared, as compared with the surgical treatment.

This is the first meta-analysis that summarizes all the data available to compare endoscopic and surgical treatment of early CRC. Although only three studies met our inclusion criteria, the pooled number of patients (768 patients undergoing endoscopic resection and 552 patients undergoing surgical resection) is significant. Considering individual study results, all three studies obtained similar, statistically significant data results concerning *en bloc* resection, curative resection, and complications, as observed after a careful systematic review. The meta-analysis depicted in this study reinforces some of these findings, and provides solid ground for future developments of larger scale, better designed studies, such as multicenter randomized controlled trials.

Limitations

Our review included three non randomized studies, which could further impair the quality of the data reported. The endoscopic techniques employed for treatment of early CRC are extremely advanced and operator-dependent; and the three studies are from two Asian centers whose good results and great expertise may influence the procedure time results. Differences in the intervention and control populations present as a possible confounding source in all three included studies: lesion location and size differ among the intervention and control groups, and in two of them (Nakamura *et al.* and Kiriyama *et al.*), preoperative invasion depth dictated the choice between surgical or endoscopic approaches.

Long-term results are available in one study, thus neither individual analysis nor analytical comparisons are feasible.

As explained previously, the choice of treatment in two of the studies (Kiriyama *et al.* and Nakamura *et al.*) depended on whether or not more advanced disease was suspected; therefore, long-term results between the intervention and control groups might suffer from this bias of allocation, as more advanced disease results in higher probability of neoplastic dissemination (2,3).

The analysis performed on complications is a difficult one, considering the different morbidity of surgical and endoscopic complications. Nonetheless, endoscopy displayed a lower frequency of complications, which should be understood as an underestimated result—perhaps an analysis of the hospitalization time would be of more use, if there was available data for comparison.

Conclusions

According to the current available data, the treatment of early CRC by surgical resection is associated with higher curative resection rates, higher *en bloc* resection rates, despite of higher complications rates, as compared to endoscopic resection. Shorter procedure times are associated with the endoscopic methods of treatment, however high heterogeneity levels limit this conclusion.

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None.

Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

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Incomplete resection after macroscopic radical endoscopic resection of T1 colorectal cancer—should a paradigm-changing approach to address the risk be considered?

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Comment on: Backes Y, de Vos Tot Nederveen Cappel WH, van Bergeijk J, *et al.* Risk for incomplete resection after macroscopic radical endoscopic resection of T1 colorectal cancer: a multicenter cohort study. Am J Gastroenterol 2017;112:785-96.

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Compared with laparoscopic resection, endoscopic resection was found to be cost-effective in the management of complex colon polyps. The effectiveness was due to superior technical success and reduced adverse event rates associated of endoscopic resection, and to the higher cost of laparoscopic resection (1). The economic analysis could explain why endoscopic interventions such as endoscopic mucosal resection and endoscopic submucosal dissection have gained popularity and are being increasingly incorporated into the management of T1 colorectal cancer (CRC). T1 CRC is one that has grown through the muscularis mucosa and extends into the submucosa (2).

In the 2010 guidelines for the treatment of CRC from the Japanese Society for Cancer of the Colon and Rectum (JSCCR), the criteria for identifying curable T1 CRC after endoscopic resection included well/moderately differentiated or papillary histologic grade, no vascular invasion, submucosal invasion depth <1,000 µm and budding grade 1 (low grade). In one report aimed to expand these criteria, 499 T1 CRC, resected endoscopically or surgically, were analyzed. Lymph node metastasis was found in 41 (8.2%). The incidence of lymph node metastasis was significantly higher in lesions with poorly differentiated/mucinous adenocarcinoma, submucosal invasion ≥1,800 µm, vascular invasion, and high-grade tumor budding. Multivariate logistic regression analysis revealed these variables to be independent risk factors for lymph node metastasis. When cases that met three of the JSCCR 2010 criteria (i.e., all but invasion <1,000 µm) were considered together, the incidence of lymph node metastasis was only 1.2% (3/249, 95% CI: 0.25–3.48%), and there were no cases of lymph node metastasis without submucosal invasion to a depth of ≥1,800 µm. The investigators concluded that even in cases of CRC with deep submucosal invasion, the risk of lymph node metastasis is minimal under certain conditions. Thus, even for such cases, endoscopic incisional biopsy could be suitable if complete *en bloc* resection was achieved (3).

The risk of lymph node metastasis appears to be dependent on the characteristics of the T1 CRC. In one study 435 patients with T1 CRC were treated by surgical or endoscopic resection. In the surgically resected group (n=324), lymph node metastasis was detected in 42 patients (13.0%). Grade 3, angiolymphatic invasion, budding, and the absence of background adenoma were factors associated with lymph node metastasis in univariate and multivariate analyses (P<0.05). In the endoscopically resected group (n=111), three of 50 patients with high risk were diagnosed with lymph node metastasis during the follow-up period. There was no lymph node metastasis in the endoscopically resected group with low risk (4). Thus, lymph node metastasis is dependent on the T1 CRC and not on the

Table 1 Characteristics of a cohort of "non endoscopically curable" T1 colorectal cancer (total No. of T1 CRC =882)

Variables	Non-curable (endoscopic)	Endoscopic resection alone	Additional surgery after endoscopic resection	Surgical resection alone
No. of patients	701	121	238	342
Recurrence (%)	0.6	5.0	5.5	3.8
5-year survival (%)	91.1	98.1	97.9	98.5
Local recurrence or distant/lymph node metastasis (n)	32	6	13	13
Died of primary CRC (n)	14	3	7	4

CRC, colorectal cancer.

mode (endoscopic or surgical) of treatment. On the basis of another retrospective study of patients who underwent endoscopic resection for T1 CRC, those with tumors with only submucosal invasion were at low risk for cancer recurrence. However, patients with high-risk tumor features have greater risks for cancer recurrence and benefit from subsequent surgery (5).

A recent Japanese report examined T1 CRC patients treated during 1992–2008 and who had ≥5 years of follow-up (6). Patients who did not meet the curative criteria after endoscopic resection according to the JSCCR guidelines were defined as "non-endoscopically curable" and classified into three groups: endoscopic resection alone, additional surgery after endoscopic resection, and surgical resection alone. *Table 1* summarizes the findings. Age ≥65 years, protruded gross type, positive lymphatic invasion, and high budding grade were significant predictors of recurrence in these patients. The authors maintained that the findings supported the JSCCR criteria for endoscopically curable T1 CRC. Endoscopic resection for T1 CRC did not worsen the clinical outcomes of patients who required additional surgical resection.

To address the controversy over the optimal management for T1 CRC, another study (7) compared initial endoscopic resection with or without additional surgery, or initial surgery for T1 CRC, and assessed risk factors for lymph node metastases and long-term recurrence. This was a registration study of patients diagnosed with T1 CRC from 1995–2011 in the southeast area of The Netherlands (n=1,315). High-risk histology was defined as the presence of poor differentiation, lymphangio-invasion, and/or deep submucosal invasion. Findings are shown in *Table 2*. Endoscopic resection was performed in 590 patients (44.9%); of these, 220 (16.7%) underwent additional surgery. Initial surgery was performed in 725 patients (55.1%). The risk of lymph node metastases was higher in T1 CRC with histologic risk factors (15.5% *vs.* 7.1% without histologic risk factors; odds ratio, 2.21; 95% CI: 1.33–3.70). The only independent risk factor for long-term recurrence was a positive resection margin (hazard ratio, 6.88; 95% CI: 2.27–20.87). Based on the population analysis, the investigators concluded that additional surgery after endoscopic resection should be considered only for patients with high-risk histology or a positive resection margin.

Patients with T1 CRC had a distinctly higher incidence of local recurrence after endoscopic resection or local resection. Explicit workup in terms of risk classification is crucial to reducing the risk of local and systemic recurrence. A non-radical approach should be only a second option for patients with T1 CRC, namely, those solely in clearly low-risk situations or those with distinct co-morbidities (8). Local resection may be effective and oncologically safe in low-risk T1 CRC. Although additional surgery should be recommended for the locally resected high-risk T1 CRC cases, intensive surveillance without additional surgery and timely salvage operation may offer another treatment option, if vascular invasion is negative (9). Data in another report did not support an increased risk of lymph node metastasis or recurrence after secondary surgery compared with primary surgery. Therefore, an attempt for an *en bloc* resection of a possible T1 CRC without evident signs of deep invasion seems justified in order to prevent surgery of low-risk T1 CRC in a significant proportion of patients (10).

With this backdrop, a recent retrospective report from the Dutch T1 CRC Working Group published in the American Journal of Gastroenterology continued to describe promising results of macroscopic radical

Table 2 Recurrence and thirty-day mortality in patients receiving endoscopic or surgical resection (total No. of T1 CRC =1,315)

Variables	Endoscopic resection	Endoscopic resection alone	Additional surgery after endoscopic resection	Surgical resection alone
No. of patients	590	370	220	725
Recurrence (%)		6.2	6.4	3.4
Thirty-day mortality (%)		1.4	0.9	

CRC, colorectal cancer.

endoscopic resection of T1 CRC (11). Data from patients treated between 2000 and 2014 with macroscopic complete endoscopic resection of T1 CRC were collected from 13 hospitals in the Netherlands. Incomplete resection was defined as local recurrence at the polypectomy site during follow-up, or malignant tissue in the surgically resected specimen when secondary surgery was performed. A total of 877 patients with a median follow-up time of 36.5 months (interquartile range, 16.0–68.3) were included, in whom secondary surgery was performed in 358 patients (40.8%). Incomplete resection was observed in 30 patients (3.4%; 95% CI: 2.3–4.6%). Incomplete resection rate was 0.7% (95% CI: 0–2.1%) in low-risk T1 CRC *vs.* 4.4% (95% CI: 2.7–6.5%) in high-risk T1 CRC (P=0.04). Overall adverse outcome rate (incomplete resection or metastasis) was 2.1% (95% CI: 0–5.0%) in low-risk T1 CRC *vs.* 11.7% (95% CI: 8.8–14.6%) in high-risk T1 CRC (P=0.001). Piecemeal resection (adjusted odds ratio, 2.60; 95% CI: 1.20–5.61, P=0.02) and non-pedunculated morphology (adjusted odds ratio 2.18; 95% CI: 1.01–4.70, P=0.05) were independent risk factors for incomplete resection. Among patients in whom no additional surgery was performed, 41.7% (95% CI: 20.8–62.5%) died as a result of recurrent cancer. The authors concluded that in the absence of histological high-risk factors, a 'wait-and-see' policy with limited follow-up is justified. Piecemeal resection and non-pedunculated morphology are independent risk factors for incomplete endoscopic resection of T1 CRC.

An editorial in *Translational Gastroenterology and Hepatology* commented extensively on an earlier phase of this work (10). The editorial concluded evolving innovative methods and new devices may change traditional paradigms to allow minimally invasive intervention for CRC in the future (12).

Underwater resection is one such paradigm-changing approach. Traditional endoscopic mucosal resection or endoscopic submucosal dissection are performed in a gas (air or carbon dioxide) filled colonic lumen. Underwater resection has evolved from two different modes of water use during colonoscopy. In one mode, water exchange was used by investigators to minimize insertion pain. A difficult to capture pedunculated polyp due to spasms in the sigmoid colon was encountered. Water infusion distention provided sufficient space around the polyp for its successful capture by snare, polypectomy and retrieval (13). The underwater resection approach has been extended safely to other pedunculated and non-pedunculated polyps (14) and for salvage resection (15). The ongoing practice of underwater polypectomy by colonoscopists in multiple countries confirm the feasibility and acceptability of the novel approach (16). In another mode, investigators filled the colonic lumen with water for endoscopic ultrasound assessment of colonic lesions. The following salient observations were made. The ultrasound images have shown that the colonic wall retains its native thickness of 3–4 mm, the muscularis propria retains a circular configuration and does not follow the involutions of the mucosa and submucosa. This configuration is maintained even during peristaltic contractions. On both ultrasound and endoscopic viewing the mucosa and submucosa appear to "float" away from the deeper muscularis propria. This is mainly an effect of the gravity-free environment of water (Binmoeller). In one report of underwater endoscopic mucosal resection without submucosal injection, 60 patients with 62 large sessile colorectal polyps were described. The mean/median polyp size was 34/30 mm, and the mean/median resection time was 21/18 minutes. Histology revealed tubular adenoma (n=22), tubulovillous adenoma (n=19), villous adenoma (n=4), serrated adenoma (n=11), and high-grade dysplasia/carcinoma *in situ* (n=6). The mean/median interval until a follow-up colonoscopy in 54 patients (90%) was 20.4/15.2 weeks. One of 54 patients (2%) had an adenoma smaller than 5 mm outside of the post-resection scar, consistent with a residual lesion missed on index underwater endoscopic mucosal resection. The technique was safe, and the early recurrence rate appeared low (17). Others described underwater endoscopic mucosal resection as easy to implement (18,19), and the third way for *en bloc* resection of colonic lesions (20). To date, only two cases of perforation following underwater endoscopic mucosal resection have been reported (21,22).

In a more recent report, 289 colorectal polyps were removed by a single endoscopist from 7/2007 to 2/2015 using endoscopic mucosal resection (in air-fill lumen) or underwater endoscopic mucosal resection. In total, 135 polyps (endoscopic mucosal resection: 62, underwater endoscopic mucosal resection: 73) that measured ≥15 mm and had not undergone prior attempted polypectomy were evaluated for rates of complete macroscopic resection and adverse events. And, 101 of these polyps (endoscopic mucosal resection: 46, underwater endoscopic mucosal resection: 55) had at least one follow-up colonoscopy and were studied for rates of recurrence and the number of procedures required to achieve curative resection. The rate of complete macroscopic resection was higher following underwater endoscopic mucosal resection compared to endoscopic mucosal resection (98.6% *vs.* 87.1%, P=0.012). Underwater endoscopic mucosal resection had a lower recurrence rate at the first follow-up colonoscopy compared to endoscopic mucosal resection (7.3% *vs.* 28.3%, OR 5.0 for post-endoscopic mucosal resection recurrence, 95% CI: 1.5–16.5, P=0.008). Underwater endoscopic mucosal resection required fewer procedures to reach curative resection than endoscopic mucosal resection (mean of 1.0 *vs.* 1.3, P=0.002). There was no significant difference in rates of adverse events. Underwater endoscopic mucosal resection appears superior to endoscopic mucosal resection for the removal of large colorectal polyps in terms of rates of complete macroscopic resection and recurrent (or residual) abnormal tissue. Compared to conventional endoscopic mucosal resection, underwater endoscopic mucosal resection may offer increased procedural effectiveness without compromising safety in the removal of large colorectal polyps without prior attempted resection (23).

The impact of underwater resection on completeness of resection and recurrence of T1 CRC is not known. Studies of underwater resection employing complete resection rate as the primary outcome and recurrence rate as secondary outcome deserve to be performed.

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Footnote

Conflicts of Interest: The author has no conflicts of interest to declare.

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Rectal cancer—state of art of laparoscopic versus open surgery

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Abstract: Since its introduction, laparoscopy has gained more and more consent in colorectal surgery, even if its role in rectal cancer surgery is still controversial and widely debated. The aim of this study is to present the ongoing situation of laparoscopic surgery for rectal cancer by a review of current literature. We performed a systematic search in the electronic databases (PubMed, Web of Science, Scopus, EMBASE) according to preferred reporting items for systematic reviews and meta-analyses (PRISMA) guidelines. We limited the search until 31 March 2017 and used the following search terms in all possible combinations: rectal cancer, laparoscopy, minimally invasive and open surgery. A total of 66 articles were include in this review, of which 38 were non-randomized trials, 8 were randomized controlled trials (RCTs) performed in a single center, 5 were multicentric RCTs and 15 were meta-analyses. Laparoscopic approach resulted in a faster and better recovery after surgery and has been proven to be equivalent in terms of short-terms outcomes comparing to the open approach. Nevertheless, the findings concerning oncologic safety of minimally invasive approach are still controversial. This should give the rationale to perform new meta-analyses based on the last evidences produced. Moreover, even more multicentric RCTs studies, hypothetically designed on new pathological outcomes, should be performed to finally assess if laparoscopy is a valid choice for the treatment of rectal cancer.

Keywords: Rectal; cancer; laparoscopy; open surgery; review

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Introduction

Since its introduction, laparoscopy has gained more and more consent in colorectal surgery, becoming the Gold Standard for the surgical treatment of colon cancer (1). On the contrary, its role in rectal cancer surgery is still controversial and widely debated. In fact rectal cancer surgery results more technically difficult than the colonic one, due to the narrow space of the pelvis, which gets laparoscopic surgery particularly challenging. For this reason laparoscopic rectal surgery gets performed only in specialized centers worldwide.

In the last decade accumulating evidence has demonstrated that recovery after laparoscopy is faster and better, moreover laparoscopic rectal resection has been proven equivalent to the traditional technique in terms of short-terms outcomes. Nevertheless, its oncologic safety remains unclear and doubts about pathologic outcomes are still open and worsened by new evidence reported by the most recent international studies. With this study we aim to present the ongoing situation of laparoscopic treatment for rectal cancer by reviewing the current literature.

Materials and methods

To identify all possible studies regarding the comparison between laparoscopic and open rectal resection for rectal cancer and to make the state of art of laparoscopic rectal

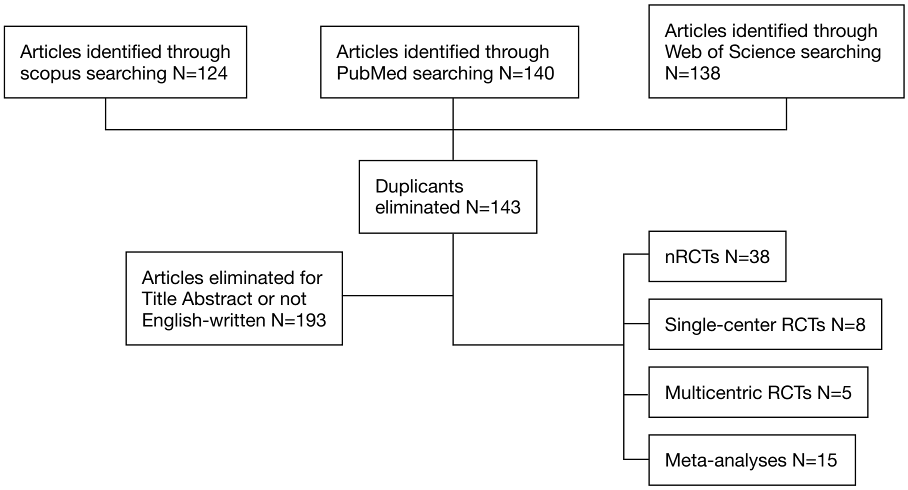

Figure 1 Studies' exclusion according to PRISMA. PRISMA, preferred reporting items for systematic reviews and meta-analyses.

resection, we performed a systematic search in the electronic databases (PubMed, Web of Science, Scopus, EMBASE) according to preferred reporting items for systematic reviews and meta-analyses (PRISMA) guidelines (2). We limited the search until 31 March 2017 and used the following search terms in all possible combinations: rectal cancer, laparoscopy, minimally invasive and open surgery. We included only English-written articles comparing laparoscopic surgery to the open technique for rectal cancer treatment.

Results

The search produced 402 articles; 143 were duplicates and were removed. Two independent Authors evaluated the remaining articles excluding the ones that were not pertinent (not comparing laparoscopy to the traditional technique in rectal cancer treatment) or not English-written. Reviews were excluded too resulting in 66 articles, of which 38 are non-randomized trials, 8 are randomized controlled trials (RCTs) performed in a single center, 5 are multicentric RCTs and 15 are meta-analyses (*Figure 1*).

Articles included in this review have been divided in four categories: non RCTs, single-center RCT, multicentric RCTs, meta-analyses; and chronologically ordered in *Tables 1-4*.

Discussion

Rectal cancer is a worldwide disease that constitutes one-third of colorectal cancers (67) and whose incidence has increased significantly in the last decades (68). The main treatment for rectal cancer is the surgical resection, which results have drastically improved since the introduction of total mesorectal excision (TME).

Thanks to accumulating evidence indicating that laparoscopic treatment of colon carcinoma is considered equivalent to the open technique, the laparoscopic technique is widely accepted and performed in the treatment of colon carcinoma. On the contrary, the role of laparoscopy in the treatment of rectal cancer is still not clear. Laparoscopic rectal surgery is more difficult than colonic one, due to the narrow space of pelvic cavity and the oncological safety remains unclear. Therefore, laparoscopy in rectal cancer is still not recommended as the gold standard treatment by international guidelines.

Anyhow the open approach too presents several limitations, especially in terms of oncologic outcomes, as it has been demonstrated by Rickles *et al.* (69) who reported a 22% less risk of positive circumferential resection margin (CRM) after laparoscopic surgery compared to an open approach.

All these reasons led to the current interest of surgeons towards new techniques, such as the use of robotics, transanal approach (taTME) or the combination of laparoscopy and transanal approach for rectal cancer surgery.

During the last decade many studies have been performed to prove the safety and feasibility of laparoscopic-assisted resection for rectal cancer. In order to demonstrate the non-inferiority of the laparoscopic approach against the open

Table 1 Non-randomized trials on rectal cancer resection

Author	Title	Year	Journal	Type	Patients	Lap	Open
Fleshman *et al.* (3)	Laparoscopic versus open abdominoperineal resection for cancer	1999	*Diseases of the Colon & Rectum*	Retrospective	194	42	152
Leung *et al.* (4)	Laparoscopic-assisted abdominoperineal resection for low rectal adenocarcinoma	2000	*Surgical Endoscopy*	Study-control	59	25	34
Anthuber *et al.* (5)	Outcome of laparoscopic surgery for rectal cancer in 101 patients	2003	*Diseases of the Colon & Rectum*	Retrospective	435	101	334
Feliciotti *et al.* (6)	Long-term results of laparoscopic versus open resections for rectal cancer for 124 unselected patients	2003	*Surgical Endoscopy*	Retrospective	86	52	34
Hu *et al.* (7)	Comparative evaluation of immune response after laparoscopical and open total mesorectal excisions with anal sphincter preservation in patients with rectal cancer	2003	*World Journal of Gastroenterology*	Retrospective	45	20	25
Wu *et al.* (8)	Laparoscopic versus conventional open resection of rectal carcinoma: a clinical comparative study	2004	*World Journal of Gastroenterology*	Retrospective	36	18	18
Morino *et al.* (9)	Laparoscopic versus open surgery for extraperitoneal rectal cancer: a prospective comparative study	2005	*Surgical Endoscopy*	Retrospective	191	98	93
Law *et al.* (10)	Laparoscopic and open anterior resection for upper and mid rectal cancer: an evaluation of outcomes	2006	*Diseases of the Colon & Rectum*	Retrospective	265	98	167
Lelong *et al.* (11)	Short-term outcome after laparoscopic or open restorative mesorectal excision for rectal cancer: a comparative cohort study	2007	*Diseases of the Colon & Rectum*	Retrospective	172	104	68
Veenhof *et al.* (12)	Laparoscopic versus open total mesorectal excision: a comparative study on short-term outcomes: a single-institution experience regarding anterior resections and abdominoperineal resections	2007	*Digestive Surgery*	Retrospective	100	50	50

Table 1 *(continued)*

Table 1 *(continued)*

Author	Title	Year	Journal	Type	Patients	Lap	Open
Staudacher *et al.* (13)	Laparoscopic versus open total mesorectal excision in unselected patients with rectal cancer: impact on early outcome	2007	*Diseases of the Colon & Rectum*	Retrospective	187	108	79
Mirza *et al.* (14)	Long-term outcomes for laparoscopic versus open resection of nonmetastatic colorectal cancer	2008	*Journal of Laparoendoscopic & Advanced Surgical Techniques*	Retrospective	92	54	38
Ströhlein *et al.* (15)	Comparison of laparoscopic versus open access surgery in patients with rectal cancer: a prospective analysis	2008	*Diseases of the Colon & Rectum*	Prospective	389	114	275
Yu *et al.* (16)	Laparoscopic versus open total mesorectal excision for the middle-lower rectal cancer: a clinical comparative study	2009	*Chinese Journal of Gastrointestinal Surgery*	Retrospective	198	93	105
González *et al.* (17)	Laparoscopic versus open total mesorectal excision: a nonrandomized comparative prospective trial in a tertiary center in Mexico City	2009	*The American Journal of Surgery*	Prospective	56	28	28
Gouvas *et al.* (18)	Laparoscopic or open surgery for the cancer of the middle and lower rectum short-term outcomes of a comparative non-randomised study	2009	*International Journal of Colorectal Disease*	Retrospective	88	45	43
Khaikin *et al.* (19)	Laparoscopic versus open proctectomy for rectal cancer: patients' outcome and oncologic adequacy	2009	*Surgical Laparoscopy Endoscopy & Percutaneous Techniques*	Retrospective	82	32	50
Koulas *et al.* (20)	Evaluations of laparoscopic proctocolectomy versus traditional technique in patients with rectal cancer	2009	*Journal of the Society of Laparoendoscopic Surgeons*	Retrospective	117	57	60
Laurent *et al.* (21)	Laparoscopic versus open surgery for rectal cancer: long-term oncologic results	2009	*Annals of Surgery*	Retrospective	471	238	233
Baik *et al.* (22)	Laparoscopic versus open resection for patients with rectal cancer: comparison of perioperative outcomes and long-term survival	2011	*Diseases of the Colon & Rectum*	Case-matched controlled prospective	162	54	108

Table 1 *(continued)*

Table 1 *(continued)*

Author	Title	Year	Journal	Type	Patients	Lap	Open
McKay *et al.* (23)	Improved short-term outcomes of laparoscopic versus open resection for colon and rectal cancer in an area health service: a multicenter study	2011	*Diseases of the Colon & Rectum*	Retrospective	545	157	388
Gunka *et al.* (24)	Long-term results of laparoscopic versus open surgery for nonmetastatic colorectal cancer	2011	*Acta Chirurgica Belgica*	Retrospective	145	75	70
Siani *et al.* (25)	Laparoscopic versus open total mesorectal excision for stage I-III mid and low rectal cancer: a retrospective 5 years analysis	2012	*Il Giornale di Chirurgia*	Retrospective	60	30	30
Jefferies *et al.* (26)	Oncological outcome after laparoscopic abdominoperineal excision of the rectum	2012	*Colorectal Disease*	Retrospective	41	16	25
Kellokumpu *et al.* (27)	Short- and long-term outcome following laparoscopic versus open resection for carcinoma of the rectum in the multimodal setting	2012	*Diseases of the Colon & Rectum*	Retrospective	191	100	91
Seshadri *et al.* (28)	Laparoscopic versus open surgery for rectal cancer after neoadjuvant chemoradiation: a matched case-control study of short-term outcomes	2012	*Surgical Endoscopy*	Retrospective	144	72	72
Kang *et al.* (29)	The impact of robotic surgery for mid and low rectal cancer: a case-matched analysis of a 3-arm comparison—open, laparoscopic, and robotic surgery	2013	*Annals of Surgery*	Retrospective	330	165	165
Lujan *et al.* (30)	Laparoscopic versus open surgery for rectal cancer: results of a prospective multicentre analysis of 4,970 patients	2013	*Surgical Endoscopy*	Prospective	4,405	1,387	3,018
Wilson *et al.* (31)	Laparoscopic colectomy is associated with a lower incidence of postoperative complications than open colectomy: a propensity score-matched cohort analysis	2014	*Colorectal Disease*	Retrospective cohort study	37,249	15,643	21,606
Moghadamyeghaneh *et al.* (32)	Outcomes of open, laparoscopic, and robotic Abdominoperineal resections in patients with rectal cancer	2015	*Diseases of the Colon & Rectum*	Retrospective	17,496	4737	12759

Table 1 *(continued)*

Table 1 *(continued)*

Author	Title	Year	Journal	Type	Patients	Lap	Open
Midura *et al.* (33)	The effect of surgical approach on short-term oncologic outcomes in rectal cancer surgery	2015	*Surgery*	Retrospective	8,272	2,337	5,935
Dural *et al.* (34)	The role of the laparoscopy on circumferential resection margin positivity in patients with rectal cancer: long-term outcomes at a single high-volume institution	2015	*Surgical Laparoscopy Endoscopy & Percutaneous Techniques*	Retrospective	579	266	313
Cho *et al.* (35)	Minimally invasive versus open total mesorectal excision for rectal cancer: long-term results from a case-matched study of 633 patients	2015	*Surgery*	Retrospective	633	211	422
Kim *et al.* (36)	Long-term outcomes of laparoscopic versus open surgery for rectal cancer: a single-center retrospective analysis	2015	*The Korean Journal of Gastroenterology*	Retrospective	307	131	176
Zaharie *et al.* (37)	Laparoscopic rectal resection versus conventional open approach for rectal cancer - a 4-year experience of a single center	2015	*Journal of BUON*	Retrospective	172	29	143
de Jesus *et al.* (38)	The circumferential resection margins status: a comparison of robotic, laparoscopic and open total mesorectal excision for mid and low rectal cancer	2016	*European Journal of Surgical Oncology*	Retrospective	241	41	200

Table 2 Single center randomized trials on rectal cancer resection

Author	Title	Year	Journal	Type	Patients	Lap	Open
Araujo *et al.* (39)	Conventional approach x laparoscopic abdominoperineal resection for rectal cancer treatment after neoadjuvant chemoradiation: results of a prospective randomized trial	2003	*Revista do Hospital das Clínicas*	Prospective	28	13	15
Zhou *et al.* (40)	Laparoscopic versus open total mesorectal excision with anal sphincter preservation for low rectal cancer	2004	*Surgical Endoscopy*	Prospective	171	82	89
Braga *et al.* (41)	Laparoscopic resection in rectal cancer patients: outcome and cost-benefit analysis	2007	*Diseases of the Colon & Rectum*	Prospective	168	83	85

Table 2 *(continued)*

Table 2 *(continued)*

Author	Title	Year	Journal	Type	Patients	Lap	Open
Pechlivanides *et al.* (42)	Lymph node clearance after total mesorectal excision for rectal cancer: laparoscopic versus open approach	2007	*Digestive Diseases*	Prospective	73	34	39
Ng *et al.* (43)	Laparoscopic-assisted versus open abdominoperineal resection for low rectal cancer: a prospective randomized trial	2008	*Annals of Surgical Oncology*	Prospective	99	51	48
Lujan *et al.* (44)	Randomized clinical trial comparing laparoscopic and open surgery in patients with rectal cancer	2009	*Surgical Endoscopy*	Prospective	204	101	103
Liang *et al.* (45)	Effectiveness and safety of laparoscopic resection versus open surgery in patients with rectal cancer: a randomized, controlled trial from China	2011	*Journal of Laparoendoscopic & Advanced Surgical Techniques*	Prospective	343	169	174
Ng *et al.* (46)	Laparoscopic-assisted versus open total mesorectal excision with anal sphincter preservation for mid and low rectal cancer: a prospective, randomized trial	2014	*Surgical Endoscopy*	Prospective	80	40	40
Fujii *et al.* (47)	Short-term results of a randomized study between laparoscopic and open surgery in elderly colorectal cancer patients	2014	*Surgical Endoscopy*	Prospective	200	100	100

Table 3 Multicentric randomized trials on rectal cancer resection

Author	Title	Year	Journal	Type	Patients	Lap	Open
Guillou *et al.* (48)	Short-term endpoints of conventional versus laparoscopic-assisted surgery in patients with colorectal cancer (MRC CLASICC trial): multicenter, randomized controlled trial	2005	*Lancet*	Prospective	794	526	628
van der Pas *et al.* (49)	Laparoscopic versus open surgery for rectal cancer (COLOR II): short-term outcomes of a randomised, phase 3 trial	2013	*Lancet Oncology*	Prospective	1,103	739	364
Kang *et al.* (50)	Open versus laparoscopic surgery for mid-rectal or low-rectal cancer after neoadjuvant chemoradiotherapy (COREAN trial): survival outcomes of an open-label, non-inferiority, randomised controlled trial.	2014	*Lancet Oncology*	Prospective	340	170	170
Fleshman *et al.* (51)	Effect of laparoscopic-assisted resection versus open resection of stage II or III rectal cancer on pathologic outcomes: the ACOSOG Z6051 randomized clinical trial	2015	*JAMA*	Prospective	462	240	222
Stevenson *et al.* (52)	Effect of Laparoscopic-Assisted Resection versus open resection on pathological outcomes in rectal cancer: the ALaCaRT randomized clinical trial	2015	*JAMA*	Prospective	475	238	237

RCT, randomized controlled trial.

Table 4 Meta-analyses on rectal cancer resection

Author	Title	Year	Journal	Patients	Lap	Open
Aziz *et al.* (53)	Laparoscopic versus open surgery for rectal cancer: a meta-analysis	2006	*Annals of Surgical Oncology*	2,071	909	1,162
Gao *et al.* (54)	Meta-analysis of short-term outcomes after laparoscopic resection for rectal cancer	2006	*International Journal of Colorectal Disease*	643	285	358
Bonjer *et al.* (55)	Laparoscopically assisted versus open colectomy for colon cancer: a meta-analysis	2007	*Archives of surgery*	1,765	796	740
Anderson *et al.* (56)	Oncologic outcomes of laparoscopic surgery for rectal cancer: a systematic review and meta-analysis of the literature	2008	*European Journal of Surgical Oncology*	2,178	1,403	1,775
Gong *et al.* (57)	A meta-analysis of clinical outcomes after laparoscopic operation for rectal cancer	2010	*Chinese Journal of Gastrointestinal Surgery*	2,850	1,145	1,705
Ohtani *et al.* (58)	A meta-analysis of the short- and long-term results of randomized controlled trials that compared laparoscopy-assisted and conventional open surgery for rectal cancer	2011	*Journal of Gastrointestinal Surgery*	2,095	1,096	999
Huang *et al.* (59)	Laparoscopic-assisted versus open surgery for rectal cancer: a meta-analysis of randomized controlled trials on oncologic adequacy of resection and long-term oncologic outcomes	2011	*International Journal of Colorectal Disease*	1,033	–	–
Ng *et al.* (60)	Long-term oncologic outcomes of laparoscopic versus open surgery for rectal cancer: a pooled analysis of 3 randomized controlled trials	2012	*Annals of Surgery*	278	136	142
Trastulli *et al.* (61)	Laparoscopic versus open resection for rectal cancer: a meta-analysis of randomized clinical trials	2012	*Colorectal Disease*	1,544	841	703
Arezzo *et al.* (62)	Laparoscopy for rectal cancer reduces short-term mortality and morbidity: results of a systematic review and meta-analysis	2013	*Surgical Endoscopy*	4,539	2,087	2,452
Ahmad *et al.* (63)	A systematic review and meta-analysis of randomized and non-randomized studies comparing laparoscopic and open abdominoperineal resection for rectal cancer	2013	*Colorectal Disease*	454	248	206
Vennix *et al.* (64)	Laparoscopic versus open total mesorectal excision for rectal cancer	2014	*The Cochrane Database of Systematic Reviews*	4,224	–	–
Zhang *et al.* (65)	Laparoscopic versus open surgery for rectal cancer: a systematic review and meta-analysis of randomized controlled trials	2014	*Asian Pacific Journal of Cancer Prevention*	3,045	1,804	1,241
Jiang *et al.* (1)	Laparoscopic versus open surgery for mid-low rectal cancer: a systematic review and meta-analysis on short- and long-term outcomes	2015	*Journal of Gastrointestinal Surgery*	3,678	–	–
Chen *et al.* (66)	Laparoscopic versus open surgery for rectal cancer: a meta-analysis of classic randomized controlled trials and high-quality nonrandomized studies in the last 5 years	2017	*International Journal of Surgery*	4,353	2,251	2,102

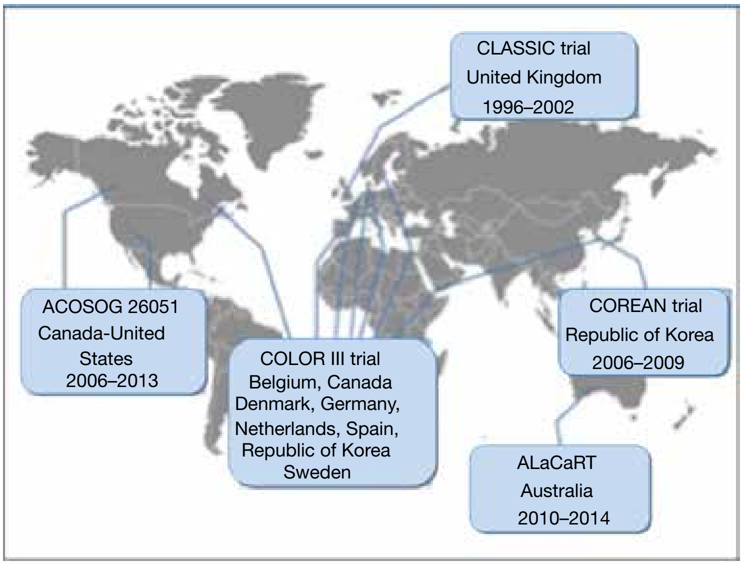

Figure 2 Multicentric studies designed and performed all over the world in the last 20 years.

surgery, Authors all over the world have compared the two techniques in terms of short- and long-term outcomes.

Most of these studies are non-randomized comparative (3-20) trials (NRCTs) (21-38). The findings of these studies were extremely encouraging, showing the non-inferiority of laparoscopy compared to the open technique in terms of oncological outcomes (like disease-free survival and local recurrence) and intraoperative and postoperative factors. Moreover the laparoscopic group presented advantages regarding antibiotic and analgesic therapy, early mobilization, hospital stay, intraoperative blood loss, resuming oral nutrition, bowel transit resumption, postoperative complications and wound complications, concluding that laparoscopic resection for rectal cancer is feasible, safe and effective.

To collect more accurate evidence about short- and long-term outcomes after laparoscopic surgery for rectal cancer compared to open surgery, a large number of randomized control trials (RCTs) have been produced in the last few years (39-47). Most of these studies focused on postoperative morbidity, length of hospital stay, quality of life, long-term survival, and local recurrences, finding no significant difference between the groups.

For an example, a recent study was developed by Ng *et al.* (43) who performed a single-center, prospective, randomized trial on 80 patients with mid and low rectal cancer, focusing on oncologic outcomes (in particular quality of the TME specimen, circumferential resection margin (CRM) involvement, and number of lymph nodes removed), which were found similar between both groups.

The results assessed with these randomized trials seem to suggest that laparoscopic surgery for rectal cancer could improve short-term results while not jeopardizing the oncological outcomes compared with open surgery. The major limitation of these studies is that, being single-centered they are based on an exiguous number of patients.

To reach a wider number of patients multicentric studies have been designed and performed all over the world in the last 20 years (*Figure 2*).

In the CLASICC trial (48) 794 patients with colorectal cancer from 27 UK centers were enrolled to be treated by either laparoscopic or open surgery. Primary short-term end-points were positivity rates of circumferential and longitudinal resection margins and in-hospital mortality. In the CLASICC trial, regarding the cancer of the rectum, no significant difference in CRM positivity was detected in patients who underwent a rectal resection in both laparoscopic and open group. CRM positivity, instead, was significantly greater in laparoscopic than in the open surgery group for patients who underwent anterior resection. It is important to highlight that positive CRM is a strong predictor of both local recurrence and overall survival, since it is associated with a high rate of local recurrence and poor morbidity and mortality for rectal cancer patients (69). As a first conclusion, at the time of its first publication, the impair short-term outcomes after a laparoscopic approach in an anterior resection of the rectum did not justify its routine use. Further studies about long-term outcomes of patient enrolled in the CLASICC trial, have been recently published focusing on the local recurrence, overall survival and disease-free survival (70,71). No significant differences between the laparoscopic and open approach were found in local recurrence, overall survival and disease-free survival after 3, 5 and 10 years follow-up. However, it is worth mentioning that the CLASICC trial (48) enrolled not only patients with rectal cancer but also patients with colon cancer, which may cause confusion on conclusions about rectal cancer.

Two other multicentric studies, aimed to compare laparoscopic and open surgery in patients with rectal cancer, were the COLOR II trial (49) and the COREAN trial (50), enrolling respectively 1,103 patients with rectal cancer within 15 cm from the anal verge and 340 patients with II and III mid- and low rectal cancer. Both studies demonstrated similar results in oncologic outcomes, disease-free survival and recurrence, confirming the safety and feasibility of the laparoscopic approach for rectal cancer. COLOR II trial was performed in 30 centers and hospitals from eight countries from 2004 to 2010. As expected, blood loss and recovery resulted better after the laparoscopic approach, even if it was connected to longer operative time. In terms of safety, completeness of the resection, positive CM (<2 mm) and median tumor distance to distal resection margin did not differ significantly between the groups. Also morbidity and mortality within 28 days after surgery were similar. So the authors concluded that laparoscopic surgery resulted in similar safety to open surgery and associated to a better recovery, if performed in selected patients treated by skilled surgeons.

The COREAN trial (50) was performed in three centers from 2006 to 2009 in Republic of Korea. Its conclusions were similar to the COLOR II trial (49): although surgery time was longer in the laparoscopic group, no significant difference was found in the involvement of the CRM, macroscopic quality of the TME specimen, number of harvested lymph nodes, and perioperative morbidity, once again stating the efficacy and safety of laparoscopic rectal resection.

More recently, two multicentric studies have been published, introducing controversial conclusions about the non-inferiority of laparoscopic surgery compared with open surgery. In the ALaCaRT Randomized Clinical Trial conducted between 2010 and 2014, 475 randomized patients with T1–T3 rectal adenocarcinoma, underwent either laparoscopic [237] or open [238] rectal resection (52). The primary end point was several oncological factors selected to an adequate surgical resection. A successful resection was achieved in 194 patients (82%) who underwent laparoscopic surgery and 208 patients (89%) who received open surgery. CRM was clear in 93% of patients in the laparoscopy group and in 97% who underwent open surgery. Distal margin was clear in 99% of cases in both groups, and TME was complete in 87% of patients in the laparoscopic surgery group and 92% in the open surgery group. Based on these findings the Authors concluded that, among patients with T1–T3 rectal tumors, there was not sufficient evidence to establish the non-inferiority of laparoscopic surgery compared to open surgery, so the choice of a laparoscopic approach for a patient with rectal cancer should be made with caution.

Similar evidence was found by Fleshman *et al.* in the ACOSOG Z6051 randomized clinical trial (51). A multicenter randomized trial enrolling patients from 35 institutions across United States and Canada, between 2008 and 2013. A total of 486 patients with a stage II or III rectal cancer within 12 cm from the anal verge were randomized after neoadjuvant therapy to receive a laparoscopic [240] or an open [222] resection. The aim of the study was to assess whether laparoscopic resection was not inferior to open resection, based on pathologic and histologic evaluation of the resected specimen. Successful resection occurred in 81.7% of laparoscopic resection cases and 86.9% of open resection cases and did not support the non-inferiority. These results too do not support the use of laparoscopic resection in patients with stage II or III rectal cancer.

It's important to notice that the chosen outcome to assess the efficacy of laparoscopic surgery in rectal cancer was a composite of a CRM greater than 1 mm, distal margin without tumor, and completeness of TME. This combination of short-terms outcomes has been arbitrarily chosen by the Authors and it still has to be proven its real impact on recurrence and long-term survival. So, both studies share the main limitation: the non-inferiority of laparoscopy compared to open surgery is based on the combination of completeness of TME and the positivity of CRM which, as short-terms outcomes, are only predictors of local recurrence. Long-terms outcomes are needed to define laparoscopy inferior compared to the traditional approach.

Moreover, although the results of the comparison between laparoscopy and open technique in terms of successful resection do not support the non-inferiority of laparoscopy, taken singularly, CRM and TME in the ALaCaRT trial are very close to be significant (P=0.06) and

Table 5 Oncologic outcomes on multicentric randomized trials on rectal cancer resection

Author	Protocol	Countries	Years	Number of patients	Distal margin	Completeness of TME	CRM	Long-term recurrence
Guillou *et al.* (48)	CLASICC	UK	1996–2002	794	Yes	No	Yes	Yes
van der Pas *et al.* (49)	COLOR II	Belgium, Canada, Denmark, Germany, Netherland, Spain, Republic of Korea, Sweden	2004–2010	1,103	Yes	Yes	Yes	Yes
Kang *et al.* (50)	COREAN	Republic of Korea	2006–2009	340	No	Yes	Yes	Yes
Fleshman *et al.* (51)	ACOSOG Z6051	United States, Canada	2008–2013	486	Yes	Yes	Yes	No
Stevenson *et al.* (52)	ALaCaRT	Australia	2010–2014	475	Yes	Yes	Yes	No

CRM, circumferential resection margin; TME, total mesorectal excision.

then equivalent in open and laparoscopic surgery.

Finally both studies do not take under consideration short-terms outcomes, like recovery, which has been worldwide demonstrated faster and associated with a lower rate of incidence of complications after laparoscopic surgery.

In the past 10 years meta-analytic studies have been performed to be able to give definitive results by pooling together a wide number of patients. Studies before the publication of ACOSOG and ALaCaRT protocols (51,52) stated the non-inferiority of laparoscopy compared to the open approach for rectal resection. Although their optimistic conclusions, we must underline how these studies share some limitations. Many of them, in fact, included non-RCT studies in the analysis that can lead to misleading results due to a selection bias.

The most recent meta-analytic study (72) has been published in February 2017, including ASOCOG and ALaCaRT trials (51,52), as well as 12 other unique RCTs with a total of 4,034 patients.

Including ALaCaRT e ACOSOG (51,52) the Authors came to the conclusion that the risk for achieving an incomplete mesorectal excision is significantly higher in patients undergoing laparoscopic rectal resection compared to the open technique, dampening the enthusiasm in support of laparoscopy for rectal surgery.

In conclusion, due to its impressing outcomes in terms of post-operative recovery and low rate of complication, laparoscopy has been seen for many years as the answer for rectal surgery. For the first time, after decades of certain advantages of laparoscopy, we are now witnessing the questioning of its equivalence to the traditional technique in terms of oncologic outcomes (*Table 5*). So the answers is yet to be found: to assess if the results of ongoing multicentric RCTs have a real impact on the disease-free and overall survival of patients undergoing rectal surgery performed with laparoscopic technique, thus we will have to wait for their long-term results. Only in the next future, in fact, we will be able to assess if the failure of laparoscopy in these trials in terms of pathologic outcomes will bring to an actual increase of recurrence and mortality, alongside a shortage of the disease-free survival. This should give the rationale to perform new meta-analyses based on the new evidence produced. Moreover, even more multicentric RCTs studies, hypothetically designed on new pathological outcomes, should be performed to finally assess if laparoscopy is a valid choice for the treatment of rectal cancer.

Furthermore, the controversial findings we are facing could be explained by the fact that TME is challenging at baseline, working in the deep pelvis, with rigid instruments, from angles that require complicated maneuvers results even more difficult. It is possible that future developing of instruments, the introduction of different technologies such as robotics and the introduction of new techniques like taTME will improve efficacy of minimally invasive techniques and exceed the limitations of laparoscopy (12).

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Footnote

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Examining outcomes for laparoscopic *vs.* open colonic resections in middle volume hospitals: comparative outcomes that need cautious interpretation

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Provenance: This is an invited Editorial commissioned by Editor-in-Chief Minhua Zheng (Department of General Surgery, Ruijin Hospital, Shanghai Jiaotong University School of Medicine, Shanghai Minimal Invasive Surgery, Shanghai, China).

Comment on: Nakao T, Shimada M, Yoshikawa K, *et al.* Propensity score-matched study of laparoscopic and open surgery for colorectal cancer in rural hospitals. J Gastroenterol Hepatol 2016;31:1700-4.

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Laparoscopy, in one form or another has been a technique used in surgery for over 100 years (1). Its progression and refinement over the decades, since its rudimentary start has resulted in the widespread use of the technique in developed countries. The first laparoscopically assisted colonic resection was performed in 1991 (2) and yet only 20 years later a third of all colonic resections in the USA were performed in this manner (3). Initial caution led, at least in the UK to the guidance (4) in the year 2000 that colonic resections for cancer only be performed within RCTs—preliminary results were encouraging with reports of reduced morbidity and pain post-operatively (5,6). Not all surgeons were convinced, however with concerns raised regarding involved margins, lymph node harvesting and post-site recurrence (7,8). It was not until the publication of studies demonstrating comparable long-term survival data (9,10) that the majority of surgeons endorsed the technique ultimately leading to the rapid expansion in the field.

It was thus we read with interest the paper by Nakao *et al.*, which examined the outcomes of patients undergoing laparoscopic and open colorectal surgery in rural, middle volume centres in Japan. The inverse relationship that exists between hospital volume and mortality (11) is well known and dependent on multiple variables. The authors do not, however compare their outcomes with higher volume centres in Japan, choosing rather to compare outcomes with propensity matched open cases within similar volume centres. The important aspect of course, is not the rural location, nor indeed the number of laparoscopic cases performed in each hospital, but crucially the experience of and the number of cases performed by each surgeon/year. As with all technical procedures there is a learning curve with greater experience leading to enhanced performance and better outcomes. In surgery, the clinical relevance of this is obvious and was aptly highlighted by an inquiry in 2006 by the UK General Medical Council into the Bristol Paediatric Surgical Unit concluding that patients should not be independently operated on by surgeons in the early stage of their learning curve (12). The authors have rightly highlighted that their study fails to take into account the operative experience of the surgeons and this remains the principal drawback to this otherwise well designed study. Without the breakdown of cases performed per surgeon the relevance of the "middle volume" relates to the post-operative care of patients and the experience of the hospital staff in dealing with and recognising complications arising from such operations.

It is important to discuss certain aspects of the methodology to correctly judge their conclusions. The distinction between Stage 2 & 3 colorectal cancers is often difficult and heavily reliant on lymph node involvement. The harvesting of 12 lymph nodes has widely been accepted as the minimum number required to achieve representative sampling (13), yet in the matched outcomes presented in the second table of the paper by Nakao *et al.*, it would appear the authors have included patients with inadequate sampling thereby compromising accurate staging leading to selection bias. Given that staging is one of their cross-matching covariates, this in turn could result in the mismatching of patients.

The authors have clearly stated that patients who required adjuvant chemotherapy were managed in accordance with JSCCR guidelines, but were not matched for adjuvant chemotherapy. Whilst including adjuvant therapy as a covariate would reduce the bias in patient selection, these guidelines (14) were drawn up to standardise treatment strategies between Institutions and can therefore be assumed that patients matched for age/stage/co-morbidities were at least offered similar therapies. An area for clarification by the Authors would be those patients with ano-rectal cancers, who received neo-adjuvant chemo-radiotherapy as this was not included or discussed.

The propensity score matching (PSM) method is itself a widely used technique, but one not without flaws and indeed argued by many that it should not be used at all (15). It primarily aims to reduce the imbalances or confounding factors between two observational groups in a similar fashion to randomising patients prospectively. The difference is that, in true randomisation all possible confounders (both measured and unmeasured) are balanced evenly between the groups thereby rendering the treatment group independent of the covariate, which enhances the "effect of treatment" estimation. With PSM, matching is achieved through the balancing of covariates on average, therefore two matched individuals may have identical propensity scores, but their covariates may differ which can in turn increase imbalance. With respect to the paper by Nakao *et al.* this could mean that two individuals could be matched despite undergoing resection of different parts of the colon or have different pathological staging. Alternative matching techniques (16) are often preferred as all covariates are matched evenly leading to a more reliable estimation of effect.

Retrospective articles are limited in that they consistently underestimate post-operative complications (17) and it is not surprising given the variability in recording of events or indeed the interpretation. As such it is difficult to draw any meaningful conclusions from the short-term outcomes data presented here other than post-operative length of stay and 30-day mortality. It would be normal procedure to include the re-operation rate for a study such as this and it is unclear why the authors have failed to do this. The reduced length of stay post-operatively is clearly in favour of the laparoscopic approach, which is unsurprising given the lower incidence of post-operative ileus, previously shown in other articles (18).

The benefit of the retrospective approach taken here is that longer term outcomes can be measured with relative ease. The incidence of incisional herniation would have been a useful addition to this study, given the morbidity and re-operative rate associated. The laparoscopic approach has a significantly reduced incidence of incisional herniation (19) and subsequent occurrence of small bowel obstruction compared with open and is an important factor to be considered. It is unsurprising that there is no significant difference between disease free survival (DFS) and overall survival (OS) given that these are determined principally by the pathological staging of the cancer. The operative technique whereby the tumour is removed, be it open or laparoscopic, should not impact on this so long as the margins are clear and the number of lymph nodes harvested is equivalent. The incidence of port-site recurrence and recurrence in a mid-line laparotomy wounds have both been shown to be around 1% (20).

To conclude, the answer as to whether laparoscopic outcomes are equivalent to open outcomes for colorectal resections in middle volume Institutions would appear to be a yes—taking into consideration the caveats regarding methodology mentioned earlier. An improved analysis would be to compare laparoscopic outcomes between middle and high volume surgeons and relate these to their open counterparts in a randomised prospective setting. Given the geography of Japan this is unlikely to be feasible and therefore Nakao *et al.* should be congratulated on their contribution to this important area.

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Footnote

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Hybrid natural orifice transluminal endoscopic surgery colectomy versus conventional laparoscopic colectomy for left-sided colonic tumors: intermediate follow up of a randomized trial

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Contributions: (I) Conception and design: MK Li; (II) Administrative support: MK Li; (III) Provision of study materials or patients: All authors; (IV) Collection and assembly of data: All authors; (V) Data analysis and interpretation: All authors; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

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Background: In 2009, we have described a novel technique of laparoscopic colectomy without abdominal incision [hybrid natural orifice transluminal endoscopic surgery (NOTES) colectomy] where laparoscopic dissection and intra-corporeal anastomosis were performed as usual but the specimen was delivered through the anus with the use of transanal endoscopic operation (TEO) device set-up without mini-laparotomy. We have completed a randomized trial comparing this technique with conventional laparoscopic colectomy (CL) for left sided colonic tumors, and early short term results had showed that in selected group of patients, they can enjoy the full benefit of minimally invasive surgery with significant lesser wound pain as well as a lower wound infection rate. This study is a follow up of previous trial, and aims to report immediate outcome between the two groups.

Method: All 70 patients including 35 patients in the hybrid NOTES group and 35 patients in conventional colectomy group were continued to follow up in our outpatient clinic with regular surveillance. Patients were compared for clinicopathological variables, disease recurrence and survival rates.

Results: Clinicopathological details were comparable between the two groups. Within median follow up of 37–45 months in the two groups, no statistically significant difference was observed in disease recurrence rate (conventional: 8.57%; hybrid: 5.71%; P value: 0.22) and 3-year disease free survival rates (conventional: 42%; hybrid: 62%; P value: 0.144). While the overall 3-year survival rate is statistically shorter in the conventional group (conventional: 54%; hybrid: 71%; P value <0.05).

Conclusions: It is safe for us to offer hybrid colectomy for selected patients with left sided colonic cancer, without adversely affect their oncological outcome and survival, while at the same time, benefit of minimally invasive surgery can be fully expressed.

Keywords: Natural orifice transluminal endoscopic surgery (NOTES); natural orifice specimen extraction; laparoscopic colectomy

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Introduction

There is now already a wealth of evidence in the literature indicating laparoscopic colectomy is associated with definite short term benefits including faster recovery, reduced postoperative pain, reduced wound infection, and faster return of bowel function and at the same time, it has comparable oncological outcomes with open colectomy (1,2). However, specimen retrieval still required a mini-

Table 1 Characteristics of patient and tumor

Characteristics	HNC	CL	P
Sex (M:F)	13:22	12:23	0.806[A]
Age (years)	62 [51–86]	72 [49–84]	0.828[A]
Tumor size (cm)	2 [2–4]	3 [2–4]	0.104[B]

A, χ^2 test; B, Mann-Whitney U-test. HNC, hybrid NOTES colectomy; CL, conventional laparoscopic colectomy.

laparotomy wound which is always the main cause of postoperative pain and pain or wound related complications. In 2009, we described a novel technique of laparoscopic colectomy without mini-laparotomy-known as hybrid natural orifice transluminal endoscopic surgery (NOTES) colectomy for patient suffered from left sided colonic tumors (3). It was in fact a marriage between laparoscopic and endoscopic operations, where laparoscopic colonic mobilization, transection, and colorectal anastomosis are performed intracorporeally, and the specimen is extracted transanally, without requiring mini-laparotomy. Complications related to the mini-laparotomy are therefore entirely abolished. As the preliminary results were promising, we set out to conduct a randomized trial to compare the short-term outcomes of patients who underwent hybrid NOTES colectomy (HNC) with those who underwent conventional laparoscopic colectomy (CL). The short term results from this RCT which was published in 2013 had showed that in selected group of patients, they can enjoy the full benefit of minimally invasive surgery with significant lesser wound pain as well as a lower wound infection rate (4). And this article is a follow up of previous trial, and aims to report immediate outcome between the two groups.

Methods

Between June 2009 to June 2012, 70 patients (35 patients in the HNC group and 35 patients in CL group) with left sided colonic tumor were recruited in a prospectively randomized trial to compare HNC and CL. Details on patient selection criteria, method of randomization, operative techniques, perioperative data and short-term outcomes have been reported previously (4).

Follow up protocol

All patients were followed up in our surgical clinic at 3-month intervals in the first 3 years, semi-annually in the subsequent 2 years, and then yearly afterward. Serum carcinoembryonic antigen was measured at every follow-up session in the first 5 years. Annual chest X-ray and transabdominal ultrasonography were performed to screen for recurrence until 5 years after surgery. Surveillance colonoscopy was performed 1 year after surgery and every 3 years thereafter if the first colonoscopy was normal; colonoscopy was performed more frequently if the patient's condition indicated otherwise.

Main outcome measures

Pathological staging, number of lymph nodes harvested and size of tumor were compared between the two groups. Patient survival and disease recurrence following curative surgery were analyzed and compared. Curative surgery was defined as no gross macroscopic tumor present clinically or radiologically at the end of surgery. Disease recurrence was defined as clinically or radiologically proven recurrence, supported by histological tissue diagnosis whenever possible. Overall survival was defined as the time from the date of surgery to the date of death or most recent follow-up.

Statistical analysis

Statistical analyses were performed with SPSS v. 13.0 (SPSS, Chicago, USA). Clinicopathologic variables were correlated using the χ^2 test, Fisher's exact test, *t*-test or Mann-Whitney U-test. A Kaplan-Meier survival curve was constructed and statistically significant differences in survival were identified by the log-rank test. A two-sided P value of less than 0.05 was considered significant.

Results

Characteristics of the patients and tumors were listed in *Table 1*. The two groups were comparable with regard to age, sex, final histopathological stage of disease and size of tumor. No significant difference between the two groups in terms of operative time, blood loss and hospital stays and major complications. Patients in HNC group experienced significantly less wound pain when compared to conventional lap colectomy group. Number of lymph nodes harvested was also comparable between the two groups (*Table 2*).

Within median follow up of 37–45 months, no statistically significant difference was observed in disease recurrence rate (conventional: 8.57%; hybrid: 5.71%; P value: 0.22) (*Table 3*) and 3-year disease free survival rates (conventional: 42%; hybrid: 62%; P value: 0.144) (*Figure 1*). While the overall 3-year survival rate is statistically shorter in the conventional group (conventional: 54%; hybrid: 71%; P value <0.05) (*Figure 2*).

Discussion

The technique and concept of trans-rectal natural orifice specimen extraction (trans-rectal NOSE) colectomy was first described in early 1990s, it was developed in an attempt to minimize the wound access trauma by abolishing the mini-laparotomy wound that used for specimen retrieval (5). Using trans-rectal route for extraction of colectomy specimen is a better option over other natural orifices as it is feasible for both sex and straightness of rectum also makes it relatively easy to access peritoneal cavity. To date, there were already numerous literature evidence indicating that NOTES colectomy are definitely associated with the presumed benefits namely less pain, lower analgesic requirement and faster recovery (4,6-8), and allowing patients to enjoy the full benefit of minimally invasive surgery. Nevertheless, one important potential clinical drawback of HNC is the need for opening up rectum in peritoneal cavity which runs the risk of peritoneal contamination and tumor seedling.

Bacterial contamination of peritoneal cavity is frequent in colorectal procedure (9). However, it was unknown whether opening rectum stump will further increase the bacterial load in the peritoneal cavity and results in clinically significant peritoneal sepsis. In our study, we would give prophylactic antibiotics during induction of anesthesia and complete one course of antibiotics post operatively, we would also ensure good mechanical bowel preparation so as to minimize the peritoneal soiling intra-operatively. And none of our study cases developed intra-abdominal sepsis in post-operative peroid. In 2012, Federico has conducted a study comparing the peritoneal contamination during laparoscopic sigmoidectomy with and without NOSE. And the result has showed that although

Table 2 Clinicopathological details

Variables	HNC	CL	P
Stages (I/II/III/IV)	4/14/7/10	1/10/12/12	0.321[C]
No. of lymph nodes harvested	12 [6–33]	12 [6–29]	0.06[B]

B, Mann-Whitney U-test; C, Fisher's exact test. HNC, hybrid NOTES colectomy; CL, conventional laparoscopic colectomy.

Table 3 Details of disease recurrence case

Patient	Stage	Details
Hybrid NOTES colectomy		
An 84-year-old female	Stage 2	Diagnosed liver metastasis in post op 10 months
		Refused further treatment
A 72-year-old female	Stage 1	Developed anastomotic recurrence in post-op 3 months
		Open TME performed
Conventional laparoscopic colectomy		
An 83-year-old female	Stage 3	Diagnosed anastomosis recurrence in post-op 2 yrs
		Refused treatment and died
A 64-year-old female	Stage 2	Diagnosed liver met in post-op 2 yrs
		Refused treatment
A 66-year-old male	Stage 2	Diagnosed liver met in post-op 4 yrs
		Wedge resection performed

NOTES, natural orifice transluminal endoscopic surgery.

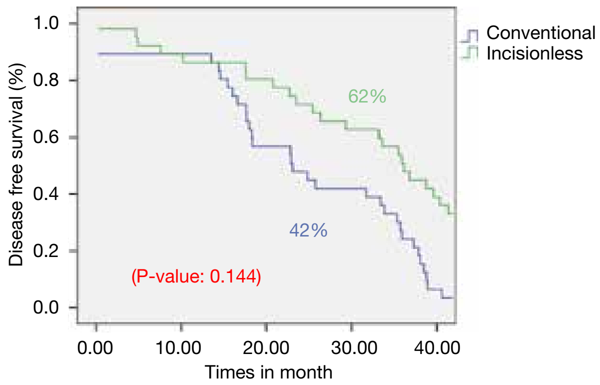

Figure 1 3-year disease-free survival rates. Conventional, conventional laparoscopic colectomy; incisionless, hybrid NOTES colectomy. NOTES, natural orifice transluminal endoscopic surgery.

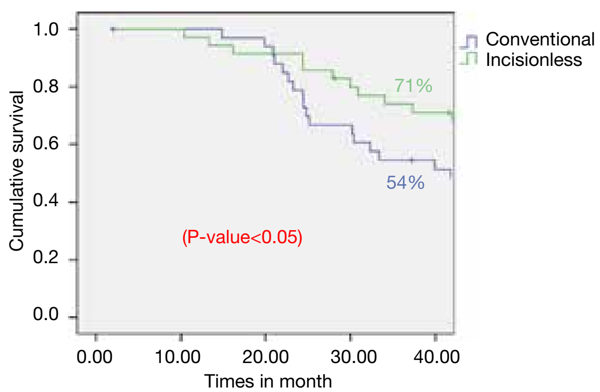

Figure 2 Overall 3 years survival rates. Conventional, conventional laparoscopic colectomy; incisionless, hybrid NOTES colectomy. NOTES, natural orifice transluminal endoscopic surgery.

a higher peritoneal contamination was found in NOSE (contamination rate of peritoneal fluid was 100% *vs.* 88.9% in NOSE and non-NOSE colectomy, P=0.23), but did not translate into infectious morbidity (10). Recently, there was also experimental study reporting a new device for reversible endoluminal colon occlusion (Coloshield) which can further reduce peritoneal contamination during trans-rectal NOTES procedure (11).

Second issue for NOTES colectomy is the increased risk of tumor seedling. Initial introduction of laparoscopic colectomy, there were concerns of port sites or extraction sites recurrence, later have been proved unfounded in many studies (12). We believed that as long as proper oncologic principles and specimen handling are respected, the chance of pelvic tumor seedling using trans-rectal route should not be higher than trans-abdominal route. We have adopted two important measures to prevent tumor seedling, firstly, we would use cytocidal rectal washout before opening up the rectum. Second, we would exclude the tumor proximally and distally with non-cutting endostapler or cotton tap. The transanal endoscopic operation (TEO) devices not only provide a stable platform to maintain the pneumoperitoneum for extraction of specimen, also protect the rectal stump in contact with the tumor bearing colon. And from our intermediate follow up data, no significant difference in terms of disease recurrence rate and survival rate was observed between the two groups. There were wide variations of the method of rectal protection among studies on trans-rectal NOTES colectomy; according to a recent systematic review—25% none, 33% rigid rectoscope, 42% camera sleeve or retrieval bag (13), however little is mentioned on the oncological outcomes following NOSE colectomy. So more long term studies was warranted to assess any impact of NOSE on colectomy for malignant cases.

To conclude, it is safe for us to offer hybrid colectomy for selected patients with left sided colonic cancer, without adversely affect their oncological outcome and survival, while at the same time, benefit of minimally invasive surgery can be fully expressed.

Acknowledgements

None.

Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

Ethical Statement: The study was approved by PYNEH Ethical Committee and written informed consent was obtained from all patients.

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Laparoscopic rectal resection versus open rectal resection with minilaparotomy for invasive rectal cancer

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Background: The minilaparotomy approach is technically feasible for the resection of rectal cancer in selected patients with rapid postoperative recovery and small incision. The study aimed to compare the clinical and oncological outcomes of minilaparotomy and laparoscopic approaches in patients with rectal cancer.

Methods: The 122 included patients with rectal cancer were assigned to either minilaparotomy group (n=65) or laparoscopic group (n=57) which ran from January 2005 to January 2008. Clinical characteristics, perioperative outcomes, postoperative and long-term complications, pathological results and survival rates were compared between the groups.

Results: The demographic data of the two groups were similar. The time to normal diet (P=0.024) and the hospital stay (P=0.043) were less in the laparoscopic group than that in the minilaparotomy group. Compared with the minilaparotomy group, the mean operation time was significantly longer [low anterior resection (LAR), P=0.030; abdominoperineal resection (APR), P=0.048] and the direct costs higher for laparoscopic group (P<0.001). The morbidity and mortality were comparable between the two groups. Local recurrence was similar (5.3% laparoscopic, 1.5% minilaparotomy, P=0.520). The 5-year overall and disease-free survival rates were also similar (overall survival is 87.1% in laparoscopic group, and 82.5%in minilaparotomy group, P=0.425; disease-free survival is 74.2% in the laparoscopic group, and 71.4% in mini- laparotomy group, P=0.633).

Conclusions: The minilaparotomy approach was similarly safe and oncologically equivalent to laparoscopic approach for patients with rectal cancer. At the expense of a longer operative time and higher cost, laparoscopic surgery was associated with faster postoperative recovery.

Keywords: Minilaparotomy; laproscopic surgery; rectal cancer

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Introduction

Since first described in 1991, laparoscopic surgery has been increasingly advocated as a safe and efficient technique for the treatment of colorectal cancer (1). In comparison with conventional open surgery, laparoscopic colorectal resection was shown to be associated with reduced blood loss, less postoperative pain and a shorter hospital stay (2-5). However, laparoscopic colorectal surgery requires special instruments and costly disposables. It is associated with a steep learning curve and longer operation time (6-8).

Although instrumentation, surgical skills and techniques in laparoscopic surgery have evolved, it is often necessary to extract the surgical specimen and perform the bowel anastomosis through a small skin incision. Recent studies reported that a minilaparotomy (incision ≤7 cm) was technically feasible and safe for colorectal cancer resections and was associated with a rapid postoperative recovery (9-12). In addition, this technique did not increase operating time and the learning curve was less steep as compared with laparoscopic colorectal surgery.

A study by Nakagoe *et al.* suggested that minilaparotomy technique for resection of rectal cancer was an attractive alternative in non-overweight patients (12). Very few studies have compared short and long term outcomes of minilaprotomy surgery for the treatment of rectal cancer (13). Hence, the oncological adequacy of minilaparotomy approach in rectal cancer remains to be determined. The aim of our study was to assess the long-term clinical and oncological outcome after laparoscopic and minilaparotomy surgery in patients with rectal cancer.

Patients and methods

Definition of minilaparotomy

The minilaparotomy approach for the resection of rectal cancer is defined as a resection performed through a skin incision ≤7 cm in length.

Patients

All patients with a rectal cancer with the edge ≤12 cm from the anal verge without other concurrent or previous malignant disease treated by minilaparotomy and laparoscopic surgery were compared retrospectively. Evaluation included physical examination, colonoscopy with biopsy, anorectal ultrasonography, pelvic magnetic resonance and thoracic and abdominal computed tomography (CT). The mobility and the location of the tumor from the anal verge were assessed by digital examination by the surgeon and radiological imaging. Patients were staged using the clinical tumor node metastasis (TNM) classification. Exclusion criteria were patients who refused to consent for the study, and patients with tumors infiltrating to adjacent organs (cT4). Patients who had associated gastrointestinal diseases that required additional extensive operative intervention or evaluation were excluded. Patients with evidence of synchronous metastatic disease were also excluded. The choice between minilaparotomy and laparoscopic surgery was based on a joint decision by the patients and doctors. This study was approved by our local research ethics committee. Written informed consent was obtained from all patients.

Preoperative preparation and neoadjuvant chemoradiotherapy

All patients had bowel preparations, including a fluid diet and administration of a polyethylene glycol electrolyte solution, one day before the operation unless there were contraindications against bowel preparation. Intravenous antibiotic prophylaxis was given on induction of anesthesia for the operation.

The basic indications for neoadjuvant chemoradiotherapy included rectal cancers (T3) and/or node-positive disease, lack of prior radiation therapy to the pelvis, and age <75 years. Neoadjuvant treatment with chemotherapy and radiation therapy was as follows: 45 Gy in five weeks with concomitant 5-fluorouracil. The operation was carried out six to eight weeks after the end of the neoadjuvant treatment.

Operation techniques

All operations were performed by the same surgical team, which included TZ, GZ, and ZL and all of whom had experience in minilaparotomy and laparoscopic approaches to rectal cancer.

All patients underwent TME with preservation of the hypogastric nerves. Abdominoperineal resection (APR) was performed when the tumor infiltrated the anal canal or when it was impossible to obtain a distal margin of more than 1 cm. For low anterior resection (LAR), stapled end-to-end colorectal anastomoses were constructed. The rectal resection via minilaparotomy approach started with a midline skin incision from the pubis towards the umbilicus less than or equal to 7 cm long (12) (*Figures 1,2*). In case a laparoscopic operation was performed, a five-port technique was used as described previously (14). Both approaches adhered to the principles of total mesorectal excision. Procedures were carried out using the medial-to-lateral approach. The root of the main mesenteric vascular pedicles was initially dissected with lymphadenectomy, and the mesentery and diseased segment of bowel were mobilized from the retroperitoneum.

Patients undergoing LAR received a 5 cm incision for the removal of the specimen and placement of the stapler head. For patients undergoing APR or coloanal anastomosis, specimens were removed through the perineum with no need for an abdominal incision. The protective colostomy was not performed in all patients. Splenic flexure mobilization was conducted when necessary in the laparoscopic approach, but was not performed in the minilaparotomy approach because of small incision. Conversion to open surgery was needed if the surgeon was unable to complete the laparoscopic resection.

Postoperative care

Patients in both groups were managed by the same

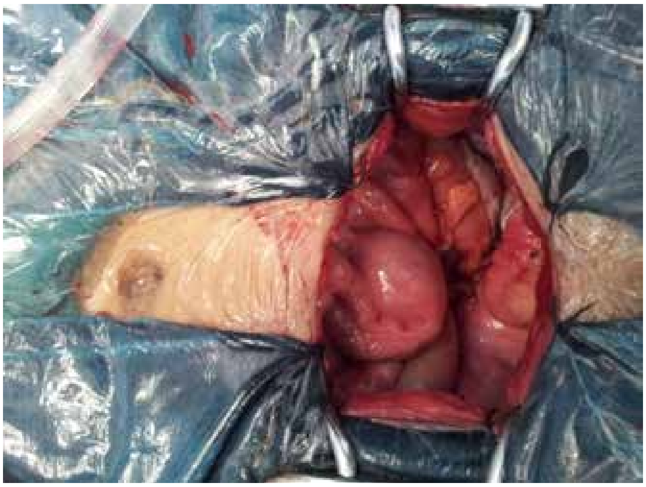


Figure 1 Low anterior resection with the minilaparotomy technique in a male patient with rectal cancer. Automatic abdominal retractor was locked into place by a supporting device to maintain an optimal view of the operating field. Surgical Incision Protective Film (Cheerain Medical Co., Ltd., Shandong, China) was used for laparotomy incisions to protect the minilaparotomy wound from bacterial infection and from contamination by tumour cells.

Figure 2 The skin incision of minilaparotomy technique for the resection of rectal cancer.

postoperative protocol, which included removal of the nasogastric tube at the end of the operation and oral liquids on postoperative day 1. Oral diet was resumed once there were passage of flatus and return of bowel function clinically. Pethidine 1 mg/kg was administered parenterally every 4 h on demand. The patients were discharged when they were fully ambulatory, were passing stools and flatus, could drink and eat solid foods and had no postoperative discomfort. After laparoscopy and open surgery, stage III patients received postoperative adjuvant chemotherapy with 5-fluorouracil and leucovorin for six months.

Follow up

Operative time, blood loss, time to first bowel movement, time to normal diet, length of stay, pain score using visual analogue scale ranging from zero to ten, and complications were recorded. Postoperative complications were classified according to the Clavien-Dindo classification of surgical complications and the grades of complication were recorded. Bladder evacuation disorder was defined as urinary incontinence or incomplete evacuation necessitating catheterization >4 weeks after surgery. Postoperative sexual dysfunction was defined as new onset erectile and/or ejaculatory dysfunction in male patients and as impairment of vaginal lubrication in female patients. The data was collected using the European Organization for Research and Treatment of Cancer (EORTC) QLQ-CR38 questionnaire at 24 months after initial surgery. The costs of the two operations were estimated by summing up the market value of theater time, disposable instruments used, and hospitalization service charge.

After discharge, follow-up was arranged regularly for clinical examination and carcinoem-bryonic antigen (CEA) test at 3-month intervals in the first two years and at 6-month intervals thereafter. The ultrasonography or imaging was not routinely performed. This was only indicated when there was a clinical suspicion of disease recurrence or when CEA level increased over time.

Local recurrence of cancer was defined as the radiologically evidence of tumor recurrence and/or histologically proven tumor within the operation field. Local recurrence in combination with distant recurrence was also considered as a local recurrence event. Distant metastases were defined as any recurrence occurring outside the pelvis.

Pathological evaluation

The rectal specimen was examined in the operation room by the surgeon to assess the distal resection margin and was then sent fresh to the histopathological department, where it was pinned on a cork board. The surface of the mesorectum was inked before slicing to assess the circumferential resection margin. Microscopic assessment included tumour infiltration through the bowel wall (T), the presence of positive lymph nodes (N), and analysis

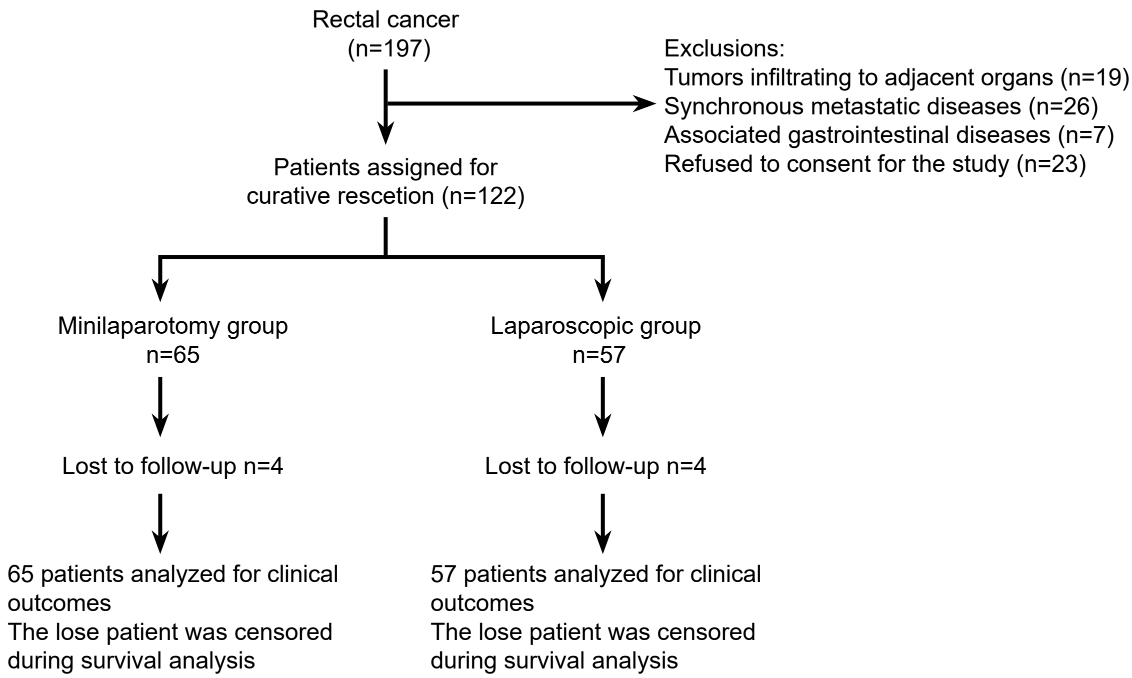


Figure 3 The consort diagram of patient flow.

of the distal and circumferential resection margins. The circumferential resection margin was considered to be positive if it was <1 mm.

Statistical analysis

Data were analyzed using the SPSS 16.0 software (SPSS, Chicago, IL, USA). The chi-square test was used for categorical variables. The Student *t* test or Mann-whitney *U* test were used for parametric and nonparametric continuous variables. Survival was calculated using the Kaplan-Meier method, and comparison between survival curves was performed using the log-rank test. Statistical significance was defined as P<0.05.

Results

Characteristics of patients

Between January 2005 and January 2008, 197 patients with rectal cancer were deemed eligible for participation in the study. Seventy five patients were excluded. The remaining 122 patients were allocated to rectal resection via a minilaparotomy (n=65) or via the laparoscopic approach (n=57). The consort flow chart is presented in *Figure 3*.

There were no differences between the two groups with regard to age, gender, ASA class, history of prior abdominal surgery and tumor location (*Table 1*).

Operative details

As shown in *Table 2*, operative time was longer in the laparoscopic group, but the time to resumption of normal diet was significantly shorter in the laparoscopic group as compared to the minilaparotomy group (median 4 *vs.* 5 days, P=0.024). Both groups were comparable for postoperative pain score. There were no differences between the two groups for the time to first bowel movement (median 3 *vs.* 4 days, P=0.056).Length of hospital stay was lower in the laparoscopic group (median 7 *vs.* 8 days, P=0.043).

The rate of conversion was 8.8% (5/57). The reasons for conversion were bleeding (n=1), pelvic adhesion (n=1) and difficulty in obtaining distal length to accomplish the anastomosis (n=3).The costs in the laparoscopic group were significantly higher than the minilaparotomy group (mean USD 5,532 *vs.* USD 3,913, P<0 .001) (*Table 2*).

Mortality and morbidity

There were no postoperative mortality in the laparoscopic group, and two deaths occurred in the minilaparotomy

Table 1 Patient demographics

	Minilaparotomy (n=65)	Laparoscopy (n=57)	P
Age (years)	59.123±10.711	58.158±11.291	0.629
BMI (kg/m^2)	23 (18.9-26.1)	23.4 (19.3-27.3)	0.117
Sex			0.465
Male	38	37	
Female	27	20	
ASA score			0.211
1	10	9	
2	39	41	
3	16	7	
Type of resection			0.580
LAR	51	47	
APR	14	10	
Distance of tumor from anal verge, cm			0.402
0-4	18	22	
4.1-8	33	23	
8.1-12	14	12	
Neoadjuvant chemoradiotherapy			0.682
Yes	40	33	
No	25	24	
Previous operation			0.374
Yes	8	4	
No	57	53	

LAR, low anterior resection; APR, abdominoperineal resection.

Table 2 Perioperative outcomes

	Minilaparotomy [n=65]	Laparoscopy [n=57]	P
Operative time (minutes, mean ± SD)			
LAR	145.784±46.619	167.064±48.842	0.030
APR	193.571±53.039	249.500±78.332	0.048
Blood loss (mL, mean ± SD)	188.662±172.622	138.842±123.844	0.073
Visual analogue pain score on postoperative day 1 (mean ± SD)	4.785±1.556	4.351±1.598	0.132
Time to first bowel movement (days, median and range)	4 [1-9]	3 [1-8]	0.056
Time to normal diet (days, median and range)	5 [3-11]	4 [3-10]	0.024
Hospital stay (days, median and range)	8 [6-31]	7 [5-22]	0.043
Conversion	—	5 [8.8]	
Direct cost (US $, mean ± SD)	3913.111±840.279	5532.971±886.936	<0.001

LAR, low anterior resection; APR, abdominoperineal resection.

Table 3 Comparison of postoperative complications between two groups

Grade	Minilaparotomy (n=65)	Laparoscopy (n=57)	P
Grade I			
Wound infection	5	2	
Anastomotic bleeding	1	0	
Grade II			
Chest infection	2	1	
Urinary tract infection	1	2	
Urinary retention	1	3	
Deep vein thrombosis	0	2	
Paralytic ileus	4	2	
Incontinence	4	2	
Sexual dysfunction	9	6	
Bladder dysfunction	4	6	
Grade IIIa			
Anastomotic leakage by pelvic tube drainage	1	1	
Abdominal abscess by percutaneous drainage	1	0	
Anastomotic stenosis	2	1	
Grade IIIb			
Reoperation due to anastomotic leakage	1	0	
Reoperation due to incisional hernia	1	0	
Grade IV			
Respiratory failure	1	0	
Congestive heart failure	2	0	
Renal failure	0	1	
Grade V			
Mortality	2	0	
Total number of complications	42 (64.6)	29 (50.9)	0.125
Total number of patients	29 (44.6)	21 (36.8)	0.384

group due to pulmonary embolism and myocardial infarction respectively. Twenty one patients had complications in the laparoscopic group (36.8%) and 29 patients had complications in the minilaparotomy group (44.6%). The total number of adverse events were 29 (50.9%) and 42 (64.6%), respectively (*Table 3*).In the minilaparotomy group, reoperation was required in two patients due to anastomotic leak (n=1) and incisional hernia (n=1).

Oncological outcome

The pathological tumor stage was similar in both groups (*Table 4*). There was no significant difference in the tumor-free distal margin between the groups, but the positive circumferential margin rate was slightly higher in the laparoscopic group although the difference was not statistically significant (*Table 4*).

The mean follow up was 56.6 months (range, 10-84 months). There was no difference in local recurrence (5.3% *vs.* 1.5%, P=0.520) and distant recurrence (8.8% *vs.* 15.4%, P=0.267) between the two groups. Overall 5-year survival was 87.1% in the laparoscopic group and 82.5% in the minilaparotomy group (*Figure 4*; P=0.425). Disease-free survival in both groups is shown in *Figure 5*.

Discussion

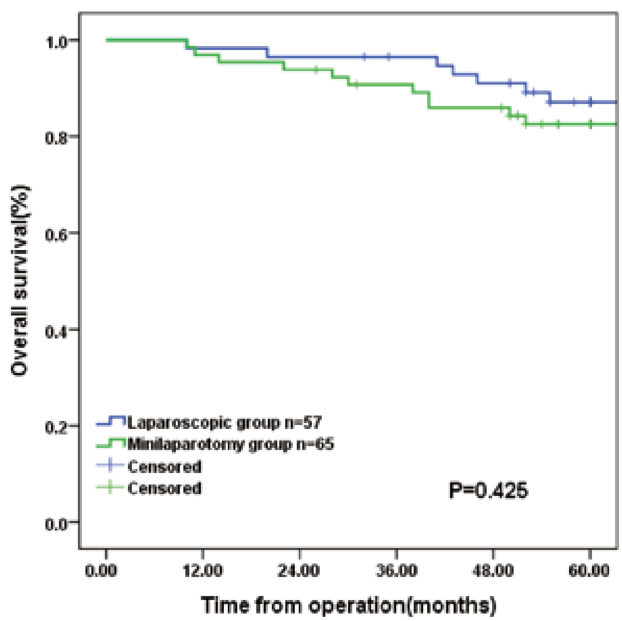
This study comparing laparoscopic with open rectal cancer resection showed that the minilaparotomy approach was similarly safe and oncologically equivalent to laparoscopic approach, and performed with a shorter operative time and lower in-hospital costs than laparoscopic approach.

A previous study showed that the laparoscopic procedure for rectal cancer was associated with a more rapid postoperative recovery and better cosmetic results without compromising oncological outcomes as compared to open surgery (2). Our results also showed that the laparoscopic approach for rectal cancer was associated with an earlier resumption of normal diet and shorter hospital stay, and the time to first bowel movement was shorter in laparoscopic group, but not significant. Contrary to what has been reported previously, the present study failed to demonstrate lower pain scores for the laparoscopic group (15,16). An explanation could be the use of five ports and an about 5 cm abdominal incision for specimen retrieval in the laparoscopic group that might produce more wound pain. The more analgesic consumption might also limit postoperative recovery.

The postoperative complication rate was less in the laparoscopic group, but the difference did not reach significance. Anastomotic leak rate was 1.8% in the laparoscopic group and 3.1% in minilaparotomy group. This leak rate was similar to the results in other studies in the literature (1-13.5%) (4,16-19). Most of the long-term

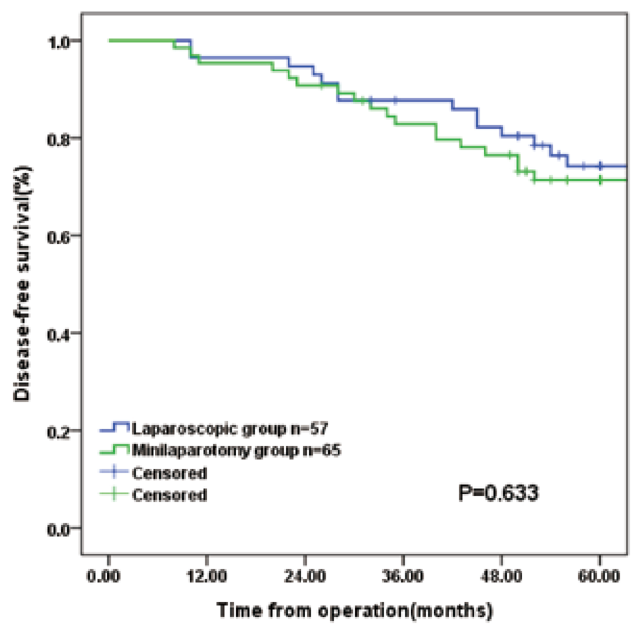
Table 4 Oncological results

	Minilaparotomy [n=65]	Laparoscopy [n=57]	P
Tumour stage			0.647
I	8	6	
II	26	19	
III	31	32	
Grade of differentiation			0.508
Well	18	20	
Moderate	32	28	
Poor	15	9	
Distal margin (mm, median and range)	24 [5-60]	18 [4-55]	0.072
Positive circumferential margin	3 [4.6]	5 [8.8]	0.576
Number of lymph nodes harvested	15.354±6.802	13.737±7.738	0.222
5-year local recurrence	1 [1.5]	3 [5.3]	0.520
5-year distant metastases	10 [15.4]	5 [8.8]	0.267



	Time from operation (months)					
Numbers at risk	0	12	24	36	48	60
Laparoscopic group	57	56	54	53	46	25
Minilaparotomy group	65	63	60	57	49	21

Figure 4 Overall survival rate of patients with laparoscopic and minilaparotomy rectal cancer surgery.



	Time from operation (months)					
Numbers at risk	0	12	24	36	48	60
Laparoscopic group	57	55	53	48	41	22
Minilaparotomy group	65	62	58	52	43	17

Figure 5 Disease-free survival rate of patients with laparoscopic and minilaparotomy rectal cancer surgery.

complications such as anastomotic stenosis, incisional hernia and urogenital dysfunctions were minor and the reoperation rate was low in both arms. This study therefore suggests that the minilaparotomy approach is as safe as the laparoscopic approach and does not lead to higher morbidity.

In the present study, the number of lymph nodes harvested was not different between the two groups. The distance between the tumor and distal resection margin was slightly less in the laparoscopic group and the rate of involved circumferential margin was higher, although these differences were not statistically significant. This finding is similar to the findings in the CLASICC-trial where the circumferential margin involvement rate was 12% in the laparoscopic group and 6% in the open group (P>0.05) (4,17). The CLASICC trial suggested that laparoscopic LAR could be associated with a slightly increased risk of local recurrence (4). However, recent studies suggested laparoscopic results showed equal distal margin length and the rate of margin positivity when compared to open surgery (20). A possible explanation may be that we did not have a longer learning curve and enough experience, and could not obtain enough distal length and locate the tumor to accomplish the anastomosis in many very low rectal cancer patients. Furthermore, in laparoscopic surgery, we used linear stapler which cannot bend at the distal shaft. It was very difficult for us to get longer distal margin in low rectal patients with narrow pelvis. The third reason may be that the tumors were slightly more distal and lower in the laparoscopic group compared with the minilaparotomy group.

Conversion to an open operation is an important indicator for laparoscopic success. The conversion rate was 8.8%, which was similar to the rates reported in the literature (6-15.5%) (16,21-23). Factors predictive of conversion are the size of tumor, bleeding, the experience of the surgeon, and the inability to localize small tumors (24). In this study, the major cause for conversion was an inadequate laparoscopic resection leading to an inadequate excision. Preoperative colonoscopic tattooing was a safe and effective method for tumor localization in laparoscopic colorectal surgery (25). Intraoperative colonoscopy was also a way of definitively localizing a lesion (26).

Port site recurrence has been reported after laparoscopic resection of colorectal cancer (0-1.4%) (24,27). In the present study, there was no port site recurrence. More importantly, there was no difference in overall and disease-free survival between minilaparotomy and laparoscopic group, and local and distant recurrence rates were similar in both groups. Similar results that supported the equivalence of oncologic outcomes have been reported in several single-institution comparative or randomized controlled studies (16,17,28). This study indicates that the minilaparotomy approach is oncologically feasible.

In this study, splenic flexure mobilization was conducted when necessary in the laparoscopic approach, but could not be performed in the minilaparotomy approach because of small incision. Some surgeons, especially those in Western countries, have suggested that wide splenic flexure mobilization was crucial to obtain adequate resection with tension-free anastomosis in rectal cancer surgery (29). However, we found that most patients need not splenic flexure mobilization to complete the anastomosis in the minilaparotomy approach, unless some patients with very short sigmoid colon and large quantities of mesentery fat. Some investigators from Asian countries have shown that Laparoscopic and open procedures without routine splenic flexure mobilization in the treatment of rectal cancer was feasible and did not seem to increase postoperative morbidity or oncologic risk (30,31).

The patients in minilaparotomy group were not overweight, because obesity was the risk factor preventing the success of the minilaparotomy approach in the resection of colorectal cancer (32), and almost all surgeons seem to agree that obesity reduced the technical feasibility of the minimally invasive laparoscopic and minilaparotomy approaches (3,10,11). Since the incidence of overweight or morbidly obese patients in Asia is probably lower than in Western countries (12,33), we feel that minilaparotomy is a suitable technique for many Asian patients with rectal cancer.

In conclusion, minilaparotomy approach is comparable to the laparoscopic approach in terms of postoperative complications and oncological outcomes, demonstrating the feasibility and the efficacy of the minilaparotomy approach. Laparoscopic approach has an advantage over minilaparotomy approach in allowing earlier recovery. However, this is at the expense of a longer operating time and higher direct costs. The minilaparotomy approach for resection of rectal cancer is an attractive alternative in highly selected patients. A criticism of the study is the fact that allocation of the patients was not random, which may present potential biases. A large-scale randomized trial for comparison of minilaparotomy and laparoscopic rectal cancer surgeries is needed. Careful patient selection is also crucial.

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None.

Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

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Emerging single port laparoscopic colorectal surgery

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We read with great interest the Editorial "Single port laparoscopic colorectal surgery: what did we learn from the ECSPECT prospective multicenter registry study?" by Marks and Nagatomo (1).

First, we gratefully appreciate the congratulations and want to thoroughly answer the questions that were raised in this article.

Oncologic outcome

Regarding the oncologic outcome of single port surgery (SPS) we want to clarify that our study (2) was not designed to prove any benefit of SPS over multiport laparoscopic surgery (MPS) in the long term follow-up. However, overall survival rates and local recurrence rates will be obtained for the study population in 2019 continuing the registry for five more years. Due to the insight we gained through the preliminary long-term registry data, we are very confident that these will be comparable to survival and recurrence rates of MPS in the current literature.

Patient selection

Another question was posed to clarify if any selection indicator for SPS versus MPS was defined throughout the protocol. As a limitation to enter the study all participating centers providing data had patients treated by experts in SPS (all being early adopters with more than 100 procedures before enrollment). No conformity was required to preoperatively select patients for SPS. Therefore five centers predominantly included patients with left-sided colectomies, two centers mainly performed right-colon resections but SPS on the rectum was performed only in seven of the eleven centers. In contrast to the recommendation to identify low risk patients in SPS for elective cholecystectomy, no selection was made based on gender, age, BMI or ASA scores. Anyhow, the large number of patients was sufficient to calculate a novel risk chart which alleviates preoperative selection according to the experience of the surgeon.

Incisional length

Regarding the concern that the technique itself is prone to develop hernia due to the length of the incision in SPS, we would like to bring to attention that literature has yet failed to give a convincing proof of principle for the following conceptual consideration:

The calculated length of an incision required to pass a 10 mm trocar (with an outside diameter of >1,150 mm) for MPS is half of the circumference and results in >1,806 mm (tissue tension and elasticity not taken into account). On the other hand three 5 mm instruments (with an outside diameter of 5 mm each) required for SPS can be delivered via a glove port through a calculated incision of 1,692 mm (using the same mathematical design approach). Derived from the ideal length of incision it is clear that SPS does not have a higher intrinsic risk for incisional hernia compared to MPS utilizing at least one 10 mm trocar or any specimen retrieval requiring an incision of 18 mm or more.

The short observational period in our study cannot refer on valid hernia rates other than wound dehiscences and infections (2.5%). It is of note that 92% of SPS were completed without any additional incision in the ECSPECT registry study. The average length of skin and fascial incision in the colorectal patient cohort of our department yielded 4,610 and 4,413 mm, respectively (tension free measurements).

Technical details

In all procedures extra-long (bariatric length) optical devices (30° rod lens systems) were used. Surgeons predominantly used straight working instruments (62.2%) followed by curved instruments (37.8%). All surgeons preferred a straight instrument in the dominant hand. Multivariate linear regression confirmed the use of one curved instruments in the helping hand as predictor for shorter operation time.

Finally, we are convinced that future data will clarify some of the concerns about SPS by providing more published evidence that this type of surgery widens the armamentarium of colorectal surgeons to offer their patients minimized minimal invasive but maximal effective surgical treatment.

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Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

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Comparison of short-term outcomes between laparoscopic-assisted and open complete mesocolic excision (CME) for the treatment of transverse colon cancer

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Contributions: (I) Conception and design: Y Wang; (II) Administrative support: All authors; (III) Provision of study materials or patients: Y Wang, C Zhang, YF Feng; (IV) Collection and assembly of data: All authors; (V) Data analysis and interpretation: All authors; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

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Background: Colorectal cancer (CRC) is the third most common cancer worldwide. Although laparoscopic-assisted complete mesocolic excision (LCME) is a superior treatment, there are few studies available on it owe to the low incidence and technical difficulty of LCME in transverse colon cancer.

Methods: The clinical data of 78 patients with transverse colon cancer who were treated by LCME and open complete mesocolic excision (OCME) were retrospectively analyzed. A total of 39 cases had been treated by LCME, compared with 39 cases treated by OCME. The patient characteristics and short-term outcomes including operation time, intra-operative blood loss, length of incision, time to first flatus, first postoperative ambulation, postoperative hospitalization time, number of harvested lymph nodes, length of resected specimen and incidence of complications were evaluated.

Results: There was no case converted to OCME in LCME group. LCME had significantly shorter length of incision, shorter operation time, less intra-operative blood loss, shorter postoperative hospitalization time ($P<0.05$). The length of resected specimen and the numbers of harvested lymph nodes were (26.5±5.4 cm) and (16.2±3.1) in LCME group, and (24.8±4.9 cm) and (15.1±3.5) in OCME group, with no differences between two groups. The incidence of wound infection was lower while the incidence of lymphatic leakage, anastomotic leakage, urinary tract infection and wound dehiscence had no significant differences between two groups. None of patients in these two groups developed urinary retention, anastomotic bleeding and postoperative intestinal obstruction.

Conclusions: Our findings suggested that LCME is a safe, feasible and effective treatment method for the treatment of transverse colon cancer due to it can provide superior short-term outcomes including less intra-operative blood loss, faster recovery and lower incidence of wound infection.

Keywords: Laparoscopy; complete mesocolic excision (CME); transverse colon cancer; short-term outcomes

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Introduction

Colorectal cancer (CRC) is the third most common cancer worldwide (1), which is a leading cause of cancer death (2). Complete mesocolic excision (CME) is considered to be the standard CRC surgeries due to it can reduce local recurrence and improve long-term survival (3). Since the first application of laparoscopic surgery in 1991 (4), laparoscopic technique has been introduced to many surgical fields such as the treatment of CRC with the advanced laparoscopic instruments and technique (5).

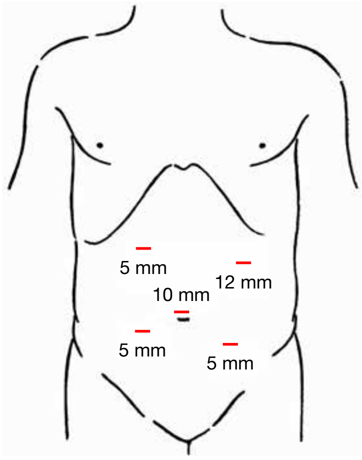

Figure 1 The position of 5 trocars in LCME. A 10-mm trocar was introduced in the umbilical region for the placement of laparoscope. A 12-mm trocar insertion was located at the intersection of the left midclavicular line (MCL) and the horizontal line of midpoint between the xiphoid and the umbilicus which can be used as a working port. Three additional 5 mm ports were placed on the midpoints of connection line between umbilicus and both sides of anterior superior iliac spine, and 3 cm under the costal margin of right subclavian midline using as assistant working ports, respectively.

Previous studies have reported that LCME is a superior approach for CRC benefit from less pain and blood loss, shorter recovery and hospital stays, better cosmetics and short-term outcomes, and reduced morbidity (6,7). However, there was no significant difference in disease-free survival of patients between LCME and OCME in a larger trials (8). Presumably because of the low incidence and technical difficulty of laparoscopic CME in transverse colon cancer (9) including safely take down and fully mobilization of the splenic flexure and hepatic flexure, large separating surface and high-precision technique (10), there are few studies available on it (11).

In this study, we aim to compare the short-term outcomes of the CME for transverse colon cancer between laparoscopic and open approaches and to identify the safety and feasibility about LCME.

Methods

Patient selection

We retrospectively collected the clinical data of patients with transverse colon cancer between October 2014 and February 2016. All participants gave informed written consent. The research protocols were approved by the ethical committee of our hospital (2014-SRFA-188). Transverse colon cancer was defined as the tumor at 1/3 in the middle of transverse colon. Transverse colon cancer was confirmed by a routine biopsy, colonoscopy, computed tomography (CT) scans and magnetic resonance imaging (MRI). MRI was used to identify the suspicious liver metastatic. A total of 78 patients were included in this study. Both LCME and OCME were treatments for transverse colon cancer and the choice of surgical approach was based on patient's wishes after the surgical procedures, possible risks and discomforts of these two approaches were informed to patients. Among the 78 patients, 39 patients underwent LCME and the remaining 39 patients underwent OCME. Exclusion criteria for CME were as follows: (I) Patients with severe cardiac, pulmonary insufficiency and can not tolerate surgery after active treatment; (II) recurrent cancer patients after operation; (III) patients with tumor involving other organs; (IV) patients with tumor perforation or acute obstruction; (V) patients with secondary CRC; (VI) patients undergoing LCME converted to OCME; (VII) patients with tumor involving adjacent tissues and organs and can not be cured by resection; (VIII) patients with non-adenocarcinoma.

Surgical techniques

Preoperative evaluations

Before surgery, routine examination including blood, coagulation, blood type, biochemical tests, electrocardiography (ECG), five hepatitis B, HIV, HCV, RPR, urine, stool, colonoscopy, chest and abdomen enhanced CT, and MRI were performed to make definite diagnosis and exclude surgical contraindications. Before surgery, all patients were fasted for 12 h, forbidden to drink for 4 h. On the evening before surgery, all patients took polyethylene glycol electrolyte powder solution for bowel preparation. All the surgeries in both groups were performed with the same surgeon. Endotracheal intubation was performed under general anesthesia and routine catheterization. All patients were placed in supine position with legs separated and fixed. The surgeon stood to the left side of the patient, the first assistant stood to the right side of the patient, while the second assistant holding a mirror stood between the two legs of patients.

LCME

Five-trocar method (*Figure 1*) was applied in CME. After routine abdominal exploration, procedures were performed with a median-to-lateral approach. Below the horizontal part of duodenum, we dissected the serous membrane, and dissected the sheath of superior mesenteric vein (SMV) (*Figure 2A*). Dissection was proceeded along the SMV. After entering the sub-fascial space of the pancreatoduodenal fascia, we dissect the superior mesenteric artery (SMA), removed connective tissues and lymph nodes in front of SMA, then enter the right Toldt's gap, followed by a dissection extending upward to the hepatic flexure ligament of the colon and outward until the lateral fusion fascia of ascending colon. After dissecting the middle colic artery along with SMV, we removed the lymph nodes following by the division of the middle colic artery from the root after the (*Figure 2B*). Thereafter, we dissected the Henle's trunk, and divided the right colic vein (*Figure 2C*) with the preservation of right gastric-omentum vein. After dividing the middle colic vein, we divided the lower edge of pancreas and anterior pancreatic space (*Figure 2D*), and separated the space between pancreatic and gastric. The surgeon exchanged the position with the first assistant. Then we pulled out the inferior mesenteric vein and dissected the serous membrane and extended upward to the lower edge of pancreas, and downward to the root region of the inferior mesenteric artery. Entered the left side of Toldt's gap with a dissection extended upward the lower edge of the pancreas tail and outward until the lateral fusion fascia of descending colon. Then the upper region of colon was steered.

After opening the gastrocolic ligament, we resected the greater omentum. Then we divided the pancreas attachment of the root region of right side of the transverse mesocolon, cut off the hepatic flexure ligament of colon (*Figure 2E*), divided the outside fusion fascia of ascending colon and converged into the inferior separation of gap. Thereafter we divided the pancreas attachment of the root region of the left side of the transverse mesocolon root, resected the ligament of splenic flexure (*Figure 2F*), divided the outside fusion fascia of descending colon and converged into the inferior separation of gap. Through above procedures, we completely separated the transverse colon, hepatic flexure, ascending colon, descending colon and splenic flexure. Finally, the resected specimen was obtained (*Figure 2G*).

OCME

A 5-cm incision protected with the protective sleeve made on the upper abdominal midline. After pulling out the transverse colon *in vitro*, the classic transverse CME techniques were conducted.

Postoperative treatment

Conventional ECG monitoring was conducted in all patients for 12 hours. Three days after surgery, all patients were routinely given treatment including supplement of body fluid, anti-infection, acid suppression, maintain the balance of acid-base and water electrolyte. On the first postoperative day, the motion of patients was encouraged. Approximately 3 days after surgery, a liquid diet was begun after first flatus which was allowed to transition to a normal diet. On the third postoperative day, blood and biochemical tests were performed to all patients, patients who were anemia or hypoproteinemia were given a blood transfusion, albumin transfusion therapy respectively. On the first or second postoperative day, the catheter was removed. A measurement of drainage fluid and observation characters was performed and the drainage tube was removed on the fifth or sixth postoperative day.

Clinical characteristics, including operation time, intra-operative blood loss, length of incision, number of harvested lymph nodes and length of resected specimen were compared between the LCME and OCME groups.

Short-term surgical outcomes including first flatus, first postoperative motion/movement, postoperative hospitalization time and complications were compared between the LCME and OCME groups.

Statistical analysis

Data were analyzed by using SPSS for Windows (version 18.0). We used chi-square test to compare categorical values between LCME and OCME group. An independent *t*-test was applied to compare measurement data between each two groups. Quantitative data are expressed as means ± standard deviations (SD), and measurement data are expressed as n or percentage. P values of less than 0.05 were considered statistically significant.

Results

Baseline characteristics

There were 39 cases in LCME group and 39 cases in OCME group, respectively. In LCME group, 21 were men and 18 were women, with a mean age of 58.3±5.8 years (range, 26–84 years). The distribution of tumors according to TNM stage was as follows: Stage I in 4 patients, Stage II in 16, Stage III in 19. In OCME group, 20 were men and 19 were women, with a mean age of 57.5±6.9 years (range, 28–

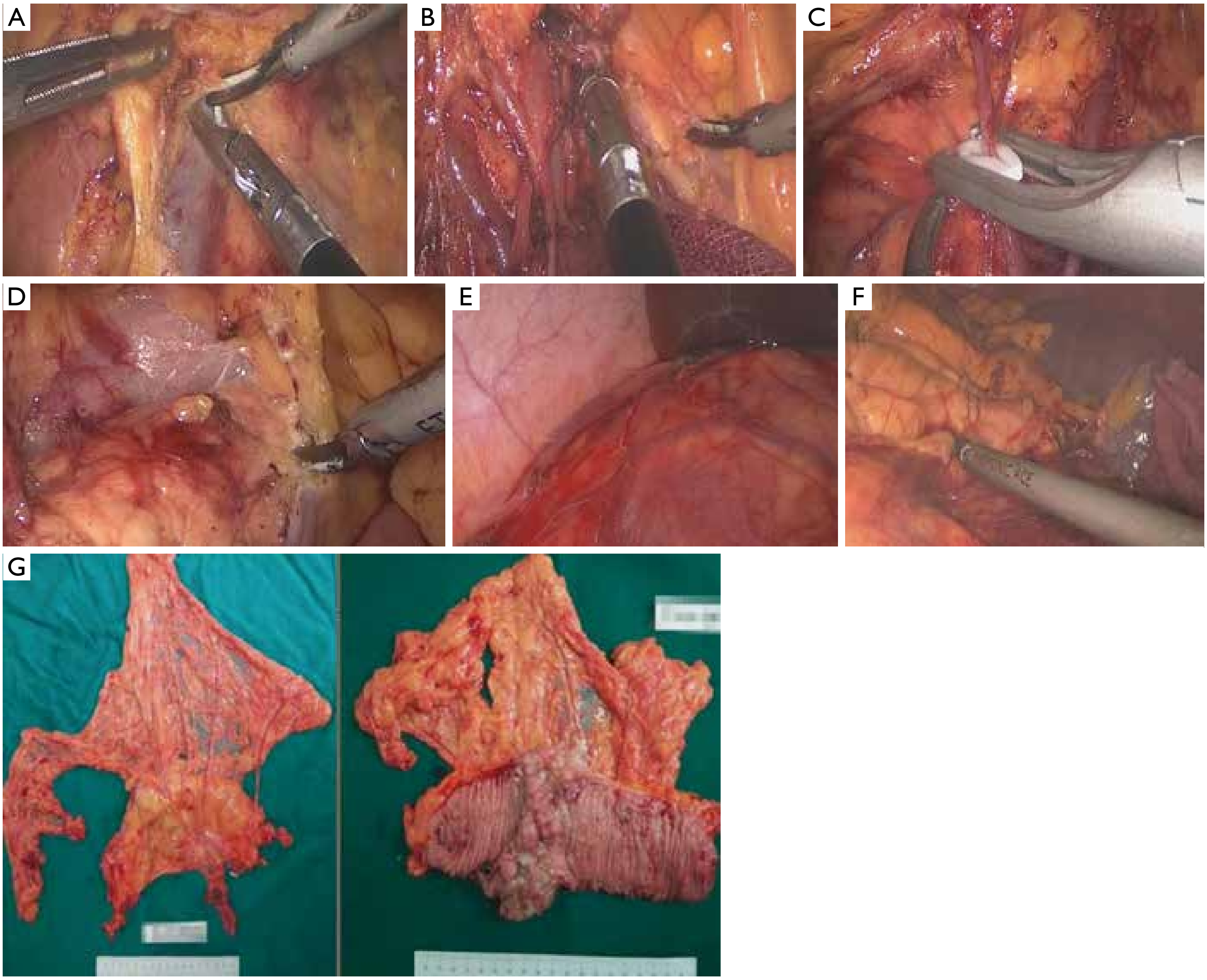

Figure 2 Laparoscopic-assisted complete mesocolic excision (LCME) for transverse colon cancer. (A) Free the root of transverse mesocolon; (B) lymph nodes resection at the root of transverse mesocolon; (C) amputated the right colic vein; (D) free the space in front of the head of the pancreas; (E) free the hepatic flexure of colon; (F) free the splenic flexure of colon; (G) resected specimen after LCME.

85 years). TNM stage was as follows: Stage I in 3 patients, Stage II in 15, Stage III in 21 (*Table 1*). There was no statistical significant difference regarding age, gender and TNM stage between the two groups.

Perioperative outcomes

LCME group were significantly better than OCME group ($P<0.05$) in intra-operative blood loss (61.6±18.7 *vs.* 115.4±35.4), length of incision (7.3±1.8 *vs.* 18.7±4.7), time to first flatus (1.5±0.6 *vs.* 3.2±0.9), and first postoperative ambulation (1.3±0.4 *vs.* 2.9±0.8). There were no significant differences in operation time (119.7±27.5 *vs.* 128.6±30.1), postoperative hospitalization time (8.1±2.9 *vs.* 10.1±2.2), number of harvested lymph nodes (16.2±3.1 *vs.* 15.1±3.5), and length of resected specimen (26.5±5.4 *vs.* 24.8±4.9) between LCME group and OCME group (*Table 2*).

There was no significant difference in the total incidence of short-term postoperative complications between LCME and OCME groups (12.81% *vs.* 15.38, $P>0.05$). However, the incidence of wound infection was significantly lower with laparoscopy (2.56%) than by the open approach

Table 1 Patient demographics

Variable	LCME (n=39)	OCME (n=39)	P value
Age	58.3±5.8	57.5±6.9	0.581
Male/female			0.821
Male	21	20	
Female	18	19	
TNM classification			0.893
0	0	0	
I	4	3	
II	16	15	
III	19	21	

LCME, laparoscopic-assisted complete mesocolic excision; OCME, open complete mesocolic excision.

Table2 Postoperative short-term outcomes in the LCME and OCME groups

Variable	LCME (n=39)	OCME (n=39)	P value
Operation time, min	119.7±27.5	128.6±30.1	0.1768
Intra-operative blood loss*, mL	61.6±18.7	115.4±35.4	<0.0001
Length of incision *, cm	7.3±1.8	18.7±4.7	<0.0001
Time to first flatus *, d	1.5±0.6	3.2±0.9	<0.0001
First postoperative ambulation*, d	1.3±0.4	2.9±0.8	<0.0001
Postoperative hospitalization time, d	8.1±2.9	10.1±2.2	0.001
number of harvested lymph nodes, n	16.2±3.1	15.1±3.5	0.1459
Length of resected specimen, cm	26.5±5.4	24.8±4.9	0.1495

*, statistically significant between-group difference (P values <0.05). LCME, laparoscopic-assisted complete mesocolic excision; OCME, open complete mesocolic excision.

(7.69%). Lymphatic leakage, anastomotic leakage, urinary tract infection and wound dehiscence were occurred in 1 group or both 2 groups, there was no significant difference in the incidence (*Table 3*). None of patients in both groups developed urinary retention, anastomotic bleeding and intestinal obstruction.

Table 3 Complications in LCME and OCME groups

Complications, n (%)	LCME (n=39) (%)	OCME (n=39) (%)	P value
Wound infection*	1 (2.56)	6 (7.69)	0.048
Lymphatic leakage	2 (5.13)	1 (2.56)	0.556
Anastomotic leakage	1 (2.56)	1 (2.56)	1
Urinary tract infection	1 (2.56)	0	1
Wound dehiscence	0	1 (2.56)	1
Total incidence	5 (12.81)	6 (15.38)	0.745

*Statistically significant between-group difference (P values<0.05). LCME, laparoscopic-assisted complete mesocolic excision; OCME, open complete mesocolic excision.

Discussion

Although previous studies have demonstrated that LCME is a safe and feasible treatment for CRC (6,7,10), the majority of trials excluded cases of transverse colon cancer due to the technical difficulty (10,12,13). Our study compared the feasibility, safety and short-term outcomes between LCME and OCME groups.

In terms of intra-operative outcomes, the length of incision was significantly shorter and the blood loss was less in LCME group than OCME group which suggested that LCME is more precise. Although there was no significant difference in operation time between these two groups, the operation time in LCME is shorter. It suggested that we can overcome the technical difficulty, shorten the operative time and be proficient in LCME. In our study, the numbers of lymph nodes retrieved in these two groups were similar. We can conclude that not only LCME but also OCME have the same oncologic clearance effects.

Previous studies have demonstrated that the postoperative hospitalization time in LCME for CRC is always shorter (7,14). Since the technical difficulty there was no significant difference in postoperative hospitalization time between these two groups, it was still shorter in LCME. In addition, LCME was found to be better in time to the first flatus and first postoperative ambulation after surgery. It suggested that recovery of patients in LCME was faster.

Similar or reduced complications were always reported in LCME for right colon cancer (7,15-18). There was no significant difference in the total incidence of short-term postoperative complications between these two groups in our study. A systematic review and meta-analysis have reported that complications were similar in LCME and OCME for transverse colon cancer, which supported our results (15). However, the incidence of wound infection was significantly less with laparoscopy due to the shorter incision. So LCME is as safe and feasible as OCME.

Due to the high-definition vision, amplification effect of laparoscope, and with the application of ultrasonic knife, laparoscopic surgery can be applied to separation of surgical surfaces, based on the similar operative effects, the length of incision in LCME is shorter and it's helpful to reduce the blood loss and recover faster.

Moreover, no tumor metastasis and recurrence is crucial for prognosis of CRC. To prevent the metastasis and local recurrence of CRC, intraperitoneal chemotherapy was proposed. Cytoreductive surgery and intraperitoneal chemotherapy may significantly increase the exposure of cancer drugs to cancer present within the peritoneal cavity or liver which may be helpful to repress the metastasis and local recurrence of CRC and are closely associated with prolonged overall survival and even cure of CRC (19-21). In our study, to prevent the formation of the incision planter and further implement the principle of non-contact, we removed the tumor with the incision was protected by protective sleeve. To prevent the formation of planter induced by direct contact between the polluted laparoscopic instruments and the puncture hole, the trocar was fixed to the abdominal wall. To prevent the formation of incision planter induced by intraperitoneal gas which carried tumor cells, we removed the trocar after the discharge with the puncture sheath in the end of surgery. In addition, Kim *et al.* has reported that central ligation of the main feeding vessels, complete removal of the mesocolon with sharp dissection, and adequate proximal and distal margins were benefit for improved oncologic outcomes. In our study, we resected both ends of the 10cm bowel of tumor, dissected the lymph nodes of mesenteric roots and removed the whole transverse mesocolon to manage for infrapyrolic node or splenic node metastases.

To ensure the security and effectiveness of CME and repress tumor metastase, several key points were concluded from our operative experiences in CME. These principles were as follows: (I) Explore the liver, spleen, stomach, pelvic, mesenteric root, tumor and adjacent organs from far to near; (II) resect adequate bowel (both ends of the 10 cm bowel of tumor) and dissect the lymph nodes of mesenteric roots; (III) separate the Toldt's gap accurately, maintain the integrity of Toldt's fascia and resect the lesions bowel and mesentery from roots completely; (IV) apply median-to-lateral approach, ligate the mesenteric vessels on the root firstly and then performed resection and dissociation; (V) precise and gentle operating practice.

Last but not least, LCME was reported to reduce the postoperative mortality and to have more clinical significance especially in elderly patients (22). The main drawback in the present study is the deficiency of long-term oncological follow-up and need further research.

In conclusion, despite the technique difficult in surgery, LCME is more safe and feasible for the treatment of transverse colon cancer because it could provide better short-term outcomes including less blood loss and faster recovery compared to that of OCME. Further studies with longer term of follow up are required to confirm the efficacy of LCME/ confirm our findings

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None.

Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

Ethical Statement: All participants gave informed written consent. The research protocols were approved by the ethical committee of our hospital (2014-SRFA-188).

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Completed mesocolic excision for right colon cancer: comparison between single-port laparoscopy and conventional laparoscopy

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Abstract: Complete mesocolic excision is believed to play an important role in the treatment for colon cancer. While evidence has shown that laparoscopic surgery is not a technique barrier for CME, the feasibility of single-port laparoscopy is still controversial. In this article we discussed the difference between the single-port and conventional laparoscopic CME surgery for right colon cancer and summarize the key techniques and tips for operation.

Keywords: Complete mesocolic excision; laparoscopy; right colon cancer; single-port surgery

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As an increasingly sophiscated procedure, laparoscopic colorectal surgery has been widely applied in clinical settings (1-3). Along with technical development and innovation, some laparoscopy-based novel techniques such as robotic surgery, natural orifice transluminal endoscopic surgery (NOTES), and single-port laparoscopic technique have emerged.

The robotic surgical systems have many advantages including decreased hand vibration, increased operational freedom, shortened living curve, and feasibility of remote operation. However, their high cost and prolonged surgical duration have restricted their applications in China. NOTES requires further innovations before it can be widely applied in clinical settings. In contrast, the single-port laparoscopy has shorter learning curve than NOTES (4); furthermore, by using the conventional laparoscopic devices, it can also achieve cosmetic and minimally invasive effects by hiding the scars. Therefore, single-port laparoscopy may be a more promising minimally invasive technique for Chinese patients.

In 2009, the German scholar Hohenberger *et al.* (5) for the first time proposed the concept of completed mesocolic excision (CME). CME shares the similar principles of embryology and anatomy with total mesorectal excision (TME). In fact, the mesocolon is also covered by two layers of visceral fascia, which are somehow like an "envelope". Just based on this anatomic basis, Hohenberger proposed the concept of CME, which includes the sharp separation of parietal fascia from visceral fascia and meanwhile avoids any visceral fascia breakage that may cause tumor spread; furthermore, the beginning portion of colon vessel must be thoroughly exposed and ligated at its root, so as to maximize the scope of lymph node dissection and thus increase the survival rate (6,7).

As people become more familar with the concept of CME, an increasing number of laparoscopic colorectal surgeons have shown interest in this hot topic and began to apply this technique in their clinical practices (8-10). For these ambitious surgeons, CME under single-port laparoscopy has become another target. Then, the

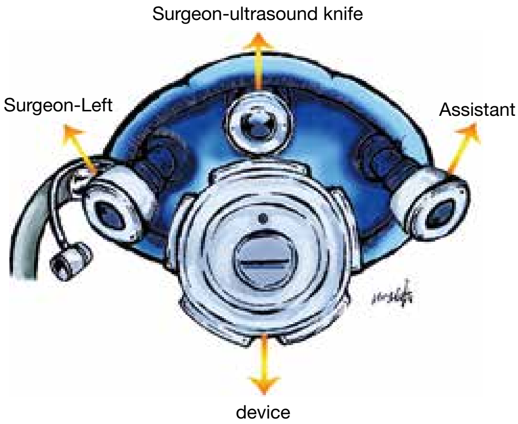

Figure 1 The four-channel single-port device.

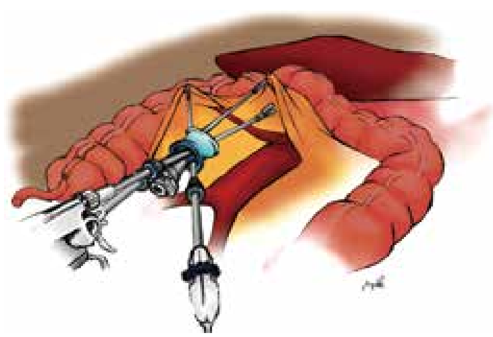

Figure 2 The traction effectiveness after the placement of relevant instruments in the single-port device.

questions are: is CME a feasible technique for the radical resection of colon cancer? What are the key techniques and difficulties of successful surgeries under single-port laparoscopy?

Differences do exist between the single-port laparoscopy and conventional laparoscopy. Compared with the conventional laparoscopy, the single-port laparoscopy is restricted by the "single port", i.e., all the devices need to enter the abdominal cavity via one single port. As a result, the surgical operations lack adequate angles and the devices may collide and interfere with each other. Counter-traction may be particularly difficult, and sometime the operator needs to cross their hands during operation. In addition, most single-port devices only provide 3–4 operating channels, which are 1–2 less than the conventional laparoscopic colorectal surgery, in which 5 ports are often used. Thus, the traction and exposure can be more difficult if these single-port devices are used (11).

Therefore, compared with the conventional laparoscopic surgeries, the main challenge of the single-port laparoscopic radical resection of right colon cancer is how to take advantage of a variety of conditions to create good operating angles; meanwhile, the operator must be skillful enough to perform CME.

Single-port devices and trocar design

Placement of the single-port device

Similar to the location of the trocar for camera port during a conventional laparoscopic surgery, the single-port device (SILS™ Port) is placed on the midline 2 cm below the umbilicus after opening the abdominal cavity layer-by-layer.

By using the insufflation channel in the SILS™ Port, a 5-mm device is also placed, so that the initially 3-channel device becomes a 4-channel device; thus, an additional Trocar and an additional auxiliary device (used by the assistant) can be applied for traction, if necessary.

In a conventional laparoscopic surgery, the locations of Trocars need to be reasonably designed; similarly, in a single-port laparoscopic surgery, which instruments should be placed in the 3–4 channels in the SILS™ Port should also be carefully considered, so as to increase the convenience of surgical operation and the effectiveness of space exposure. According to our experience, when these channels are placed as in *Figures 1* and *2*, a good operation triangle can be obtained, which can facilitate the exposure of surgical field, increase the convenience of operation, and reduce the interferences among devices.

Selection of surgical approaches

Similar to the surgical approaches used in the conventional laparoscopic multi-port radical surgery for right colon surgery, the single-port laparoscopic right colon surgery also follows the principle of medial approach, during which a strategy of "making breakthrough in central area after encircling the lateral areas" and a tactic of "upwards, outwards, and combination of downwards and upwards" were adopted (12).

Surgical skills

We divide the radical treatment of right colon cancer by conventional 5-port laparoscopy or single-port laparoscopy into several key operational scenarios to compare these two surgeries; furthermore, based on the similarities and

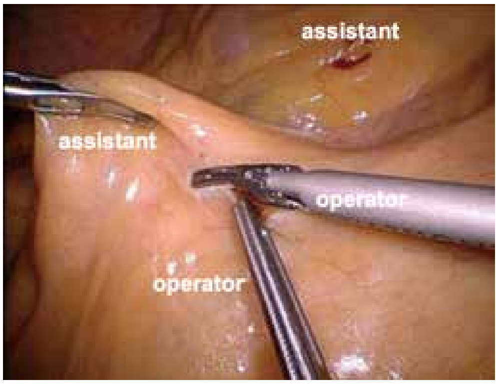

Figure 3 Opening a window in the mesentery using a conventional 5-port method.

Figure 4 Opening a window in the mesentery using single-port laparoscopy.

differences between these two operations, we try to explore whether the single-port laparoscopy could also achieve the effectiveness of 5-port laparoscopy during the CME in right colon.

Scenario 1: handle ileocolic vessels—open a window at the mesenterium

The conventional 5-port laparoscopy

Beginning from the lower margin of ileocolic vascular pedicle, the operator cut open the mesocolon to open the "window", so as to search for and enter the space behind the right colon.

The assistant lifts the mesocolon at the middle of middle colic vascular pedicle towards the head and abdominal sides with left hand and lifted the ileocolic vascular pedicle outwards and downwards using using his/her right hand, so

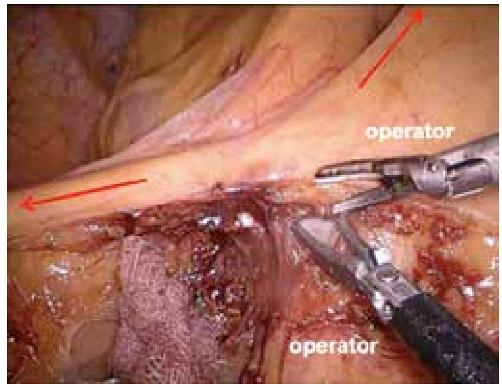

Figure 5 Opening the SMV sheath using a conventional 5-port method.

as to produce sufficient tension and thus achieve exposure (*Figure 3*).

Single-port laparoscopy

The operator pulls the ileocolic vascule pedicle with his/her own left hand, which replaces the role played by the assistant during a conventional 5-port laparoscopic surgery; meanwhile, the operation by the right hand begins from the lower margin of ileocolic vascular pedicle, so as to open a window on the mesocolon and identify the space behind the right colon.

The assistant then can take a break. If the operation can be completed using a small number of devices, the smallest number of devices should be used as possible, so as to avoid unnecessary interference among devices in a single port (*Figure 4*).

Scenario 2: handle ileocolic vessels—open the SMV sheath

The conventional 5-port laparoscopy

The operator uses a separating forceps in left hand to open the vascular sheath on SMV surface and uses the high intensity focused ultrasound (HIFU) in right hand to cut open the vascular sheath.

The assistant lifts the mesocolon at the middle of middle colic vascular pedicle towards the head and abdominal sides with left hand and lifts the ileocolic vascular pedicle outwards and downwards with right hand, so as to produce sufficient tension and thus achieve exposure (*Figure 5*).

Single-port laparoscopy

The operator lifts the vascular sheath on SMV surface with

Figure 6 Opening the SMV sheath using single-port laparoscopy.

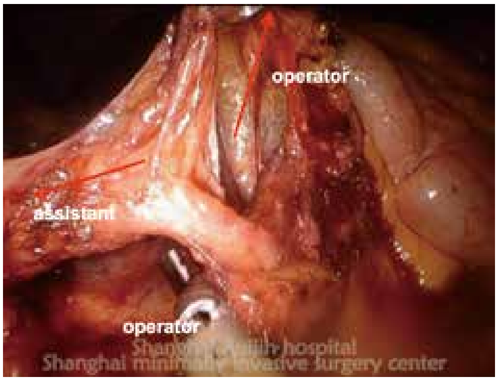

Figure 8 Exposing the vascular root using single-port laparoscopy.

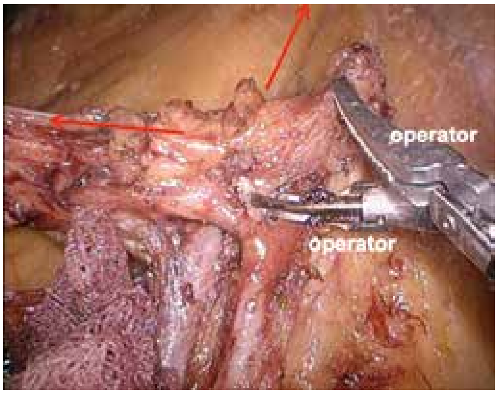

Figure 7 Exposing the vascular root using a conventional 5-port method.

left hand and cuts open the vascular sheath using HIFU in right hand.

The assistant pulls the ileocolic vascule pedicle (*Figure 6*).

Scenario 3: handle ileocolic vessels—expose the vascular root

The conventional 5-port laparoscopy

The operator lifts the mesocolon in front of SMV with left hand and then exposes the vascular root with a separating forceps or HIFU in right hand.

The assistant lifts the mesocolon at the middle of middle colic vascular pedicle towards the head and abdominal sides with left hand and lifts the ileocolic vascular pedicle with right hand (*Figure 7*).

Single-port laparoscopy

The operator uses left hand to lift the mesocolon in front of SMV, which partially replaces actions initially performed by the assistant. The right hand, in most cases, still goes alone: it uses a separating forceps or HIFU to complete technical actions such as picking, pulling, isolating, and separating, so as to expose the vascular root.

The assistant's actions are relatively simple: he/she pulls the ileocolic vascular pedicle outwards with right hand to maintain appropriate tension (*Figure 8*).

Scenario 4: extend the space behind right colon

The conventional 5-port laparoscopy

In this scenario, the operator's left hand and right hand cooperate with each other; by using both blunt and sharp methods, the operator extend the whole space behind the right colon upwards and outwards.

The assistant inserts a non-invasive forceps with left hand into the space behind the right colon and lifts the mesocolon towards the left upper side; the right hand also enters this space to lift the mesentery towards the right upper side, so as to provide appropriate tension and space for the operator to perform extension (*Figure 9*).

Single-port laparoscopy

The operator uses left hand to replace the assistant's role in the 5-port method; the left hand enters the space behind the right colon to lift the mesocolon towards the left upper side.

The right hand alone can completely extend the space behind right colon by using both blunt and sharp methods.

The assistant uses a non-traumatic forceps with right hand to enter the space behind the right colon and then lift the mesentery towards the right upper side (*Figure 10*).

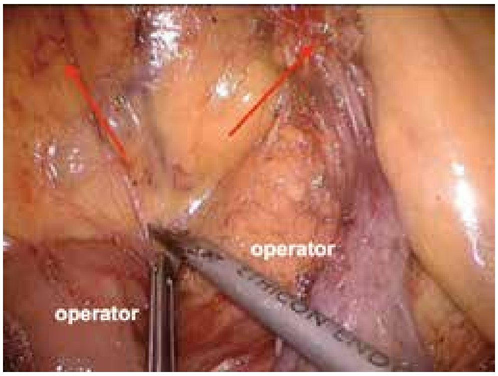

Figure 9 Extending the space behind right colon using a conventional 5-port method.

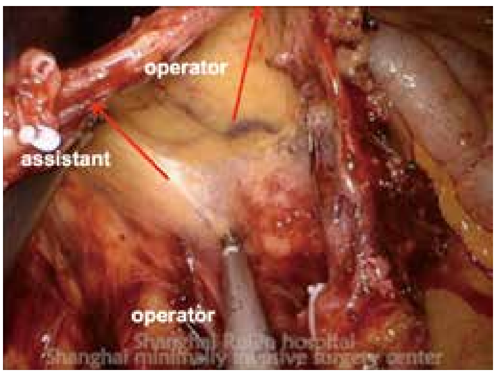

Figure 10 Extending the space behind right colon using single-port laparoscopy.

Scenario 5: dissect the surgical trunk

The conventional 5-port laparoscopy

The operator uses a separating forceps or a non-traumatic forceps with left hand to open the vascular sheath along the SMV surface and expose and handle the vascular root using HIFU in right hand.

The assistant pulls the mesocolon at the middle of middle colon vascular pedicle with left hand and pulls the mesocolon towards the right side with right hand (*Figure 11*).

Single-port laparoscopy

The operator uses left hand to lift the mesocolon in front of SMV and exposes and handles the vascular root using a separating forceps and HIFU in right hand.

The assistant still uses a forceps with right hand to pull the mesocolon rightwards (*Figure 12*).

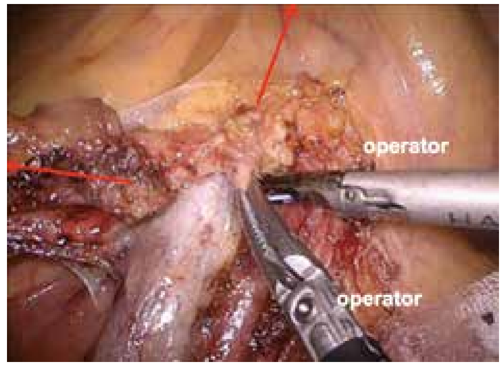

Figure 11 Dissecting the surgical trunk using a conventional 5-port method.

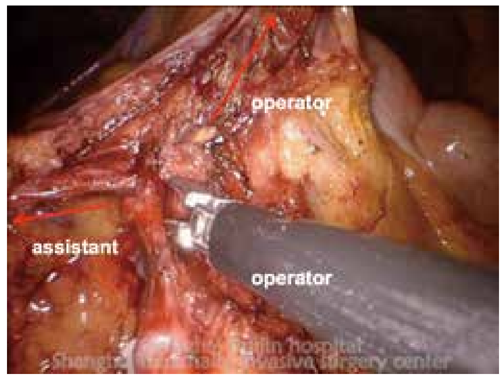

Figure 12 Dissecting the surgical trunk using single-port laparoscopy.

Scenario 6: dissect the Henle's trunk

The conventional 5-port laparoscopy

The operator uses a separating forceps with left hand to divide and separate the mesentery on SMV surface to expose the root of the common trunk; then, using the HIFU in right hand, the operator continue to open the mesentery on the surfaces of SMV, common trunk, and its branches, so as to gradually expose the common trunk and its branches.

The assistant pulls the transverse mesocolon with left hand towards the left upper side and pull the mesocolon towards the right upper side with right hand (*Figure 13*).

Single-port laparoscopy

The operator uses the left hand to replace the role of the assistant in the conventional 5-port method (pulling the middle colic vascular pedicle towards the left upper side) and uses HIFU and a separating forceps in right hand

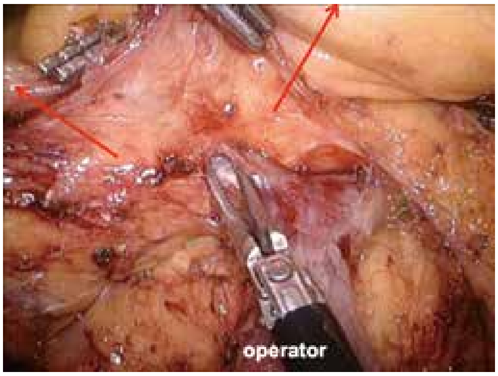

Figure 13 Dissecting the Henle's trunk using a conventional 5-port method.

Figure 15 Handling the middle colon vessels using a conventional 5-port method.

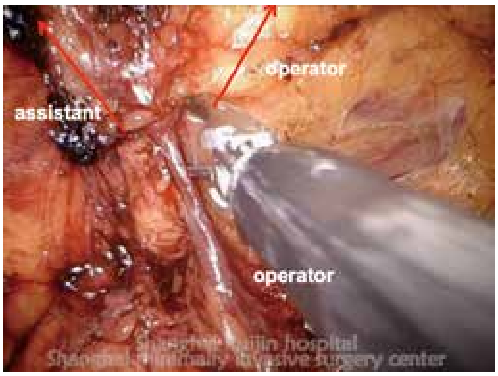

Figure 14 Dissecting the Henle's trunk using single-port laparoscopy.

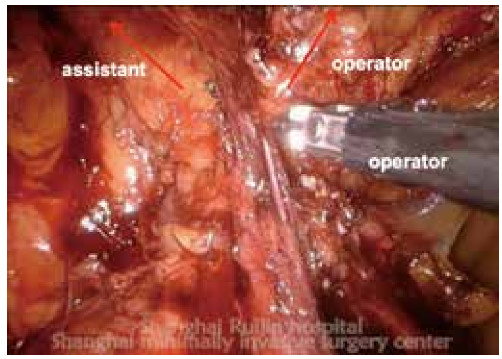

Figure 16 Handling the middle colon vessels using single-port laparoscopy.

to open, separate, and expose the common trunk and its branches.

The assistant only uses the right hand to pull the mesocolon towards the right upper side (*Figure 14*).

Scenario 7: handle the middle colic vessels

The conventional 5-port laparoscopy

The operator uses left hand to dissociate and divide the middle colic vessels and uses right hand to expose and handle the vascular root.

The assistant uses left hand to pull the middle colic vascular pedicle towards the left upper side and uses right hand to pull the transverse mesocolon towards the right upper side (*Figure 15*).

Single-port laparoscopy

The operator uses the left hand to replace the role of the assistant in the 5-port method (i.e., pulling the middle colic vascular pedicle towards the left upper side) and uses the right hand alone to expose and handle the vascular root.

The assistant still uses right hand to pull the transverse mesocolon towards the right upper side, as done in the 5-port method (*Figure 16*).

Scenario 8: enter the lesser omental bursa via the lower edge of pancreas

The conventional 5-port laparoscopy

The operator uses both left and right hands to cut open the lesser omental bursa to expose the posterior gastric wall.

The assistant uses left hand to pull the middle colic

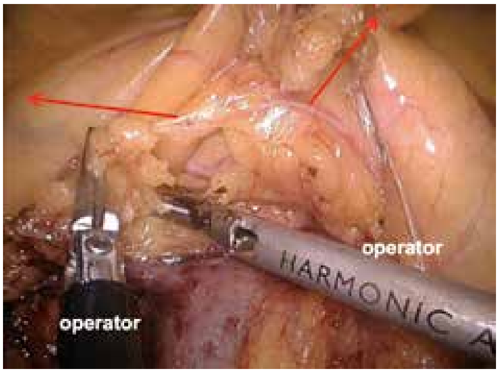

Figure 17 Entering the lesser omental bursa via the lower edge of pancreas using a conventional 5-port method.

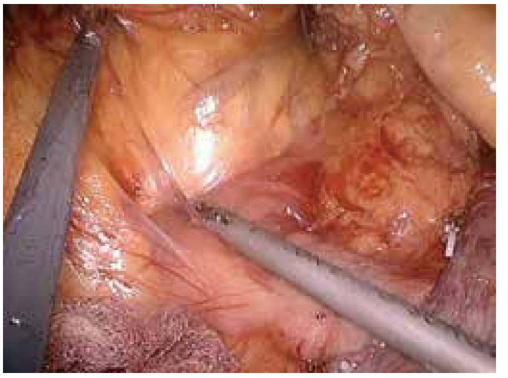

Figure 19 Extending the space behind the transverse colon using a conventional 5-port method.

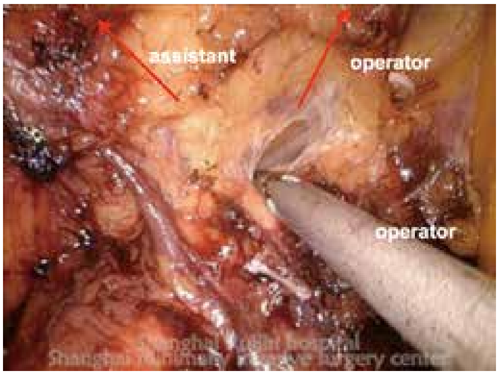

Figure 18 Entering the lesser omental bursa via the lower edge of pancreas using single-port laparoscopy.

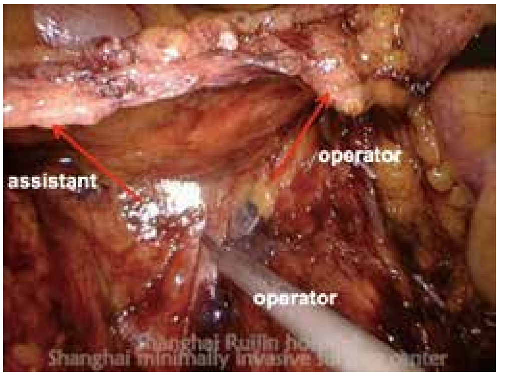

Figure 20 Extending the space behind the transverse colon using single-port laparoscopy.

vascular pedicle or transverse mesocolon towards the left upper side and uses right hand to pull the transverse mesocolon towards the right upper side (*Figure 17*).

Single-port laparoscopy

The operator uses the left hand to replace the role of the assistant in the 5-port method (i.e., pulling the middle colic vascular pedicle or transverse mesocolon towards the left upper side) and uses the right hand to cut open the lesser omental bursa to expose the posterior gastric wall.

The assistant uses the right hand to pull the transverse mesocolon towards the right upper side (*Figure 18*).

Scenario 9: extend the space behind transverse colon

The operative strategy used in this scenario is similar to that for the extension of the space behind right colon (*Figures 19* and *20*).

Scenario 10: cut open the gastrocolic ligament

The conventional 5-port laparoscopy

The operator pulls the greater omentum downwards with left hand and divides the gastrocolic ligament with left hand.

The assistant uses the left hand to lift the anterior wall of stomach and uses the right hand to pull the anterior wall of the gastric antrum (the traction direction is consistent with the left hand of the operator); thus, the gastrocolic ligament is pulled into a fan-shaped or triangular stretching, which not only provides sufficient tension but also offers a clear and reliable visual field (*Figure 21*).

Single-port laparoscopy

The operator pulls the greater omentum downwards with left hand and divides the gastrocolic ligament with left hand, as done in the conventional 5-port method.

Figure 21 Dividing the gastrocolic ligament using a conventional 5-port method.

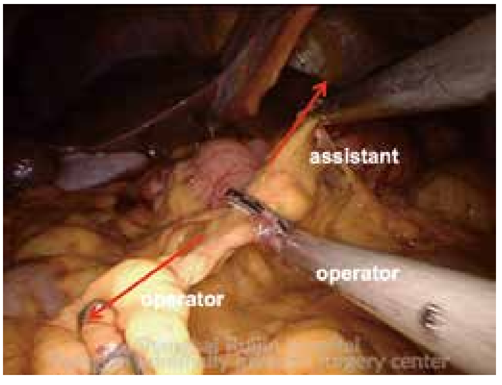

Figure 22 Dividing the gastrocolic ligament using single-port laparoscopy.

Figure 23 Dissociating the hepatic flexure using a conventional 5-port method.

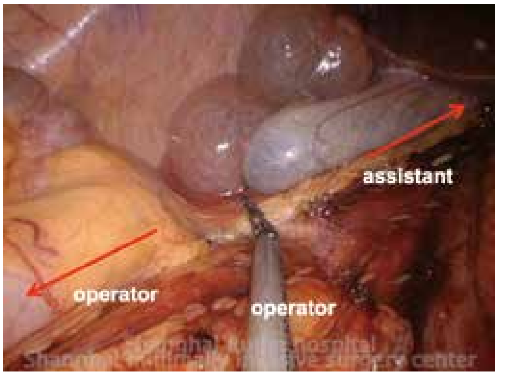

Figure 24 Dissociating the hepatic flexure using single-port laparoscopy.

The assistant can only use right hand to counter-tract the anterior wall of gastric body; meanwhile, he/she can also provide sufficient tension for dividing the gastrocolic ligament. However, since the whole gastrocolic ligament is not stretched in a fan shape, the exposure of the visual field behind the HIFU cutting point is not as adequate as in the 5-port method (*Figure 22*).

Scenario 11: dissociate the hepatic flexure of the colon

The conventional 5-port laparoscopy

The operator uses left hand to pull the mesocolon downwards and uses right hand to divide both the fusion between mesocolon and mesogastrium and open the transverse mesocolon; then, they meet at the gap that has already divided via the lower approach.

The assistant uses left had to pull the the mesentery of gastric antrum towards the left upper side and uses right hand to counter-tract the hepatic flexure of colon and the mesocolon (*Figure 23*).

Single-port laparoscopy

The operator uses left hand to pull the mesocolon downwards and uses right hand to divide both the fusion between mesocolon and mesogastrium and open the transverse mesocolon; then, they meet at the gap that has already divided via the lower approach.

The assistant only uses right hand to counter-tract the mesentery of gastric antrum (*Figure 24*).

Scenario 12: cut open the lateral peritoneum

The conventional 5-port laparoscopy

The operator uses left hand to lift the lateral peritoneum or parry the small intestine (if it appears); then, the operator uses right hand to cut open the lateral peritoneum.

Figure 25 Opening the lateral peritoneum using a conventional 5-port method.

Figure 26 Opening the lateral peritoneum using single-port laparoscopy.

The assistant uses left hand to lift the ascending colon towards the left and upper side and uses right hand to lift the ileocecal region or appendix towards the left upper side (*Figure 25*).

Single-port laparoscopy

The operator uses left had to pull the ileocecal region towards the left and left upper sides and uses right hand to cut open the lateral peritoneum upwards to finalize the "surrounding", and meanwhile finalize the endoscopic dissociation of the right colon.

The assistant can take a break, so as to avoid any unnecessary interference to the operations of the operator (*Figure 26*).

Along with the maturing of surgical techniques, optimization of surgical instruments, and deeper understanding of the concept of "single-port" by surgeons involved in minimally invasive surgery, single-port laparoscopy now allows high-quality radical resection of colorectal cancer. The use of "auxillary-port" or the use of four-channel single-port devices such as SILS Port somehow resolves the problems such as few inserted instruments and lacking of operation triangles. As a result, key techniques such as intraoperative traction and exposure, division of vascular sheath, blunt/sharp separation of the Toldt's membrane, complete resection of mesocolon, and high ligation of vascular root can be performed. Therefore, when performed by a surgeon with rich experience in minimally invasive colorectal surgery, the single-port laparoscopy can also successfully complete the CME of colorectal cancer or D3 lymph node dissection, suggesting that single-port laparoscopy is not a technical obstacle for high-quality lymph node dissection. It is believed that the single-port laparoscopy will play an increasingly important role in the radical treatment of colorectal cancer (*Figure 27*).

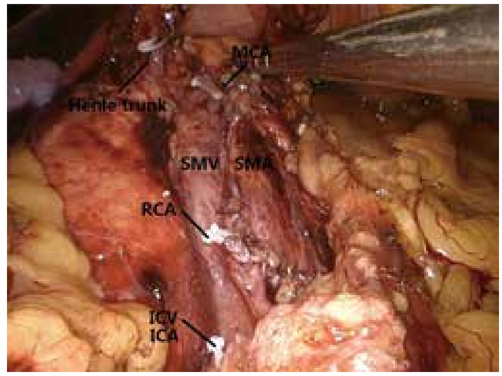

Figure 27 Effectiveness after lymph node dissection.

Acknowledgements

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Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

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Operational approaches for laparoscopic complete mesocolic excision in right hemicolon cancer

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Abstract: Complete mesocolic excision (CME) has the potential to become the standard procedure for colon cancer surgery as a result of its effectiveness in reducing local recurrence rate and improving prognosis. There are two strategies to perform CME: medial and lateral. Researchers have demonstrated that laparoscopic CME via medial access is comparable to a traditional open surgery. Technically, we proposed two approaches for medial access: hybrid medial approach (HMA) and completely medial approach (CMA). HMA involves the entrance to the intermesenteric space (IMS) by an incision of the gastrocolonic ligament followed by the dissection of the middle colic vessels and the Henle trunk in a top-to-bottom fashion. The approach is capped by the dissection of the inferior edge of the pancreas, requiring the blending of both top-to-bottom and bottom-to-top approaches. CMA, on the other hand, involves a bottom-to-top approach in every step, including the entrance of IMS through transverse retrocolic space (TRCS); dissection of the middle colic vessels and the Henle trunk; and dissection of the inferior edge of the pancreas. According to the previous research of our medical center, laparoscopic CME via the total medial approach is safe and technically feasible after the precise identification of the surgical planes and spaces for the right hemicolon. Meanwhile, this procedure reduces operation time and has fewer vessel-related complications, which is a better choice for right hemicolectomy.

Keywords: Right hemicolon cancer; complete mesocolic excision (CME); hybrid medial approach (HMA); completely medial approach (CMA)

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In 2009, Hohenberger, a German scholar, proposed the term of complete mesocolic excision (CME), whose basic theory is mainly composed of two concepts in fetal anatomy and surgical oncology: sharp dissection of the mesocolic plane and the parietal plane. CME helps to keep the colonic mesentery intact, clarify the dissected area from central lymph nodes, emphasize the importance of transecting colon-feeding blood at the root, and increase the range of longitudinal enterotomy. Thus, CME provides a standardization of surgeries for colon cancer. Research has shown that the rate of lymph node metastasis from colon cancer ranges 5–11% (it was 6.5% among Dukes C2 cases in the MRC CLASICC trial). Therefore, central lymph node dissection is necessary. CME can maximize the clearing of the micrometastases sized <2 mm after special staining of the lymph nodes and the free tumor cells or clusters inside the lymph nodes. One tumor specimen may have 1–5 micrometastases, which may explain why CME can prolong the survival of patients with stage II colon cancer. In a prospective non-randomized trial, Galizia *et al.*

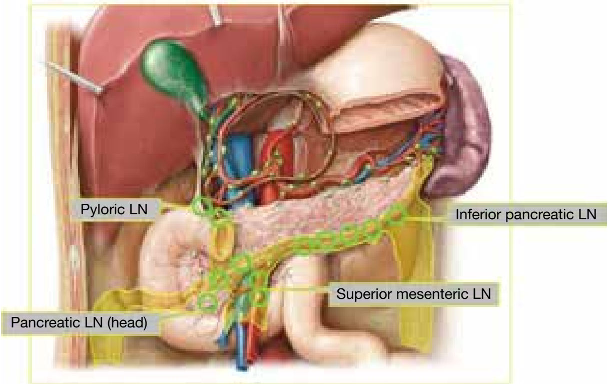

Figure 1 During CME, the transverse mesocolon can be completely dissociated beginning from the lower edge of pancreas, along with dissection; also, the TRCS can be extended upwards to enter IMS. CME, complete mesocolic excision; TRCS, transverse retrocolic space; IMS, intermesenteric space.

compared the outcomes of patients who had received CME for right hemicolon cancer (n=45) or conventional right hemicolectomy (n=58). It was found that there was no local relapse in the CME group, along with significantly decreased tumor-related death. Therefore, CME is safe and feasible for right hemicolon cancer; it can remarkably reduce local relapse and increase survival rate. In particular, CME can confer long-term survival benefit in patients with lymph node-positive disease. Thus, CME reduces local recurrence rate, improves the prognosis of colon cancer, and therefore is expected to become a standard surgical procedure for the radical resection of colon cancer. Unfortunately, no randomized controlled trial (RCT) has demonstrated that CME can improve the long-term efficacy in colon cancer patients.

CME is performed via two surgical accesses: lateral access and medial access. The conventional celiotomy typically applies the lateral access. According to the previous studies performed by our group, laparoscopic CME via the medial access is comparable to traditional open colectomy. In accordance with the theory of comparative anatomy, the intermesenteric space (IMS) is located between the posterior layer of the greater omentum and the top of the transverse mesocolon and communicates only with the transverse retrocolic space (TRCS) behind the root of the transverse mesocolon; thus, the mobilization of transverse mesocolon requires the entrance of the IMS. We proposed two approaches for medial-access CME: hybrid medial approach (HMA) and complete medial approach (CMA). HMA requires the entrance of IMS via an incision of the gastrocolonic ligament, followed by the dissection of the middle colic vessels and the Henle trunk in a top-to-bottom fashion. The dissection for the inferior edge of the pancreas requires the blending of both top-to-bottom and bottom-to-top approaches. Meanwhile, CMA enters the IMS in bottom-to-top fashion, with the extension of TRCS. The approach is capped by dissection at the inferior edge of the pancreas, requiring the blending of both top-to-bottom and bottom-to-top approaches (*Figure 1*).

Surgical methods

HMA

Similar to TME, the visceral fascia surrounds the whole colonic mesentery just like an envelope. During the surgery, a HIFU was used for the sharp dissection of visceral fascia and parietal fascia; the colonic mesentery was completely resected to achieve more thorough lymph node dissection and ligation of the vascular root. The West grading system was applied for evaluating the surgical quality: (I) grade A (at the layer of muscularis propria): only a small proportion of colonic mesentery is resected, with the axial nearest resection margin reaching the muscularis propria of the intestinal wall; (II) grade B (at the inner layer of colonic mesentery): parts of the colonic mesentery was irregularly resected, with the axial nearest resection margin exceeding the muscularis propria of the intestinal wall; and (III) grade C (at the layer of colonic mesentery): the colonic mesentery was completely resected, the mesenteric visceral layer was intact and smooth, and high ligation of the feeding vessels was performed.

Initiation

The medial approach was applied, with the projection area of ileocolic vessels (ICA and ICV) as the initiation; the vessels were dissected mainly along the superior mesenteric vein (SMV) (*Figures 2* and *3*).

Identification and maintenance of the surgical planes

The natural surgical planes (located between Told's fascia and anterior renal fascia) was entered to expose the head of pancreas; after the duodenum was thoroughly dissociated, the dissection continued along the lateral side till the colonic side and then turned upwards till the root of the transverse mesocolon (*Figure 4*). Colonic feeding vessels were dissected at their roots, and then the whole colonic mesentery was completely resected (*Figure 4*).

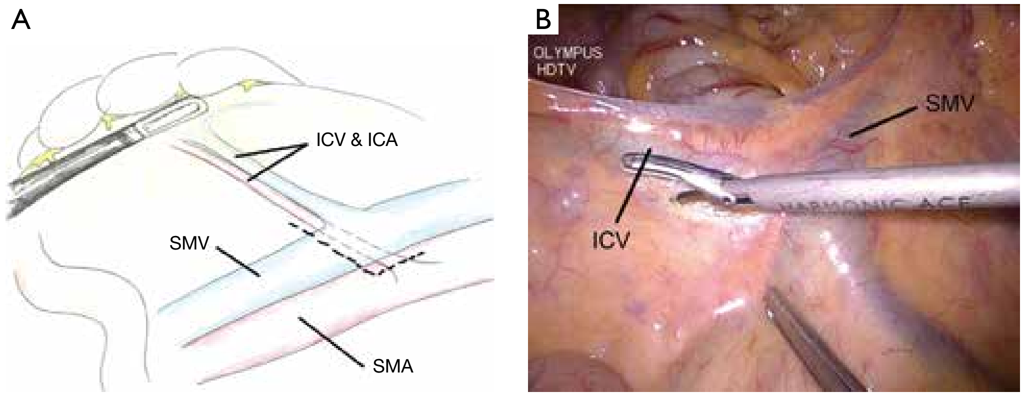

Figure 2 The anatomic projection of ileocolic vessels (ICA and ICV) is used as the initiation. (A) Schematic diagram; (B) photo of a surgery.

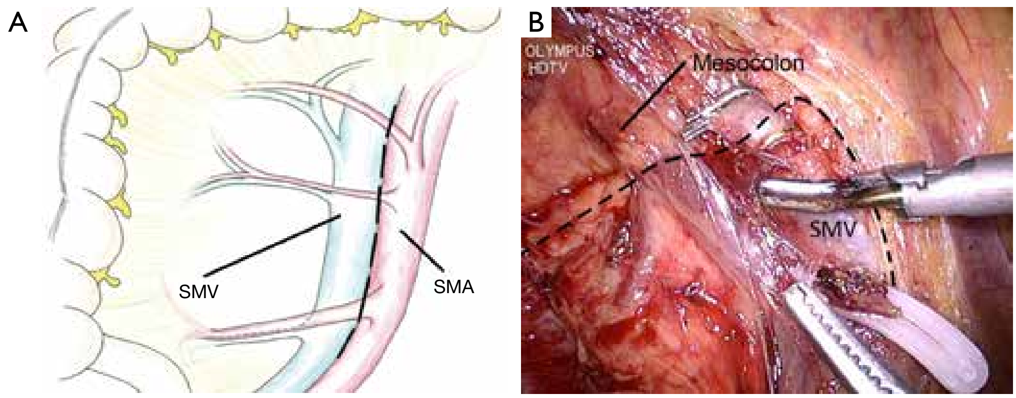

Figure 3 The vessel is dissected along the superior mesenteric vein (SMV). (A) Schematic diagram; (B) photo of a surgery.

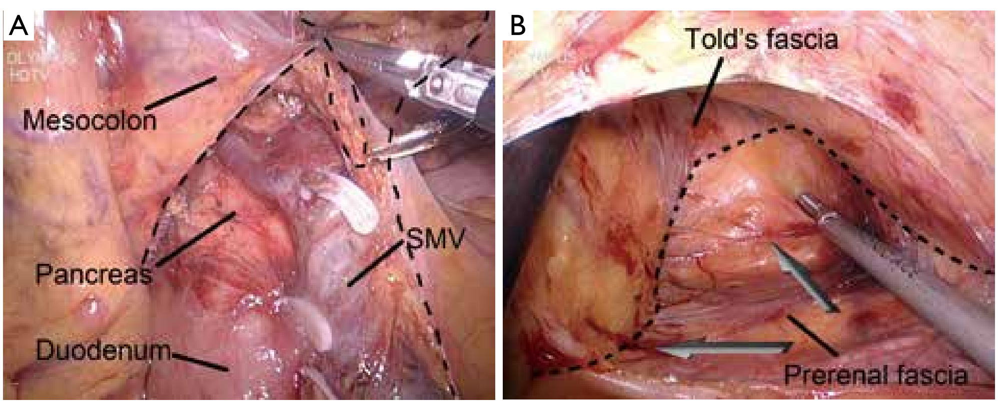

Figure 4 Natural surgical plane between Told fascia and prerenal fascia. (A) The exposed duodenum and pancreatic head; (B) root of the colonic mesentery.

Key points of lymph node dissection

The cecum cancer and ascending colon cancer, lymph nodes on ileum-colon, right colon, and middle colic artery must be completely removed. If the cancer is at the hepatic flexure end of the transverse colon, the right gastroepiploic vein should be transected at its root for the dissection of the

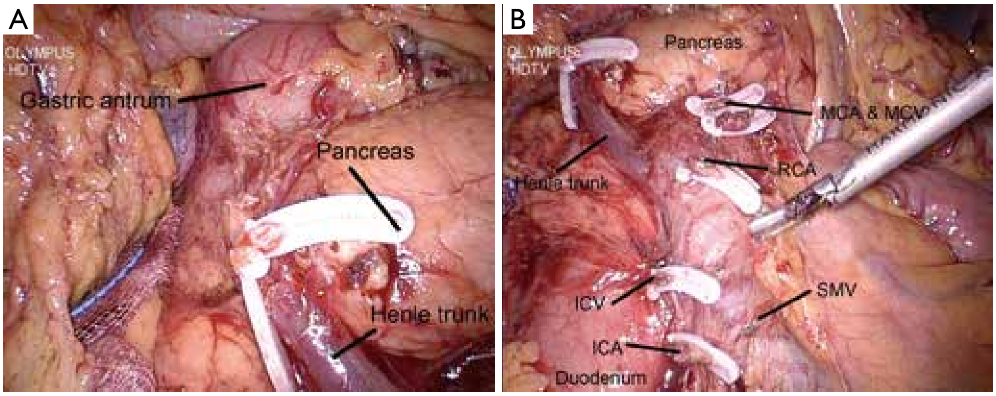

Figure 5 Lymph node dissection for cancer located at the hepatic flexure end of the transverse colon. (A) Dissection of the lymph node station 6; (B) after lymph node dissection.

station 6 lymph nodes; in addition, the gastric omentum near the greater curvature of the stomach 10–15 cm away from the tumor should be removed along the gastroepiploic vessel arch (*Figure 5*). If necessary, the duodenum, pancreatic head, and mesenteric root should be mobilized via the Kocher approach, followed by the sharp dissection of the colonic mesentery till the superior mesenteric artery (SMA), so as to thoroughly expose the vessels feeding the colon and dissect the lymph nodes.

Features of the HMA

The IMS is entered via an incision of the gastrocolonic ligament, followed by the dissection of the middle colic vessels and the Henle trunk in a top-to-bottom fashion. The approach is capped by dissection at the inferior edge of the pancreas, requiring the blending of both top-to-bottom and bottom-to-top approaches.

Completely medial approach (CMA)

The CMA should also follow the principles of CME and central artery ligation.

Features of CMA

The dissection starts at the ileocolic vessel and proceeds along the SMV to enter the TRCS in bottom-to-top fashion. The dissection of the TRCS is extended laterally to the right retrocolic space (RRCS) and superiorly enters the IMS, followed by the dissection of middle colon vessels, the Henle trunk, and pancreatic lower edge in a bottom-to-top fashion (*Figure 6*).

Discussion

Anatomical basis of the CMA for CME

Lateral access is applied for open CME, during which the right colon was dissociated inwards firstly; then, the visceral fascia that covers the pancreas and the mesentery and the parietal peritoneum that covers the retroperitoneal tissues were sharply mobilized till the SMA to expose the colon-feeding vessels. In contrast, the laparoscopic CME applies a medial approach, during which the lymph nodes on surgical trunk were dissected firstly, followed by ligation of the central vessels, so as to achieve the mobilization of colonic mesentery outwards and upwards. The mobilization of the right hemicolon is based on one surgical plane and three avascular potential surgical spaces between intestinal canal and its nearby structure. Prerenal fascia (PRF) provides a smooth surgical plane for the mobilization of right colonic mesentery, whereas the IMSs between RRCS, TRCS, and greater omentum and the transverse mesocolon are the three surgical spaces. IMS is located between the posterior layer of the greater omentum and the top of the transverse mesocolon and communicates only with TRCS behind the root of the transverse mesocolon; thus, the mobilization of transverse mesocolon requires the entrance of the IMS (*Figure 7*).

The transverse mesocolon can be completely resected after the IMS is entered by directly extending TRCS towards its head, which is the anatomical basis for CMA. The mobilization of colonic mesentery upwards can be smoothly performed via this approach; theoretically, it is more in line with the principle of CME (*Figure 8*).

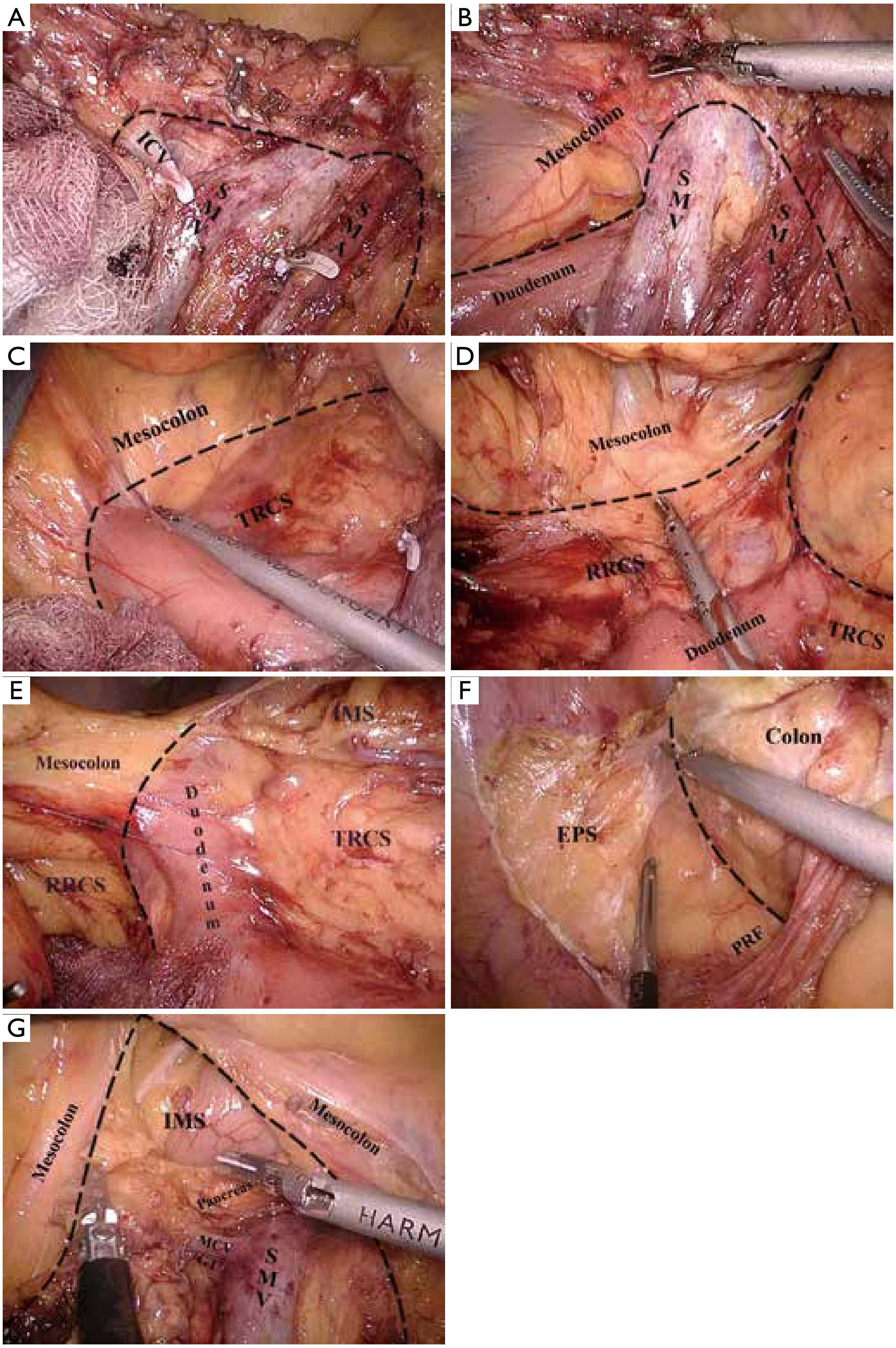

Figure 6 CMA for laparoscopic completed mesocolic excision for right hemicolon cancer. (A) Initiation; (B) dissection of lymph nodes in the surgical trunk; (C) identification and extension of TRCS; (D) identification and extension of RRCS; (E) TRCS communicates with IMS via the root of transverse mesocolon; (F) EPS and PRF; (G) climbing via the inferior edge of pancreas to enter IMS. CMA, completely medial approach; TRCS, transverse retrocolic space; IMS, intermesenteric space; PRF, prerenal fascia.

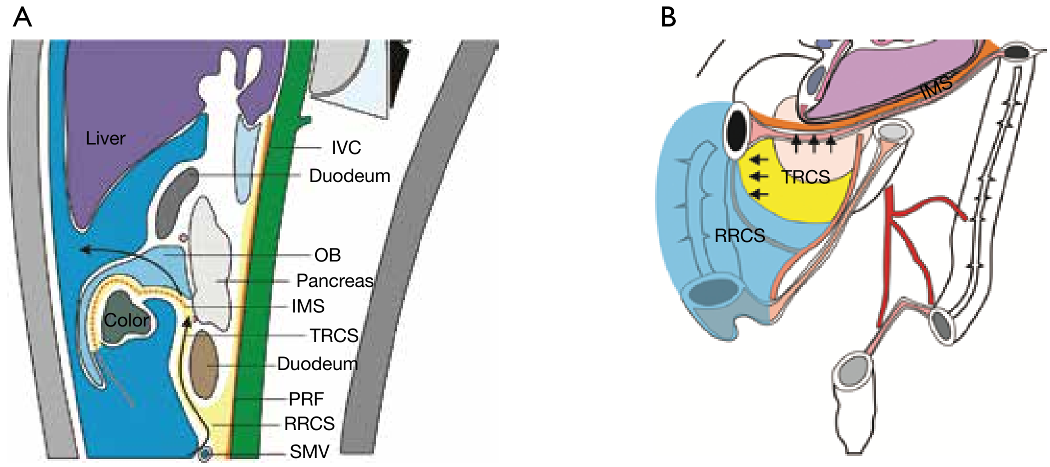

Figure 7 Anatomy of CMA for CME. (A) TMS can be entered from TRCS via the root of transverse mesocolon, thus achieving the complete resection of transverse mesocolon; (B) identification and maintenance of TRCS is a key step for HMA. CMA, completely medial approach; CME, complete mesocolic excision; TRCS, transverse retrocolic space; HMA, hybrid medial approach.

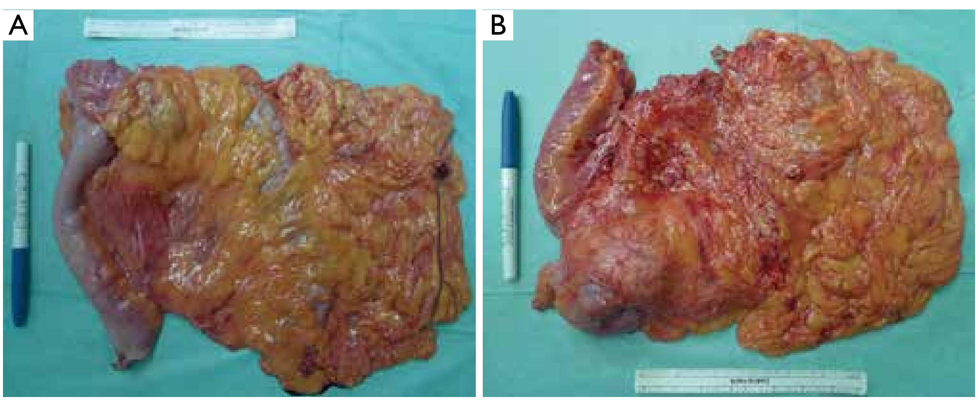

Figure 8 During CME, the two layers of visceral fascia in colonic mesentery should be kept intact. CME, complete mesocolic excision.

Meanwhile, it avoids the repeated turnover of the bowel and its mesentery upwards and downwards, which is required during HMA and thus can not meet the requirements of CME due to different anatomy of the upper and lower levels. Furthermore, when this approach is applied for dissection of lymph nodes at the inferior edge of pancreas, the small vessel branches at the inferior edge of pancreas can be handled under direct vision, with less bleeding. As shown in our current study, CMA can shorten the vessel ligation time, laparoscopic operative time and reduce the vascular complications, especially pancreaticoduodenal vascular complications. Therefore, CMA is a better choice for laparoscopic CME in right hemicolon cancer.

Key points and difficulties in the CMA for CME

Identification and extension of TRCS

TRCS is located between the transverse mesocolon and the inferior portion of pancreas-duodenum, with its tail connecting with RRCS at the inferior edge of the horizontal part of duodenum and its head with IMS at the root of transverse mesocolon. Therefore, proper identification and extension of TRCS is a key step in performing CMA for CME. Two ways may be applied for the proper identification of TRCS: (I) SMV is the boundary between ascending mesocolon and mesentery of small intestine and also the middle boundary of the centerline and approach of the TRCS; therefore, successful entrance to the TRCS can be achieved after sharp lateral dissection of the ascending mesocolon along the surface of the SMV sheath; (II) after the ileocolic vessels are identified, the lower portion of the SRRC can be smoothly entered and then extended upwards; then, the TRCS is entered after the mobilization of the duodenal third portion and ventral part of the pancreas. Then, IMS is entered after extension towards the head side and RRCS is entered after right extensions, so as to smoothly dissociate the colonic mesentery.

"Climbing" along the inferior edge of pancreas

During the performing of CMA, the TRCS needs to be extended upwards, IMS should be entered via the root of transverse mesocolon, and identification and "climbing" of the lower edge of pancreas is one of the key steps. Entering the posterior side of pancreas and injuring the pancreatic parenchyma, which may lead to bleeding and other vascular complications, are the potential risk of CMA. Therefore, it is particularly critical to correctly identify the lower edge of pancreas and properly grasp the timing of "climbing". According to our experiences, after the lymph nodes on surgical trunk are dissected. The appearance of Henle trunk prompts that it is very close to the inferior edge of pancreas; dissection should then be performed forwards and upwards and "climbing" should be prepared. The appearance of right gastroepiploic vein prompts that it is time for entering IMS; dissection can be performed along the left edge of this vein, which allows easy entering of the IMS.

CME provides rational for the radical resection of right hemicolon cancer from the perspectives of fetal anatomy and surgical oncology. TMA for laparoscopic CME is technically feasible; however, it should be based on the deeper understanding of the laparoscopic anatomical plane of right hemicolon and the surgical spaces and on the fine anatomic basis. TMA for the right hemicolon CME can further shorten operative time and decrease the vascular complications and thus warrants further clinical applications.

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Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

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Laparoscopic assisted multi-visceral resection in stage IV rectal cancer

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Abstract: Hepatic metastasis is the difficult part and key point in treating colorectal cancer. Meanwhile, there still exists an argument that if doing hepatic metastasis of colorectal cancer resection simultaneously. Our center is carrying on multidisciplinary treatments of hepatic metastasis of colorectal cancer and has gained some outcomes from the clinical trials. According to the features of this case, we should get simultaneous resection of both primary and metastatic tumor following by the pre-operation MDT discussion. Here, we show the achievement of laparoscopy-assisted right hemicolectomy combined with liver resection. We want to share the experiences and discuss with each other.

Keywords: Laparoscopy; colectomy; hepatectomy; simultaneity

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Liver is the primary hematogenous metastatic organ of colon cancer. Hepatic metastasis is the difficult part and key point in treating colorectal cancer. Generally, hepatic metastasis is the main death reason of colorectal cancer. The principle of treating hepatic metastasis of c is surgical resection of metastatic lesion. Till now, Chinese and foreign experts consensus suggest that colorectal cancer patients with hepatic metastasis that meet the surgery indication should have appropriate surgical treatment.

Usually our strategy for colorectal cancer with hepatic metastasis is MDT discussion. We got the further treatment strategy when experts from different departments have discussed together. We decide whether the patients should get simultaneous resection of both primary and metastatic tumor mainly on the anatomic site of the metastasis, the residual liver function, the number of metastatic lesion and radical purpose. Although the mortality of simultaneous resection surgery is higher than two-period surgical therapy, there are emerging studies showing that the overall survival and disease-free survival rate are similar between the two therapies. Our medical center has carried out laparoscopy-assisted simultaneously multiple organ resection, and has got some results. Here, we show the achievement of laparoscopy-assisted right hemicolectomy combined with liver resection. We want to share the experience and discuss with each other.

Body position

Supine position, hands at body side, avoids hands abduction in order not to influence the operation of surgeon. For better view of the operation field, we change body position by the adjustment of operating table.

Position of surgeon

The primary operator stands at right or between the two legs of the patients. The operator that holds the laparoscopy stands at the left side of the patient, while the operator that holds the assistant pincers stands next to the primary operator. The main purpose of the assistant pincers is helping to show better views. Obviously, during the operation, the three operators could change the position to make the primary operator feel convenient as much as possible.

Figure 1 This video is about the laparoscopic colectomy combined hepatectomy surgery (1). Our team finished the application of laparoscopy operation. This case is the advanced skill compares to other hospitals in China.
Available online: http://www.asvide.com/articles/1518

Trocar position—usually, we use five trocars

(I) Observational trocar: 1 cm upside the belly button, avoid side-effects caused by puncture. This trocar site is chosen because the relative low density of fat. However, when isolating superior mesenteric vein, a vertical sight cannot be avoided. The vertical sight needs operator to accommodate.

(II) Main operational trocar: the primary main operational trocar was 2 cm right of the ligature between the belly button and symphysis pubis; the secondary main operational trocar was 3 cm left of belly button.

(III) Assistant operational trocar: the primary assistant operational trocar was the down border of the right costal arch; the secondary assistant operational trocar was the left down border of the costal arch at the same line with nipple. The assistant pincers was mainly to pull transverse colon, omentum, stomach and liver in order to show the better view.

Operation procedure (*Figure 1*)

We facilitate the middle pathway, from upside to downside, from medial to lateral. First we isolated the ileocolic artery and vein, and then we cut off the colic mesentery along the left side of superior mesenteric vein. Then we dealt with the right branch of middle colic artery, and we clean the six station lymph nodes when opened the omental bursa. We isolated the total colic mesentery according to the CME principle. Finally, we did the anastomosis outside the body. Procedures related to the malignant tumor resection conformed to the no tumor touch principle; we usually carried out D3 radical resection.

Abdominal exploration

Colorectal cancer patients need thoroughly abdominal exploration, from far to near, to be sure whether there were metastatic sites in abdomen.

Reveal the anatomic marks

Change the operating table to make the patients head is high and the legs are low while make the left side of body low and the right side high. Pull the small intestine at the inferior left part of the abdomen by gravity in order not influence the operating maneuver. The primary operator and the assistant put the greater mesentery up of transverse colon. The assistant operator pulls the transverse colon in order to reveal the middle colic vessels, superior mesenteric vein and the horizontal part of duodenum. At this time, the assistant operator pulls the colic mesentery and keeps some tense.

Isolation of ileocolic vessels

The primary operator reveal, isolate and cut off the ileocolic vessels at the bifurcation of ileocolic vessels and mesenteric vessels, be careful about the anatomic variation. After cutting off the ileocolic vessels, isolating the mesentery along the superior mesenteric vein, pull the isolated tissues to the right side and enough space left. In this enough space, we find out Toldt's space. Beginners would use no harm pincers to hold the gauze to facilitate blunt dissection. Blunt dissection help to avoid the side effects to duodenum. When dealing with the mesentery of fat people, be careful about the reproductive vessels and the ureter, for the anatomic markers were not clear in fat patients.

Cut off right colic vessels and the right branch of middle colic vessels

Isolate the mesentery along the superior mesenteric vein. The assistant operator who holds the laparoscopy should adjust a 30 degree. The right side of vessels usually has anatomic variation, so please be sure about the line that vessels flow. During these procedures, be careful about the pancreas.

Clean the lymph nodes at the root of middle colic artery

When cleaning the lymph nodes, we should pay lots of attention, because there are lots of the anatomic variations. The vessels needs to be skeletonized, we must manage the use of ultrasound knife. Be careful about the side effects of ultrasound knife, during these procedures, Toldt's space extent to the paracolic sulci.

Cut off greater omentum and omental bursa

The assistant operator help to pull the great omentum, cut off the great omentum in the middle to the root of transverse colon. Open the omental bursa and clean the sixth station lymph nodes. Isolate transverse colon along omental bursa and keep careful about the gall bladder.

Isolating liver colon treatment. And paracolic sulci

At this time the tissue between right hemicolon and paracolic sulci was only a thin film. Some patients would see the Toldt's line.

Deal with ileocecal part

Carefully recognize the fusion part of ileocecal part and the later abdominal wall. When dealing with these using ultrasound knife, the maneuver should slow down. By this, the right hemicolon were isolated.

Resection of hepatic metastatic lesion

If the metastatic lesion was on the surface of liver, we should define the scope using electronic hook. Resect the metastatic lesion using electrocoagulation. As the liver is brittle, some stitches would be needed to pull the organ. The primary operator pulls the lesion and resects the lesion while the assistant uses the aspirator. The resected lesion should be put into bags according to no tumor touch principle.

Cut off transverse colon and side to end anastomosis

Cut off the transverse colon in the body, also cut off or remain the ileum. Whether cut or remain the ileum depends on the thoughts of primary operator. Elongate the observational trocar hole and make sure the tumor could be carried out through the hole. After the anastomosis, we usually did the reinforce stitches in order to avoid the anastomosis fistula and bleeding.

Close the lesion and abdominal exploration again

After close the lesion, we re-established the pneumoperitoneum. Re-evaluate the anastomosis direction, mesenteric direction. Check that whether there exist side-effects.

Experience

Laparoscopic surgery should follow the no tumor touch principle as the open surgery. However, the operating space is limited so that the cooperation seems important. In the surgery, we should take care of anatomic marks; avoid the small field caused isolation deviation. Thus, we should always adjust back to large views to make sure the isolating sites. Cutting off vessels at the root of the vessels so that we could have enough isolation, then we can decrease the difficulty of anastomosis. Vessels skeletonization by ultrasound knife needs practice and it definitely decreases the blood loss. The assistant that hold the laparoscopy should avoid angle problem to cause the primary operator puzzled.

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Footnote

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Laparoscopic-assisted radical left hemicolectomy for colon cancer

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Introduction

Laparoscopic surgery has been enthusiastically applied to the resection of colorectal cancer for more than many years. Nowadays, more and more colorectal surgeons believe that laparoscopic approach gains quicker functional recovery, achieves comparable (1-3), and even better oncologic results (4,5) for the treatment of patients with colorectal cancer. However, the safety of laparoscopic left hemi-colectomy for cancer remains to be established, owing to its exclusion from previous randomized controlled trials. Laparoscopic left hemi-colectomy, involving the takedown of splenic flexure, has been more challenging than the other laparoscopic colorectal procedures. Because there is the technical variability between colorectal surgeons, the clinical trial of laparoscopic left hemi-colectomy which required the takedown of splenic flexure for the curative resection of cancers and tension-free colonic anastomosis has been rare. This video article aims to describe safe and feasibility of laparoscopic left hemi-colectomy, authors would like to share the surgical techniques with you via a case of descending colonic neoplasm who underwent the laparoscopic left hemi-colectomy (*Figure 1*) (6).

Discussion

Cancer of splenic flexure is rare, comprising only 2% to 5% of all colorectal cancers (7-10). Very few studies have specifically investigated the use of laparoscopic left hemi-colectomy for cancer (11). However, surgical approaches for transverse or descending colon cancer vary considerably depending on the relative location of the tumor. Thus, the purpose of this video article is to show safe and efficiency for the tumor locates in the left hemi-colon.

Laparoscopic left hemi-colectomy is suitable for the tumors locate in distal a third of the transverse colon, splenic flexure, descending colon and upper sigmoid colon. Left hemi-colectomy was defined as a procedure requiring division of the left colic and the left branch of the middle colic vessels at their origins. Generally, left hemi-colectomy was carried out for stage I/II/III tumors. Briefly, the surgeon and camera operator stood on the right side of the patient, with the first assistant positioned to the left or between the legs of the patient. Medial-to-lateral retroperitoneal dissection was performed to allow division of the left colic artery. The inferior mesenteric vein was divided near the inferior border of the pancreas. The omentum was then transected to allow entry into the omental bursa (lesser sac) and mobilization of the splenic flexure. The left branch of the middle colic vessels was identified at the inferior border of the pancreas and divided at its origin. The specimen was extracted through the camera port, which was extended to about 4–5 cm, and the anastomosis was formed extracorporeally by functional end-to-end anastomosis or intracorporeally by side-to-side anastomosis using linear staplers.

The blood supply to distal a third of the transverse colon, splenic flexure, descending colon and upper sigmoid colon has been shown to vary between patients. Specifically, blood is carried by the inferior mesenteric artery through the left colic artery in 89% of cases and by the superior mesenteric artery through the middle colic artery in 11% of cases (12). The optimal surgical treatment for left hemi-colon cancer remains controversial. Some surgeons have argued that subtotal colectomy or extended right hemi-colectomy improves oncological outcome (7,13). However, other studies have demonstrated that the prognosis for left hemi-colon cancer is no worse than for other colon cancers,

Figure 1 Laparoscopic-assisted radical left hemi-colectomy. Available online: http://www.asvide.com/articles/709, [Reprinted with permission (6)].

and that left hemi-colectomy is sufficient for a satisfactory oncological outcome (8,9,14). A recent study showed that complete mesocolic excision in the mesocolic plane with central vascular ligation is associated with the removal of more mesocolon and a greater lymph node yield, and might improve 5-year survival (15). In this video article, it was considered the optimal method to remove cancer that inferior mesenteric artery, vein and their branch should be dissected and the vessels for descending colon should be ligated.

Laparoscopic left hemi-colectomy involves splenic flexure mobilization, which has been reported to be technically demanding (16) and associated with greater intraoperative blood loss and intraoperative complications (17). Intraoperative complications occurring during laparoscopic left hemi-colectomy included bleeding from the pancreas or spleen, which was difficult to repair by laparoscopy and required transfusion. Minimizing intraoperative complications and the need for conversion to open surgery during laparoscopic left hemi-colectomy will require careful case selection and experienced surgical teams. So, laparoscopic left hemi-colectomy is really difficult for many surgeons, especially for young. First attempt should be on the base of wealthy experiences of laparoscopy techniques. It had better be under guidance of the experienced surgeon. When laparoscopy is hard to go on, we should convert to laparotomy as soon as possible.

Prospective study for short-term and long-term outcomes is needed to demonstrate that laparoscopic left hemi-colectomy is more feasible and has significant advantages. Through further research, laparoscopic left hemi-colectomy will be established procedure.

Conclusions

If a laparoscopic left hemi-colectomy is performed in the experienced center and if it is performed on appropriate patient groups under accurate preoperative diagnosis, it should be a safe and useful treatment for left hemi-colon cancer.

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Footnote

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Laparoscopy-assisted complete mesocolic excision for right-hemi colon cancer

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Abstract: There aren't any standardized ways of controlling operating, although laparoscopic-assisted right-hemi colon cancer complete mesocolic excision (LR-CME), has been widely applied used in China and abroad. Hohenberger gave a new concept that treating complete mesocolic excision (CME) as a colon cancer standard operation for the first time in 2009. And the LR-CME that based on the anatomy of the vascular and level coincide with the concept. One case, male, 69 years old. LR-CME was performed in our department. Following we will introduce correlation experiences and skills of LR-CME. It took about 110 minutes to finish the whole operation with bleeding of about 20 mL. This case recovers well postoperation without any significant complication and discharged from hospital on the 10th day.

Keywords: Ascending colon carcinoma; laparoscopy; complete mesocolic excision operation skills

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Introduction

Jacobs first describes laparoscopy-assisted right hemi colectomy (1). Clinical trials have proven laparoscopy-assisted right hemi colectomy is feasible, safe and effective. 2009, Hohenberger, of Germany, and others (2) first proposed the new concept of complete mesocolic excision (CME). Recent research has proved, CME improves the surgical quality with keeping more harvested lymph nodes (3) and better effect of oncology (4). There are two different operation ways (middle approach and lateral approach) for laparoscopy-assisted right hemi colectomy. More surgeons choose middle approach that marked by ileocolie artery and superior mesenteric vein. Some studies indicate that middle approach has obvious advantages in complication and shorten the hospitalization time (5).

Methods

Surgical indications

The tumor is located in the ileocecal junction, ascending colon, hepatic flexure of colon, the right side of the transverse colon. Operation method obtained the informed consent. Cases of exclusion criteria: (I) the diameter of tumor >8 cm; (II) with ileus or enterobrosis and accepted emergency surgery; (III) IV period tumor or tumor invading other organs were found during the preoperative or operative; (IV) others can't tolerate laparoscopic surgery.

Surgical position

Under general anesthesia, the patient was placed horizontal position with legs split. The surgeon was positioned on the left side of the patient, with the camera operator between the legs and the first assistance on the right of patient. And then place the patient at foot-high right side tilt position with starting the operation.

Surgical procedures

Incise 1cm skin in the middle point of 3–5 cm below the umbilicus. And making a 12 mm trocar as an observation hole. Building pneumoperitoneum and keeping the pressure in 12–15 mmHg. Chose a 12 mm trocar as the main operation hole under the umbilical 3 cm and left about 4 cm. Keeping three 5 mm trocars separated into the holds of under the umbilical 3 cm and right about 4 cm and the intersection points above the umbilicus 4 cm level and left and right collarbone midline.

The first step of the operation is abdominal exploration with a 30 degree camera to know whether there has any metastasis or invasion to adjacent organs and to verify the position, size and degree of external invasion. Then we cut the mesentery with ultrasound knife along the front left of superior mesenteric vein surgical trunk. Lymph nodes and adipose tissue around the roots should be dissected and the ileocolic vessel and the right colonic vessel should be ligated.

Cut avascular area in the left of the middle colic artery above the pancreatic body on the edge of the left transverse mesocolon root. Separation of the middle colic artery around to the branch in the colon, keep left to cut off the right one.

Along the ileocolic vein cut back the mesocolon, where we can enter the Toldt's fascia and extend it. If we enter the correct space, we can separate the ascending colon from retroperitoneum without bleeding. The last step of laparoscopy is to divide other ligament of ascending colon so that we can mobilize the ascending colon completely and reconstruct the digestive tract.

Results

The postoperative pathological says: colonic mucinous carcinomas have infiltrated all layer of serosa. Vascular cancer embolus can be seeing. There are two paracolic lymph nodes with metastasis, other 22 lymph nodes from colic mesentery and surgical trunk without metastasis.

Discussion

The CME proposed by Hohenberger *et al.* (2) brings a completely new concept for advanced colon cancer of normative surgery. CME was performed in 1,438 cases and proved that CME can improve 5-year survival rate after surgery and reduce relapse rate. The difference of the beginning time and the case numbers of such surgery lead to unbalance development of operation. There isn't normalizing surgery control criteria.

We support that there are three keys in Laparoscopy-assisted CME for right-hemi colon cancer: (I) first cut down the right-hemicolon feeding arteries which left to superior mesenteric vein surgical trunk and clear away 203, 213 group lymph nodes. Then dissect avascular area which in the left of middle colic artery of inferior border of body of pancreas and clear away 223 group lymph nodes; (II) identify the surgical plane and mesocolon can't be destroyed; (III) emphasizing block resection of lymph nodes and mesentery.

Conclusions

LR-CME is safe and efficient for the tumor locates in the right hemicolon.

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Footnote

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Lighted ureteral stents in laparoscopic colorectal surgery; a five-year experience

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Background: Ureteral injuries during colorectal surgery are a rare event, ranging in the literature from 0.28–7.6%. Debate surrounds the use of prophylactic lighted ureteral stents to help protect the ureter during laparoscopic surgery. It has been suggested that they help to identify injuries but do not prevent them. The authors look to challenge this.

Methods: Over 66 months, every laparoscopic or colectomy involving ureteral stents was recorded. Researchers documented any injury to the ureter intraoperatively. The chart was also reviewed for the complications of urinary tract infection (UTI) and urinary retention post-operatively.

Results: During the 66 months, 402 laparoscopic colon resections were done. There were no ureteral injuries. The lighted ureteral stent was identified during every case in the effort to prevent injury during dissection and resection. No catheter associated UTIs were identified, while 14 (3.5%) suffered from post-operative urinary retention.

Conclusions: The authors of this study present a large series of colon resections with no intraoperative ureteral injuries. In addition, these catheters were not associated with any UTIs and a rate of urinary retention similar to that of the at large data. This series provides compelling data to use lighted ureteral stents during laparoscopic colon surgery.

Keywords: Laparoscopic colorectal surgery; colon cancer; minimally invasive surgery; ureteral injury; ureteral stents

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Introduction

Identifying the ureter during colorectal surgery is one of the most critical steps of the operation. Ureteral injuries are often discussed, albeit rarely encountered, ranging in the literature from 0.28–7.6% (1). However rare, a ureteral jury has the potential to be a devastating complication and prevention is a top priority for the surgeon. Prophylactic ureteral stent placement has been utilized in pelvic surgery to facilitate intraoperative ureter identification and allow for immediate recognition of injury (2). Similarly, in laparoscopic colorectal surgery (CRS), lighted stents have been introduced to enhance visualization of the ureter with the goal to overcome the limitations of tactile feedback (3).

Despite their apparent theoretical advantages, much debate still surrounds the use of prophylactic stent placement, including lighted stents, and their effectiveness in preventing injury (4). Although there have been no randomized control trials to determine the utility of stents in preventing injury, several studies have suggested that they

Table 1 nature of operation, number of ureteral injuries, incidence of urinary retention and UTIs

Operation	Cases	Ureteral injury	Urinary retention	UTI
Right	42	0	1	0
Extended right	4	0	0	0
Transverse	3	0	0	0
Left	115	0	2	0
Extended left	4	0	0	0
Sigmoid	12	0	1	0
LAR	228	0	12	0
Total abdominal colectomy	23	0	1	0
Subtotal colectomy	5	0	0	0
Reversal	18	0	0	0
APR	5	0	1	0
Rectopexy	6	0	1	0

UTI, urinary tract infection; LAR, low anterior resection; APR, abdominal perineal resection.

help to identify injuries at time of surgery. Nevertheless, complications secondary to stent placement have been documented in the literature and include urinary tract infections (UTIs), oliguria, hydronephrosis and hematuria. However, these complications are largely self-limited and rates of UTIs with stent placement have been comparable to published rates of nosocomial UTIs after colorectal surgery (1). This study reports a single institution's experience utilizing prophylactic lighted ureteral stents in laparoscopic CRS and documents any ureteral injuries along with any complications from their placement.

Methods

The study was a retrospective review of the case logs of two board certified colorectal surgeons at Monmouth Medical Center in Long Branch, New Jersey. Cases reviewed were from January 2010 through June 2015 and include all laparoscopic or robotic-assisted colectomies in which prophylactic ureteral stents were inserted. All ureteral stents, size five French, were placed utilizing cystoscopy by one of four urologists. Catheters were placed after induction of general endotracheal anesthesia prior to starting the colorectal procedure. Stents were removed at the conclusion of the laparoscopic procedure prior to extubation. All patients had Foley catheters inserted by the urologist at the time of the ureteral stent insertion. Foley catheters remained in place for all patients postoperatively. A review of the incidence of ureteral injuries, UTIs, and urinary retention was done. Urinary retention was documented when the Foley catheter was reinserted post operatively.

Results

A total of 465 laparoscopic colorectal resections with prophylactic lighted ureteral stents were performed between January 2010 and June 2015 (66 months). Average age of patients was 60.9 years old. The series included 214 (46%) male and 251 (54%) female patients. Of the 465 cases, 160 (34%) were performed for malignant disease, while 305 (66%) were performed for benign disease. Diverticular disease (n=264) and ulcerative colitis (n=15) were the most common benign indications for operative intervention. Rectal cancer comprised 76 out of the 160 malignant cases (47.5%). The remainder were performed for colon cancer (n=84, 52.5%). Laparoscopic low anterior resection (n=228) and laparoscopic left colectomies (n=115) were the most commonly performed procedures. There were no ureteral injuries or urinary tract infections identified postoperatively. Nineteen patients (4.1%) suffered from postoperative urinary retention. All patients (n=465) had transient postoperative hematuria, which resolved prior to discharge. Expanded in *Table 1*.

Discussion

Iatrogenic injury is a major concern during any surgery. Low dissection during colorectal surgery requires constant awareness of ureteral location. In the past surgeons had to rely on their knowledge of anatomy to identify the ureters and prevent injury during surgery. According to Bieniek *et al*., the incidence of ureteral injuries during CRS has been cited as high as 7.6%. Alternatively, 5–15% of all ureteral injuries occur during CRS (5,6). Pokala *et al*. suggests ureteral catheters might increase risk of injury during open colorectal procedures by making ureters less pliable, which may predispose to intraoperative ureteral injury, and also propose that stents do not reduce injury but may aid in early recognition (2).

Laparoscopic CRS sparked a new challenge to surgeons, giving them less tactile feedback and more dependence on visual identification to avoid iatrogenic injury. In an effort to enhance visualization of ureters, lighted ureteral stents were devised to improve visual identification of ureters throughout the dissection. Although these catheters also helped to identify injuries intraoperatively, their use did not change the overall incidence of ureteral injuries (2).

The series done at this institution revealed no ureteral injuries from either catheter insertion or during the surgery in 465 laparoscopic colorectal resections in a time period spanning 66 months. The practice of bilateral stent placement for all colon resections has shifted to only placing left sided stents during left colon resections. The authors propose that stents are more helpful during left colon resections secondary to proximity of the ureter during a low pelvic dissection. The careful identification of the LED illuminated ureter is a major step in preventing ureteral injuries during these cases.

Catheter associated urinary tract infections (CAUTIs) are a known complication of ureteral stent insertion (1). However, in this series out of 465 cases with ureteral stent placement, no CAUTIs occurred. Beraldo *et al*. also showed a UTI occurrence as low as 2.2% in their 89 patients who underwent prophylactic ureteral stents (7). One study showed UTI rates lower (2% *vs*. 4.3%) in cases that used catheters (8). All of the catheters inserted in this review were done by one of four experienced urologists in a sterile environment. Furthermore, every patient received preoperative antibiotics prior to the start of the case. A final contributing factor is that this institution utilizes an enhanced recovery pathway, which standardizes removing all Foley catheters on postoperative day one.

Transient hematuria is a known effect of instrumentation to the ureter. This was seen in all 465 cases which ureteral stents were used. However, the hematuria resolved in all cases. Ureteral edema and subsequent urinary retention has been reported as a complication of ureteral stent placement (9). Nineteen patients (4%) required Foley reinsertion during the postoperative period prior to discharge. Changchien *et al*. reviewed 2,355 who underwent surgery without the aid of ureteral stents for CRS and reports 5.5% incidence of urinary retention after colorectal resection. The authors conclude that the addition of ureteral stents poses no additional risk of urinary retention than a traditional laparoscopic colon resection without stents.

Prophylactic ureteral stent placement has been associated with increased operative time (2). The average time for stent insertion prior to CRS was eight minutes. The average total additional time including set up, draping, procedure, and re-prep for the colorectal procedure was 28 minutes. Other studies which emphasize a coordinated approach to prophylactic stent placement and predefined protocols have demonstrated much shorter amount of additional time under general anesthesia to 11 minutes (6). With additional coordination involving the entire treatment team, extra time spent in the operating room could potentially be decreased significantly.

The illuminated catheter used at the author's institution costs $167.01 and therefore adds 1.76% to the standard elective laparoscopic colon operation totaling a median cost of $9,476. The exact cost of a ureteral injury is difficult to calculate as it could result in a variety of different treatments whether it was found at time of original operation versus delayed. Inevitably the increased length of stay and necessity of another procedure will increase costs more than $167.01. For these reasons and the overall benefit to the patient, the authors surmise that 1.76% increase in cost is worth considering the lack of complications both intraoperatively and from the stent insertion itself.

It has become increasing evident that the benefits of universal ureteral catheter placement for colorectal surgery far exceeds the risk. While attempts in the literature have been made to identify certain cases which may benefit most from lighted ureteral stents, such as obese patients, those with extensive inflammation, or those with history of surgery, it is not always possible to accurately make these judgments preoperatively.

Certain protocols regarding the use of ureteral catheters have helped to mitigate risk from cystoscopy and catheter placement. For example, patients undergoing segmental resection with an undisrupted retroperitoneum receive unilateral catheters while those with a history of previous retroperitoneal dissections now receive bilateral catheters. We have found that such protocols add minimal time, cost, and risk to the overall case while providing added security from injury to a vital structure. While it may be conceded that number needed to treat to prevent a ureteral injury with catheter placement is relatively high, the complications of such an injury are all too morbid emotionally, physically, and financially to undergo such risk.

The data presented in this series demonstrates no ureteral injuries over the course of 465 laparoscopic colorectal surgeries in which prophylactic lighted ureteral stents were used. This supports the notion that identification of the ureter via lighted stents can help prevent injury in colorectal resections without a large amount of additional risk. Standardization of operating room logistics may help to reduce additional operative time. Randomized studies are needed to prove definitive correlation between ureteral stent insertion and reduction of intraoperative ureteral injury during CRS.

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Footnote

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Monopolar hook electrode assisted laparoscopic resection of descending colon cancer

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Abstract: Colorectal cancer accounts for about 25% of all malignant tumors in China. Efficacy and safety of laparoscopic assisted descending colon cancer radical resection have been recognized, and that complete mesocolic excision (CME) plays an important role. For this surgery, most surgeons choose scalpel as the primary instrument, and monopolar hook electrode minimal. A 72-year-old female patient with an adenocarcinoma of the left colon, with pre-operative clinical stage CT3N1M0, was chosen for the study. We use the monopolar hook electrode to finish the laparoscopic assisted descending colon cancer radical resection. The tumor with the surrounding tissue and 4/15 lymph nodes was resected by laparoscopy and colon side to side anastomosis performed. The procedure lasted about 120 minutes with minimal bleeding. Postoperative tumor biopsy revealed a tumor staging of T3N2M0 (IIIB). The patient recovered well following the procedure and was discharged after 4 days. The use of monopolar hook electrode in laparoscopy assisted descending colon cancer radical removal is safe, feasible and effective. The procedure is accurate, safe, provides ease of operating in a narrow space and is relatively inexpensive.

Keywords: Laparoscopy; descending colon cancer; adenocarcinoma; complete mesocolic excision (CME); monopolar hook electrode

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Colorectal cancer accounts for a fourth of the malignant tumors in China. In 1991, Jacobs *et al.* (1) used laparoscopy to treat colorectal cancer, for the first time. In the following 20 years, minimally invasive treatment concept has been widely adopted and it has the advantages of rapid recovery, less trauma, and the long-term efficacy (2,3). Especially in 2009, Hohenberger *et al.* (4) put forward the concept of complete mesocolic excision (CME), it was found to improve the treatment of colorectal cancer and promoted the extensive adoption of laparoscopic surgery. Due to the complexity of the anatomy (5,6), attention must be paid to the correct clearance, and the relationship between the spleen, pancreas, stomach and their blood supply must be recognized, throughout the surgical procedure. For this surgery, most surgeons choose scalpel as the primary instrument, and monopolar hook electrode minimal. In addition to this, monopolar hook electrode has unique advantages: (I) accurate surgery with good separation of the vasculature; (II) fast and safe cutting, on the premise of ensuring safety shortening the procedure time; (III) the unique design of the monopolar hook electrode aids in adapting to the angle the bleeding, thus helping to preserve hemostasis; (IV) can be used repeatedly, is low cost and suitable for primary hospitals.

Materials and methods

Case selection

A 72-year-old female who underwent a preoperative colonoscopy: revealed a visible mass 48 cm from the

Figure 1 Monopolar hook electrode assisted laparoscopic resection of descending colon cancer (7).
Available online: http://www.asvide.com/articles/1085

anus. The surface had a crisp texture, bled easily and the colonoscope could barely pass through. Biopsy of the mass revealed that it was an adenocarcinoma. The result of the CT scan showed that the middle of the descending colon was thickened, and the size of the film is violated. The preoperative clinical stage of the tumor was CT3N1M0.

Surgical position (Figure 1)

Patient was placed in a foot high position (10–30 degrees), on a recumbent straddle, towards the right (10–20 degrees). The splenic flexure was maintained as the body position changed. The surgeon was on the patient's right side and the assistant on the left side. The endoscope handles should change the position between the side legs and locate on the head side with postural.

Surgical procedure

Disconnection of the inferior mesenteric artery, descending colon branch and sigmoid colon branch

Following the traditional intermediate approach, the sigmoid mesocolon was cut apart on the sacral promontory level until the inferior mesenteric artery root was reached. To reach the correct level we used nerve guidance, along the gap into the left posterior lobe of the mesocolon, named Todlt's fascia. Isolating the gap towards the descending colon side ditch, attention was paid to expose and protect the left ureter and reproductive blood vessels. The lymph nodes of the inferior mesenteric artery were dissected and the distal portion was exposed. Then the descending colon branch was exposed and the sigmoid colon branch was closed off at the root of the two branches, thereby preserving the rectal artery. Continued on to free the inferior mesenteric vein up to the pancreatic edge, sweeping the corresponding regional lymph adipose tissue close to the lower edge of the pancreas to cut off the mesenteric vein.

Separation of the upper part of the rectum

We followed through by separating the upper rectum and the lateral ligament to protect the abdomen and the pelvic nerve floor. At this point, the left half of the colon, the splenic flexure, descending colon, sigmoid colon, rectum and mesentery had been completely cut off.

Transverse colon lymph node dissection

We cut apart the right transverse mesocolon along the surface of the pancreas until the edge of the pancreatic neck, leaving the left branch. Then we followed along the pancreatic body to the tail of the pancreas and then cut off the left transverse mesocolon.

Splenic flexure dissociation

The patient was placed in a head high position that provided enough tension, along the outside of the vascular arch of the stomach. The gastrocolic ligament was severed and the gastrosplenic ligament was completely released up to the splenic flexure.

Left lateral dissociation

For complete left lateral dissociation, we cut along the Todlt's line and towards the cephalad, then we cut the left paracolic sulci as far as the phrenicocolic ligament. Once this was accomplished the medial free plane gets through.

Tumor removal and anastomosis

A 4-cm vertical incision was made on the left side of the abdominal wall. Using plastic protective sleeve as protection, the free intestinal segment was pulled out and the tissue was cut on both sides of the tumor for a distance of 10 cm and Ethicon TCR 75 mm suture was used for side to side anastomosis of the colon. No bleeding was observed in the abdominal cavity and the abdomen was closed.

Results

The surgical procedure lasted 120 minutes, and the bleeding was about 20 mL. Postoperative biopsy revealed an adenocarcinoma stage T3N2M0 (IIIB) and total lymph node 4/15 (+). The patient recovered well, without serious complications and 6 hours after the procedure the patient was able to consume liquid diet. The patient had anus exhaust on the second day and was started on semisolid diet on the third day. The patient was discharged on the fourth day.

Discussion

Surgical treatment of colon cancer which radical lymph node clearance has different requirements depending on the location of the tumor in the descending colon (8). For patients with tumors located in the distal colon, depending on the lymph node clearance, the inferior mesenteric artery and rectal artery need to be avoided. The monopolar hook electrode allows for the removal of lymph nodes while avoiding the inferior mesenteric arterial root and guarantees that the distal sigmoid colon and rectum have a good blood supply. In addition, proper planning of the surgical can ensure the continuity of the procedure, considerably reduce the time needed and the patients need to assume only one position throughout the procedure.

Ultrasound scalpel in laparoscopic surgery is in the early stages of development. It allows for laparoscopic surgery and ensures for proper blood coagulation (9). However, it also has a few disadvantages: (I) surgical cutting of two different levels together leads to anatomical level loss; (II) less blood vessels, especially for some fascial connective tissue may reduce the speed of cutting (10). However, with the promotion of laparoscopic technology and the improvement of surgical skills as the surgeons learn more about the procedure and the monopolar hook electrode allowing better separation from blood vessels in the local areas, it's possible to improve the effectiveness of the procedure. Monopolar hook electrode allows for a 360° operating angle and better mobility in the operating space. Its operational advantages in blood vessels become more prominent in the nude. In this case the monopolar hook electrode allowed for multi-angle cutting around the blood vessels in the process of clearing the lymph nodes. Video can also be observed in the separation of monopolar hook electrode in different angles, cutting and blood coagulation has certain advantages.

To sum up, monopolar hook electrode in the application of laparoscopy assisted descending colon cancer radical removal is safe, feasible and effective. It is clear in separating blood vessels and looking for developmental gaps to identify the anatomical level. Cutting membranous structures has the obvious advantages, blood coagulation being one of them. The procedure is accurate, safe, makes it easy to perform in a narrow space, and reduces the frequency of use of expensive surgical instruments and results in reduction in the patient's treatment cost. However, the procedure will cause more smoke and the lack of the grasping function of the ultrasonic knife will, to some extent, influence the observation and grasp functionality in the surgical field, and thus impact the clinical experience. The skill of the assistant in positioning the mirror will be key to the effectiveness of the procedure.

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Key points of tumor-free operation in laparoscopic resection for colorectal cancer

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Abstract: Tumor-free operation is an important principle of oncological surgery for colorectal cancer. Laparoscopic resection of colorectal cancer should also adhere to the tumor-free operation principle. Iatrogenic dissemination of cancer cells into the abdominal cavity during the laparoscopic resection of colorectal cancer is possible and should be paid attention by the surgeons. In order to reduce the rate of peritoneal seeding, the tumor-free operation principle should be implemented throughout the whole laparoscopic procedure. The steps we should follow as a routine practice include: (I) proper management of trocars and the pneumoperitoneum; (II) no-touch and protection of the tumor; (III) protection of the incision wound; (IV) priority of the high vascular ligation; (V) *en bloc* resection of the primary tumor and regional lymph nodes; (VI) sharp resection of the tumor; (VII) complete mesocolic excision (CME) of colon cancer and total mesorectal excision (TME) of rectal cancer; (VIII) replacement of the surgical instrument and gloves after the removal of the tumor; (IX) satisfactory scrub and irrigation; and (X) selective intraperitoneal chemotherapy.

Keywords: Colorectal cancer; laparoscopic resection; tumor-free operation

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In the current age of minimally invasive surgery, laparoscopic technique has accomplished a major progress in the treatment of colorectal cancer (1-3). As with conventional open surgery, laparoscopic surgery for colorectal cancer is also required to follow the principles of tumor-free operation to reduce the risk of iatrogenic dissemination of cancer cells on the peritoneal surface. In the early 1990s, there was reports of port site recurrence up to 21% when the laparoscopic resection for colorectal cancer started initially (4). However, with the increasing maturity of laparoscopic procedure and highly emphasizing the importance of the principle of tumor-free operation, the incidence of port site metastases has significantly decreased to below 3% (5-7).

Reports of port site metastasis have stimulated clinical and basic research, attempt to explain the possible mechanisms involved in the pathogenesis of peritoneal dissemination in laparoscopic surgery for colorectal cancer (8-10). The possible mechanisms of peritoneal seeding of colorectal cancer cells in laparoscopic procedure include the following aspects: (I) the tumor penetrates the serosa, escapes from the primary tumor and spreads in the peritoneum; (II) the excessive manipulation of tumor during laparoscopic surgery; (III) tumor cells spread during lymphadenectomy in patients with lymphatic invasion or lymph node involvement; (IV) the hemorrhage during the surgery for colorectal cancers with vascular invasion. These shedding cancer cells enter the abdominal cavity, enwrapped by the fibrin and blood clots, inducing the peritoneal implantation with the effect of immunologic responses. The exploring and understanding of the mechanisms of peritoneal dissemination of colorectal cancer cells provides clues for surgeons to take essential measures to reduce the cancer cell dissemination.

In order to reduce the potential peritoneal dissemination of cancer cells, the following three principles should be obeyed by surgeons:

(I) The principle of multidisciplinary comprehensive treatment. For colorectal cancer patients with high risks of metastasis, such as primary carcinoma invading the surrounding organs (T4), lymph node involvement and positive resection margin, perioperative neoadjuvant and adjuvant chemotherapy or chemoradiotherapy should be taken into consideration.

(II) The principle of tumor-free operation. A set of effective measures of tumor-free operation performed in the open surgery can also be applied in the laparoscopic surgery.

(III) Awareness of the specificity of laparoscopic operation. Strengthen the management of pneumoperitoneum during the laparoscopic surgery.

The principle of tumor-free operation should be kept in mind by surgeons, which runs through the whole process of laparoscopic operation. The following are key points of tumor-free operation in laparoscopic resection for colorectal cancer.

Operation associated with trocars

Placement of trocars

Proper placement of trocars to minimize tissue trauma is important. A suitable size of puncture hole made with trocar helps to perform trocar fixation to prevent trocars slipping off and CO_2 leakage around trocars. Caution should be exercised during the operation to reduce the risk of bleeding.

Removal of trocars

Before the trocar removal, the gas in the trocar sheath should be exhausted first, then the trocar can be removed. In that case, it can reduce the incidence of port site recurrence caused by the "chimney effect" (the chimney effect refers to the increase in the number of tumor cells at the port sites caused by leakage of gas along the trocars) (11).

The pressure of pneumoperitoneum

Appropriate pneumoperitoneum pressure is essential in the laparoscopic operation. A carbondioxide pneumoperitoneum at 12–15 mmHg is most commonly used which provides good laparoscopic visualization and sufficient working space (12). In the premise of obtaining sufficient operation space, it's recommended to choose a relatively low pressure of pneumoperitoneum.

The principles of laparoscopic exploration

Laparoscopic exploration should follow the principle of "from far to near", and explore the tumor in the end.

The principles of tumor resection

Protection of the tumor surface

It is recommended for carcinomas with serosa invasion to isolate serous surface by using gauze or blocking glue, in an attempt to prevent the shedding of cancer cells.

No-touch technique

"No-touch" principle should be followed throughout the operation: (I) minimal or even no touch with tumor; (II) avoidance of squeezing the tumor. The following four points should be complied with to the best of the surgeons' efforts: (I) minimum frequency of tumor touch; (II) minimum duration of tumor touch; (III) latest time of tumor touch; and (IV) preferably no touch with tumor.

Use protective bags to retrieve specimen

For the specimens resected from different regions, each specimen can be placed in a protective bag, which can be taken out together when the resection of all lesions and tissues and organs involved is accomplished. For example, in the laparoscopic resection of rectal cancer combined with bilateral lateral lymph nodes, the preferential removal of lateral lymph nodes can be put into a protective bag (gloves or disposable protective bags, etc.), which can be taken out together with other resected specimens(the other side of lateral lymph nodes and the rectal cancer).

Performing high vascular ligature

Once the resection scope is determined, central ligation of main supplying vessels first may reduce the risk of hematogenous dissemination of cancer cells (13). A high main reflux vein ligation is recommended if circumstances permit. For instance, in the radical resection of rectal carcinoma, surgeons can cut off the inferior mesenteric vein first, then cut off the main artery (the inferior mesenteric artery or superior rectal artery) and finally perform tumor resection.

Regional lymph node dissection

Current principle of colorectal cancer surgery is en bloc resection of the primary tumor with regional lymph nodes and all grossly suspected or involved lesions should be removed during operation (14). The operation of single lymph node resection should be avoided as possible. As it should be, a biopsy or resection of lymph nodes outside the drainage area is acceptable.

Sharp dissection

Sharp dissection is conducive to reducing the traction and squeeze involved in handling of tumor. To carry out accurate sharp dissection needs to maintain good tension in the operation. Nevertheless, some experts suggest that sharp dissection and blunt dissection be combined in laparoscopic surgery due to its particularity, in that case, the operation will be more secure and easier to master from a technical aspect. However, in terms of the principles of oncology, sharp dissection may be more reasonable and is proposed to be performed in laparoscopic surgery.

Removing the mesocolon or mesorectum as one package

Total mesorectal excision (TME) and complete mesocolic excision (CME) have become essential principles of radical resection for colorectal cancer (15,16). The concept of membrane anatomy has been increasingly emphasized by surgeons. TME/CME prevents the shedding of cancer cells by en bloc resection of a primary tumor and mesorectum/mesocolon as one package, contributing to the improvement of outcomes (15,16).

Minimizing haemorrhage

Only by minimizing haemorrhage can surgeons obtain a clear surgical field to ensure laparoscopic operation smooth and successful. If there are free cancer cells in circulatory system or vascular involvement, haemorrhage may also result in the spillage of cancer cells into the peritoneal cavity and onto the surfaces traumatized during surgery. Therefore, to minimize haemorrhage by operating carefully and suctioning blood clots promptly and thoroughly can also help to reduce the spread of cancer cells.

Instruments cleaning and glove replacement

The instruments should be cleaned or even replaced if there's obvious contact with tumor. After the removal of tumor specimens, the gloves should be replaced and the resection margin should be washed before the intestinal reconstruction. Rinsing the tip of instruments if they touch the tumor before they are reintroduced into the abdominal cavity (13). Betadine solution is recommended since it has been confirmed to be tumoricidal by many investigators (17).

Scrub and irrigation

The procedure of scrub and irrigation

When specimen is removed out of the abdominal cavity, the resection margin and surgical field should be irrigating *in vivo* or *in vitro*. The cut edge of intestine is proposed to be scrubbed with iodophor gauze or gauze ball before the anastomosis of intestines, aiming to avoid cancer cells shedding into the anastomosis. Anastomosis site needs irrigating again when the anastomosis is completed. Besides, the abdominal auxiliary incision wound and puncture port-site should also be irrigated with iodophor and water. The careful suction of blood clots and fat blocks is also needed.

The application of irrigation fluid

There are many arguments about the application of irrigation fluid in clinical practice. In addition to cleaning effect, ideal irrigation fluid needs to be capable of destroying cancer cells. In general, double distilled water (DDW) is better than normal saline (NS). Immersion in 43 ℃ DDW is better than that in DDW at ambient temperature. Immersion in 1:2,000 chlorhexidine at ambient temperature lasting for 3 minutes is equal to that in 43 ℃ DDW lasting for 10 minutes. Therefore, irrigation with 1:2,000 chlorhexidine at ambient temperature after the removal of specimens is a relatively simple and effective method. However, there is no supply of chlorhexidine in many hospitals, as a result, chlorhexidine is replaced by diluted iodophor. Diluted iodophor is effective disinfectant confirmed by many investigators (17). The 0.5–1% diluted iodophor is widely used for disinfection of skin and instruments. It is noteworthy that the surgical area should be irrigated with sufficient NS (500–1,000 mL) after irrigation with chlorhexidine or diluted iodophor.

Incision protection

Incision protection must be done immediately after entering the abdominal cavity in open surgery. Different from open surgery, the auxiliary incision from which specimen is taken out is created in laparoscopic surgery when the tumor is resected or is about to be removed. The incision in laparoscopic surgery also needs protection in order to reduce the incidence of specimens touching incision leading to tumor cell implantation. There are many products and ways for incision protection. The incision protection sleeve with sealing cover is recommended.

Selective intraperitoneal chemotherapy

Intraperitoneal chemotherapy is not the standard treatment for colorectal cancer at present. But intraperitoneal chemotherapy, especially hyperthermic intraperitoneal chemotherapy (HIPEC), may reduce the risk of peritoneal metastasis for colorectal cancer patients with the following high risk factors: (I) serosa invasion (T3/T4); (II) mucinous carcinoma or signet ring cell cancer; (III) positive resection margins; (IV) tumor rupture; or (V) intestinal perforation. A small sample study conducted by Sammartino *et al.* indicated that HIPEC seems to achieve a good local control in preventing peritoneal dissemination without significant increase of the perioperative morbidity (18). Mitomycin, cisplatin and oxaliplatin are chemotherapeutics commonly used in HIPEC. HIPEC is carried out lasting 30–90 minutes at a temperature of 42–43 ℃ (19,20). The time of HIPEC lasting varies in different chemotherapeutic drugs.

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Virtual reality training in laparoscopic colorectal surgery

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Due to the critical balance between patient safety and long learning curves for new surgical techniques, there has been rising interest in *ex vivo* surgical training models using simulators. Currently used training methods that thought to be beneficial in improving laparoscopic skills are lately questioned due to their limitations. The most realistic option, live animal training models, is expensive and has limited access for many practitioners. As opposed to other simulators, cadaveric platforms provide excellent tissue felling; however, it is not commonly easy to get to and requires supervision by experienced teachers (1).

On the other hand, virtual reality (VR) simulators are considered as being safe, effective and may be an available tool and can overcome problems regarding legal issues and time-consuming features of conventional apprenticeship. This system has been probably best described by Riva as a communication interface through interactive three-dimensional visualization which enables users to interface, interact with, and integrate different types of sensory inputs stimulating real-world practice (2). With this toll, monitoring learning process by autonomic and instantaneous measures seems to be ergonomic for the aim of acquisition of basic skills in laparoscopic surgery (3). However, despite its early introduction to surgery in 1990s (4), adoption of VR training appears to be slower paced, particularly due to the lack of well-designed clinical trials. Earliest comparison of standard surgical residency and VR was drawn in prospective, randomized double-blinded fashion for part of a laparoscopic cholecystectomy.

The earliest comparison of standard surgical residency and VR was drawn in prospective, randomized double-blinded fashion for part of a laparoscopic cholecystectomy and showed improved intraoperative performance with VR (5). More research is pending to delineate outcomes for the application of VR systems for more complex minimally invasive procedures.

Laparoscopic approach for colorectal surgery is considered as representative of complex procedures with its technology-dependent features (6,7). Although colorectal surgery showed a significant modernization in regards to operative approach in favor of the minimal invasive techniques, it still constitutes more technically challenging areas of laparoscopic surgery. The advantages—reduced morbidity, hospital length of stay, and institutional cost, and equivalent oncological outcomes—of laparoscopic approach however, are mitigated by its time-consuming technical complexity that imposes a long learning curve (8-10). A survey of program directors revealed that general surgery residents are inadequately prepared with respect to technical and non-technical skills during their minimally invasive and colorectal practices (11). Moreover, surgical residents face the need to learn relatively complex laparoscopic surgical skills within a limited time frame and in an environment where health system payers pay attention to competence, quality, and particularly cost-effectiveness (12). Considering required high number of cases (at least 30) for the learning curve of laparoscopic colorectal surgery (LCS) as the primary surgeon and that this expertise is not expected to be reached at the end of residency, simulation-based training of these technical skills has gained paramount importance.

Table 1 Studies addressing virtual reality simulators in colorectal surgery

Author	Year	Method	Participants, numbers	VR simulator	Procedure (assessment method)	Outcome assessment
Beyer-Berjot L	2016	Randomised, multicenter	Novice (n=20) *vs.* intermediate (n=7) *vs.* experienced (n=6)	LAP Mentor*	Sigmoid colectomy	Time, path length, number of movements,
Araujo SE	2014	Nonrandomised	Novice (n=14)	LAP Mentor	sigmoid colectomy	Global rating scale
Araujo SE	2014	Randomised	Novice (n=7) *vs.* control (n=7)	LAP Mentor	Sigmoid colectomy	Generic technical skills Likert ratings
Neary PC	2008	Randomised	Novice (n=11) *vs.* experienced (n=3)	ProMIS VR[&]	Left-sided colectomy	Time, instrument path length, and the smoothness of the trajectory of the instruments

*, LAP Mentor (Simbionix, Cleveland, OH, USA); [&], ProMIS augmented-reality simulator (Haptica, Dublin, Ireland). VR, virtual reality.

Although a significant amount of work has been performed to validate simulators as viable systems for teaching technical skills outside the operating room, it is necessary to integrate simulation training into comprehensive curricula. The optimal introduction of a VR simulator into an evidence-based, effective, and ergonomic surgical skills curriculum is a core and contentious issue. Before its utilization as training and assessment tool, the validity of simulation, as a first step, should be demonstrated based on performance metrics. One of the most important types of validation is demonstration of construct validity, which is best characterized as the ability to distinguish between surgeons with different levels of experience or skills. Demonstration of validity enables to further establish a technical skill proficiency level. The establishment of a level of proficiency allows determining an objective benchmark for trainees to reach before they can operate on a patient. In todays' surgical era, set up of structured curricula for laparoscopic colorectal procedures is crucial as there are few reports on dedicated programs for advanced techniques (13,14). As a further step, all metrics showing validity evidence can be ultimately incorporated in the training curriculum.

Palter and colleagues conducted the first randomized controlled trial developing and validating a comprehensive technical skills curriculum for LCS (15). During the study design, a total of eight tasks were ideally identified based on a 'consensus' of a large international team, rather than personal choice of tutors (16). They assessed the 'real' surgical performance in operating room and demonstrated higher performance in curricular-trained residents compared to controls, who followed only classical apprenticeship.

Table 1 summarizes the main studies regarding VR simulation for colorectal surgery (17-20). Beyer-Berjot and colleagues firstly implemented a competency-based VR curriculum in advanced training in laparoscopic abdominal surgery (17). The concept of this study is crucial when considering only few structured guidelines exist in the training of this field. In a sigmoid colectomy simulation, tasks comprising medial dissection, lateral dissection, anastomosis and full laparoscopic sigmoid colectomy have been measured with respect to time taken to complete each task, the total number of movements, and the total path length. Authors stated that these metrics—which showed validity evidence based on relations to experience during laparoscopic sigmoid colectomy simulation—had already been validated for specific tasks laparoscopic cholecystectomy as a basic laparoscopic procedure. These findings were confirmed by another work by Shanmugan and colleagues who questioned the optimal metrics for laparoscopic sigmoid colectomy demonstrating validity evidence (21). In their report, unexperienced general *vs.* experienced laparoscopic colorectal surgeons were participated in a prospectively designed study, in which only procedural metrics including reduced instrument path length, accuracy of the peritoneal/medial mobilization, and dissection and division of the inferior mesenteric artery showed evidence of construct validity. Contrary to these findings, intraoperative errors, e.g., grasping tumor, major vessel injury, minor bleeding episodes and injury of vital structures did not differentiate between surgeons varying degrees of expertise for laparoscopic sigmoid procedure. However, at this point, we are a bit skeptical to VR simulator in terms of their capability to determine intraoperative errors—which can be directly associated with morbidity and perhaps mortality in a real operating theater—when considering these errors can be lessened with increasing laparoscopic experience for colectomy (18). Moreover, suturing is not considered a task for sigmoid colectomy simulation in Beyer-Berjot and colleagues' work (17). Although this task can be considered more demanding, novices should be familiar with suturing before experiencing real atmosphere of the operating room, to be able to manage complications including iatrogenic bowel injury and perhaps anastomotic separation.

What constitutes an acceptable outcome measure as a proxy for clinical effectiveness in LCS is a contentious issue. Dedicated performance metrics for an advanced and more complex procedure, laparoscopic sigmoid colectomy, could be used for a more realistic measurement. To our knowledge, operating time does not perfectly reflect learning curve characteristics in LCS due to its complex nature. Time taken has been broadly criticized as a weak proxy for learning curve evaluation and does not relate to proficiency (1,22). From this perspective, in addition to time-related and instrument handling-related parameters used, assessment of error-related parameters including tissue damage, instrument misses, badly placed and/or dropped clips, burn damage and blood loss, would be more convenient. As there is always a risk of facing with these unpleasant complications, even for experienced surgeons, during LCS.

We believe that VR simulators designed to assess relevant performance metrics are selected optimally based on outcome measures, with patient specific data would be more reliable and show better validity evidence. Since colonic VR simulations designed based on individual patient's imaging data may improve training by a stepwise increase in task difficulty similar to the real practice. Novel high-quality educational tools such as specially embalmed human anatomical specimen can offer unexperienced surgeons more accurate interpretation of tissues before operating room (23).

Methodologically, learning curves and quality of surgery should be measured and controlled through risk adjusted cumulative sum (CUSUM) analysis, which is an extension of the original CUSUM method, plotting the difference between the cumulative expected failures and the failures that actually occurred (8,24,25). With respect to the fidelity, effect on clinical training, trainee satisfaction; released reports questioning the utilization of VR tools demonstrated obvious contribution to learning process for LCS (15,26). However, determining how many cases are required to achieve learning curve is critical in order to give reliable data to colorectal surgeons. For this aim, specific and optimal outcome measures should be assessed in a statistically sound fashion. Beyer-Berjot and colleagues noted that there were no significant differences between novice surgeons' 10th attempt and experienced surgeons' performance based on VR training assessment (17). On the other hand, other works characterizing the learning curve for LCS indicated that at least 30 cases were necessary to demonstrate a significant improvement in outcomes (8,27,28). They justified this finding based on different characteristics between simulation, which has a fixed nature, and additional challenges encountered during real procedure (necessity of splenic flexure mobilization and small bowel to recline). Additionally, it would be addressed that end points of conversion, harvested lymph nodes, perioperative complications, morbidity, and mortality were used for learning curve evaluation, in addition to the end point of operating time, which can probably better reflect surgical complexity for LCS.

In summary, current standard of residency training in LCS would be better qualified by a curriculum including competency-based VR training. Further research is required to characterize more dedicated VR simulators and which metrics in VR training should be assessed to improve its educational value.

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None.

Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

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Laparoscopic radical treatment with preservation of left colon artery and superior rectal artery for sigmoid colon cancer

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Abstract: During the classical radical treatment for sigmoid colon cancer, ligation of the inferior mesenteric artery (IMA) at its root is typically performed to achieve better dissection of central and intermediate lymph node groups and improve the surgical outcomes. However, the blood supply to the left colon artery (LCA), sigmoid artery, and superior rectal artery (SRA) is blocked after the ligation at the root of the IMA. Here, we report laparoscopic radical treatment with preservation of the LCA and SRA for sigmoid colon cancer to preservation of blood supply to the anastomosis. The method was indicated to treat cancer at the middle portion of sigmoid colon. In the operation, we careful dissection of IMA exposes the trunk of IMA. The surrounding lymphatic tissue is dissected from the IMA root to its distal end. The LCA is preserved. After IMA divides LCA, 2–5 sigmoid colon arteries are transected one after another at the distal end of the LCA until it further divides into left and right rectal arteries before entering the lateral wall of rectum. The inferior mesenteric vein (IMV) is transected at the lower edge of the pancreas, and the mesorectum is cut open towards the spleen curvature at the lower edge of the pancreas. Other procedures are similar with IMA high ligation surgery. Generally, LCA and SRA can be successfully preserved, and if necessary, the colonic splenic flexure should be mobilized to ensure that there is no tension at the anastomosis. The operation doesn't significantly prolonged operation, but retrieved comparable lymph node counts with IMA high ligation surgery. Dissection of the lymphoadipose tissues at the root of IMA with the preservation of LCA and SRA is an easily performed surgery. It guarantees further prospective clinical research to compare the anastomosis leakage and oncological outcome with IMA high ligation surgery.

Keywords: Sigmoid colon cancer; surgery; preservation of left colon artery (LCA); preservation of superior rectal artery (preservation of SRA)

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Introduction

During the classical radical treatment for sigmoid colon cancer, especially in patients with advanced diseases, ligation of the inferior mesenteric artery (IMA) at its root is typically performed to achieve better dissection of central and intermediate lymph node groups and improve the surgical outcomes. However, the blood supply to the left colon artery (LCA), sigmoid artery, and superior rectal artery (SRA) is blocked after the ligation at the root of the IMA. While the healing of the anastomosis is the most important factor affecting the success of the surgery, blood supply is one of the key factors affecting the anastomotic healing (1,2). The blood supply to the proximal resection margin of the descending colon and the distal resection margin of the rectum tends to be poor in patient with abnormal vascular anatomy; therefore, the operator has to mobilize the splenic flexure to search for a well-supplied segment of the intestine to establish anastomosis with the rectum, which often requires the mobilization of splenic flexure or even the removal of part of the descending colon. Therefore, laparoscopic radical treatment with preservation of the LCA and SRA for sigmoid colon cancer is particularly meaningful for the preservation of blood supply to the anastomosis.

Indications

It is indicated to treat cancer at the middle portion of sigmoid colon. Generally, cancers near the sigmoid-descending colon junction are treated as descending colon cancer, and those near the sigmoid colon-rectum junction as rectal cancer.

Contraindications

Tumor-related contraindications: (I) tumor >10 cm in diameter and/or with extensive invasion into surrounding tissues and organs; and (II) accompanied by acute intestinal obstruction, perforation, and/or other conditions.

Patient-related contraindications: (I) poor general condition; (II) accompanied with severe heart, liver, lung and kidney diseases and therefore cannot tolerate anesthesia or surgery; (III) extensive abdominal adhesions; (IV) severe obesity; and (V) with underlying diseases that can easily cause bleeding.

Preoperative preparations

(I) Preoperative examinations are performed to learn the functions of the whole body and the potential lymph node metastasis in liver, lungs, retroperitoneum, and/or mesentery;
(II) Diseases (e.g., hypertension, diabetes, and coronary heart disease) that may affect the surgery should be controlled;
(III) Anaemia and hypoproteinemia should be corrected; if necessary, enteral nutrition is added one week before surgery;
(IV) For patients with chronic bronchitis, obstructive emphysema and other respiratory complications before surgery, the respiratory function should be assessed before surgery, along with breathing exercises; if necessary, nebulizers may be applied to facilitate expectoration;
(V) If the patients have urinary symptoms, cystoscopy or urography should be performed before surgery to exclude the possibility of tumor invasion of the urinary tract; if necessary, ureteral catheter may be indwelled before surgery to facilitate identification of the ureter during surgery;
(VI) Bowel preparation liquid diets are given one day prior to surgery, and laxatives are administered the night before surgery.

Anesthesia

Tracheal intubation under general anesthesia is performed, and continuous epidural anesthesia may be added if necessary.

Body position

The patient is place on a lithotripsy position, with bilateral hip joint held at 45° of flexion and abduction and knee joint at 30° of flexion. The lower limbs are lower than or flush with the abdomen, the hips are raised, and the right upper limb is adducted (so that the operator and the camera holder can stand at right positions). The left upper limb is adducted or abducted as needed, and the feet are raised 30° over head after the surgery begins (*Figure 1*). The operator's standing position is shown in *Figure 2*.

Operator's standing position, trocar placement, and main surgical steps

Operator's standing position

The operator and the camera holder stand at the patient's right side, and the first assistant at the opposite side of the operator.

Trocar placement

A 10- or 12-mm trocar is placed on the upper edge of the umbilicus, and the laparoscope is placed as an observation port after the trocar is inflated. A second 12-mm trocar is placed at the McBurney's point in the right lower abdomen under the laparoscope (two fingers above the anterior superior iliac spine) and used as the main operating port. A 5-mm trocar is inserted at the flat umbilical point on the right midclavicular line as the auxiliary operating port; if the patient is short, the point can be moved upwards by 3–4 cm to facilitate operation. A 5-mm trocar is inserted at the outer 1/3 site of the connection between the left anterior superior

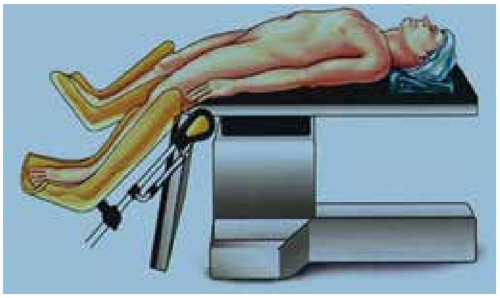

Figure 1 Body position of an operator performing laparoscopic radical treatment for sigmoid colon cancer.

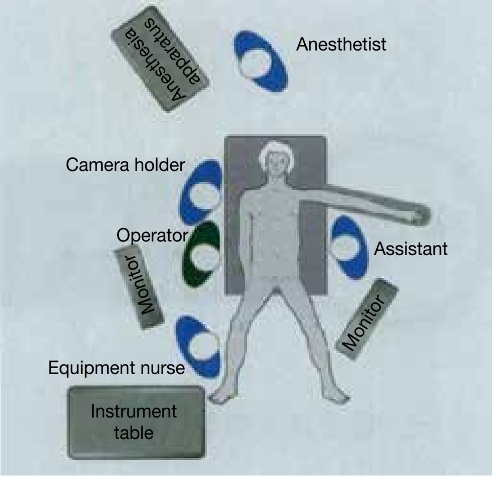

Figure 2 Placement of trocars in the laparoscopic radical treatment of sigmoid colon cancer.

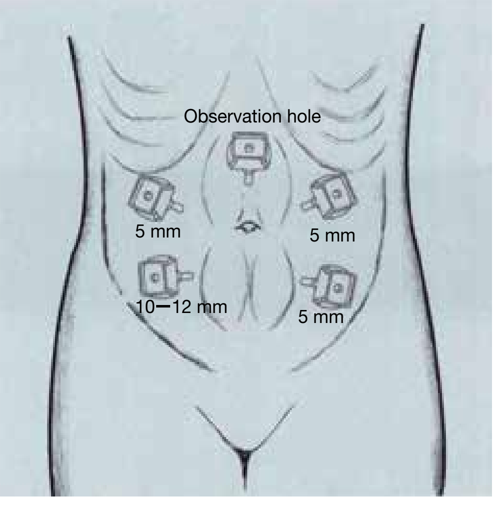

Figure 3 Placement of trocars in the laparoscopic radical treatment of sigmoid colon cancer.

Figure 4 Cut open the right side of the sigmoid mesocolon along the iliac crest level.

Figure 5 Mobilization towards caudal portion, cephalic portion, and left side after entering the Toldt's gap.

iliac spine and the umbilicus as the main operating port for the assistant. Finally, a second 5-mm trocar is inserted 1–2 cm above the umbilicus near the left rectus abdominis muscle as the auxiliary operating port for the assistant (*Figure 3*).

Main surgical steps

(I) Mobilization of mesenteric vessels and lymph node dissection: after the exploration is completed, the physiological adhesions of sigmoid colon and lateral peritoneum are firstly separated. After the bifurcation of the abdominal aorta is identified, the right side of the sigmoid mesocolon is cut open along the tibial condyle (*Figure 4*). After the Toldt's gap is exposed, mobilization is performed towards its caudal portion (till the rectum-sigmoid junction), cephalic portion (till the root of IMA), and left-sided walls (till the Toldt line), respectively (*Figure 5*), thus forming a tunnel between the sigmoid mesocolon and the abdominal aorta. The mobilization continues along the tunnel towards the caudal portion and reaches the posterior rectal space, approximately at the S3 level. Special care

Figure 6 Mobilization along the Toldt's gap (pay attention to protecting the left ureter and left-sided vessels that feed the reproductive system).

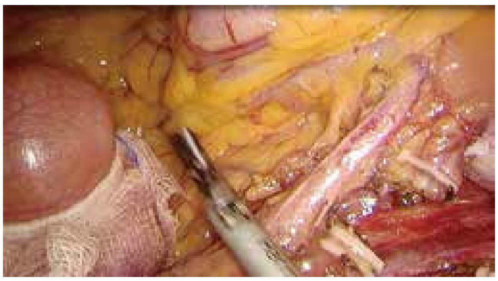

Figure 7 Dissect and skeletonize the IMA trunk, with the LCA preserved. IMA, inferior mesenteric artery; LCA, left colic artery.

Figure 8 Transect 2–5 sigmoid arteries one after another.

Figure 9 Preserve the superior rectal artery, after cutting off each artery branch of sigmoid colon in order.

Figure 10 Clean and cut off the lymph nodes around the mesenteric vein.

should be taken to maintain the integrity of the left colonic mesentery and prerenal fascia, so as to avoid damage to the inferior mesenteric plexus, left ureter, and left genital vasculature (*Figure 6*). Careful dissection of IMA exposes the trunk of IMA. The surrounding lymphatic tissue is dissected from the IMA root to its distal end. The LCA is preserved (*Figure 7*). After IMA divides LCA, 2–5 sigmoid colon arteries are transected one after another at the distal end of the left colon artery (*Figure 8*) until it further divides into left and right rectal arteries before entering the lateral wall of rectum. The mobilization continues along the Toldt gap towards the cephalic portion and the left side until the inferior mesenteric vein (IMV) is exposed (*Figure 9*). After the adjacent lymph nodes are dissected, the IMV is transected at the lower edge of the pancreas (*Figure 10*). Then, the mobilization continues towards the caudal portion of the pancreas along the Toldt's gap, and the mesorectum is cut open towards the spleen curvature at the lower edge of the pancreas. If necessary, the colonic splenic flexure should be mobilized to ensure that there is no tension at the anastomosis. The cutting of the descending mesorectum should be performed in the avascular zone near the IMV to avoid any damage to the vascular arch at the edge of the descending colon.

(II) XMobilization of sigmoid colon and cutting of mesentery: after the transection of the branches of sigmoid artery and IMV, the lateral peritoneum and the retroperitoneum behind left paracolic sulcus can be cut open along the Toldt's line at the left side of sigmoid colon. If the above-mentioned

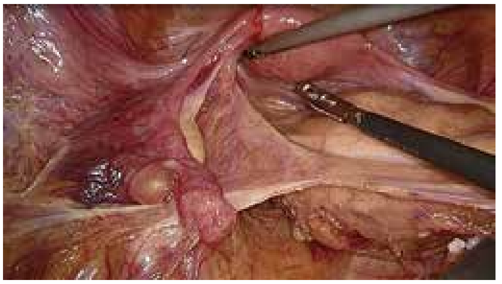

Figure 11 Pull the sigmoid colon to the right to fully expose the Toldt's gap.

Figure 12 The preserved left colon artery and superior rectal artery have good blood supply.

"tunnel" has been fully mobilized, cutting along the Toldt's line can achieve the communication with the "tunnel". If the "tunnel" has not been fully mobilized, the sigmoid colon can be pulled to the right to fully expose the Toldt's gap (*Figure 11*). Mobilizing along this gap till the original "tunnel" can achieve the complete mobilization of the entire sigmoid colon. If the sigmoid colon is found to be short and the intestine might not be long enough after tumor resection, mobilization of the left colic flexure may be considered.

(III) Removal of tumor and reconstruction of the digestive tract: if the sigmoid colon is long, extraperitoneal resection and anastomosis can be performed. The original camera port can be utilized to create umbilical midline incision, and side-to-side or end-to-side anastomosis is performed after the tumor is removed (*Figure 12*). Notably, at least 10 cm of bowel on both sides of the tumor should be resected. If the extraperitoneal anastomosis is not feasible, the bowel can be skeletonized 10 cm beneath the lower edge of tumor, followed by the laparoscopic transection of the bowel by using the linear cutter stapler. The precut site at proximal bowel is marked with a titanium clip to ensure that there is no tensional anastomosis after transection. After the tumor is resected, the proximal bowel is placed into the anvil of the stapler to return to the abdominal cavity, and the pneumoperitoneum is then reconstructed. The stapler is inserted via the anus to complete the anastomosis with the proximal bowel, during which the bowel should not be twisted. If there is a large tension on the anastomosis, the splenic flexure of the descending colon must be further mobilized to the cephalic side. After the anastomosis is completed, routinely check the integrity of two anastomosis rings on the stapler and place a drainage tube close to the anastomosis before the abdomen is closed.

Key points of surgery

Maintaining a correct anatomical plane

The dissection must be performed on the correct anatomical plane (i.e., the Toldt's gap). The Toldt's gap is a fascial plane which is formed by the fusion of left mesentery and prerenal fascia.

Transection of vessels

Vessels should be transected at the origins of the branches of sigmoid artery where the IMA divides, along with the dissection of lymphoadipose tissues around the vessels.

Reducing the incidence of anastomotic leak

Maintaining anastomotic blood supply, reducing tension, and preventing infections are key measures to reduce the incidence of anastomotic leak. The left colon artery and SRA should be preserved. If there is a large tension on the anastomosis, the bowel shall be thoroughly mobilized, along with good nutritional support and adequate preoperative preparation.

Discussion

Lymph node metastasis of sigmoid colon cancer has been widely recognized as one of the most important factors leading to poor prognosis. Therefore, both the scope of lymph node dissection and the quality of surgical specimens can affect the prognosis. For patients with locally advanced sigmoid colon cancer, D2 lymph node dissection (i.e., the removal of lymph nodes around the colon, in the intermediate group, and at the root of IMA) is typically recommended. During the classical radical treatment of sigmoid colon cancer, ligation of the IMA at its root is often performed to ensure better scope of lymph node dissection (3,4). Kanemits *et al.* (5) reported that high ligation of the IMA prolonged the survival of patients, and postoperative pathology confirmed that the 5-year survival rate reached 40% in patients with lymph node metastases at the root of IMA. Chin *et al.* (6) also had similar findings. This procedure is simple and time-saving and is helpful for freeing the descending colon and lowering the tension of the descending colon-rectum anastomosis. However, the ligation of the IMA at its root also blocks the blood supply of the left colon artery, sigmoid arteries, and SRA and reduces blood supply to the descending colon-rectum anastomosis (1,2). Anatomically, most of the rectal blood supply above the dentate line comes from the SRA; furthermore, while the blood supply of the distal rectum and anal canal mainly depends on the middle rectal artery and the internal pudendal artery, the descending colon is mainly supplied by the left branch of middle colonic artery and LCA. It has been reported that about LCA is absent in about 12% of patients (7). In patients with certain physiological/anatomical abnormalities (e.g., the LCA offers major blood supply to the descending colon, especially the distal end of the descending colon), the LCA should be preserved to the maximum extent possible. Furthermore, in order to achieve the optimal oncological cure, the LCA and the SRA should be completely skeletonized and preserved while dissecting the lymphoadipose tissues near the IMA, along with ligation of the branch of sigmoid artery at its origin. Such a procedure not only fully ensures the oncological effectiveness of the radical treatment but also satisfies the blood supply required by descending colon and rectum. The tension of the descending colon-rectum anastomosis will not increase after surgery. Dissection of the lymphoadipose tissues at the root of IMA with the preservation of LCA and SRA does not significantly increase the operative time and blood loss compared with the direct ligation of the IMA at its root. Finally, postoperative pathology has confirmed the number of lymph node harvested was comparable between two groups, which was consistent with literature (8).

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Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

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Simultaneous laparoscopic distal gastrectomy (uncut Roux-en-Y anastomosis), right hemi-colectomy and radical rectectomy (Dixon) in a synchronous triple primary stomach, colon and rectal cancers patient

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Contributions: (I) Conception and design: All authors; (II) Administrative support: None; (III) Provision of study materials or patients: L Yang; (IV) Collection and assembly of data: L Yang; (V) Data analysis and interpretation: L Yang; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

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Background: Gastric and colorectal cancers are both one of the most common tumors worldwide, while the morbidity of multiple synchronous primary tumors are really rare, and triple synchronous primary cancers are considered has a lower incidence. In this report, we demonstrate a rare case of synchronous triple primary cancers involving gastric, colon and rectal, and the laparoscopic operation procedure of the patient.

Methods: A 49-year-old male diagnosed with synchronous triple primary gastric, colon and rectal cancer, underwent simultaneous laparoscopic distal gastrectomy (uncut Roux-en-Y anastomosis, D2), right hemi-colectomy and radical rectectomy (Dixon).

Results: The operation lasts 305 min with about 300 mL blood lost. The patient discharged from hospital on the 12th day without any complication.

Conclusions: Laparoscopic surgery is a safe and feasible way in synchronous gastrointestinal triple primary cancers. Nevertheless, because of the rare incidence, many details and specific condition should be considered during the peri-operative period of this multiple synchronous cancers patient.

Keywords: Synchronous triple primary cancers; laparoscopic surgery; uncut Roux-en-Y reconstruction; right hemi-colectomy; radical rectectomy

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Introduction

Gastric cancer and colorectal cancer are common malignancies, while synchronous gastric cancer, primary colon and primary rectal cancel are extremely rare. Here we report a rare case of synchronous triple primary tumors involving gastric, colon and rectal in a 49-year-old male. Uncut Roux-en-Y anastomosis is relatively difficult procedures during distal gastrectomy, and laparoscopic radical right hemicolectomy as well as radical rectectomy (Dixon) are common procedures in colorectal surgery, while carrying out the three laparoscopic operations simultaneously has not been reported yet and the procedure is relatively complicated. Now we will describe our surgical techniques.

Methods

Ethical approval and patient consent

The present study was approved by the Ethics Committee of the First Affiliated Hospital of Nanjing Medical University (Nanjing, Jiangsu, China). Written informed consent was obtained from the present subject prior to enrollment in the present study.

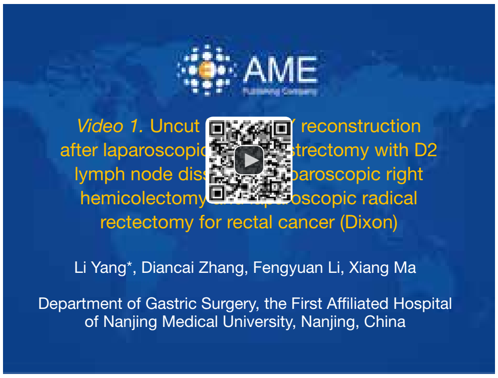

Figure 1 Uncut Roux-en-Y reconstruction after laparoscopic distal gastrectomy with D2 lymph node dissection, laparoscopic right hemicolectomy and laparoscopic radical rectectomy for rectal cancer (Dixon) (1).
Available online: http://www.asvide.com/articles/986

Patient selection and workup

In the video (*Figure 1*), the patient is a 49-year-old man who was diagnosed with synchronous triple primary cancers involving gastric, colon and rectal by gastroscopy, colonoscopy and pathological examination (*Figure 2*). The tumor stages were evaluated to be cT1N0M0 for stomach, cT4N0M0 for colon and cT2N0M0 for rectal by CT scan pre-operation (*Figure 3*). Uncut Roux-en-Y anastomosis after laparoscopic distal gastrectomy with D2 lymph node dissection, laparoscopic right hemicolectomy and laparoscopic radical rectectomy for rectal cancer were intended to be carried out.

Procedure

After successful anesthesia, the patient was placed horizontal position with legs apart. At the beginning of this operation, five trocars are required. Firstly, the 10-mm trocar was placed above the umbilicus and a 30-degree laparoscope was inserted. Then other four trocars were installed under direct sight: two 5-mm trocars into the right upper and

Figure 2 Gastroscopy and colonoscopy.

Figure 3 CT scan.

right lower abdomen, and two 12-mm trocars into the right upper and left lower abdomen.

Firstly, the peritoneal cavity and pelvic cavity were explored to rule out underlying metastasis or invasion.

Laparoscopic distal gastrectomy with D2 lymph nodes dissection procedure: after D2 lymph nodes dissection, duodenum was divided 2 cm away from pylorus using 60 mm linear stapler. The distal stomach was divided by two firings of a linear stapler, and the resected specimen was put in a plastic bag. In the same time, the jejunum 20 cm away from the Traitz ligament was labeled by silk thread.

Laparoscopic right hemicolectomy: we chose the McBurney's point incision and lower abdomen middle incision to put in another two trocars, one 5-mm, and one 12-mm under direct vision. Then we exposed and separated the superior mesenteric vein and the ileocolic vascular, then ligated the ileocolic vascular at the root. Next we entered Toldt's fascia to expose and prevent damage to the right gonadal vessels and ureter. Lymph nodes alone the superior mesenteric artery should be dissected and the horizontal and descending part of the duodenum should be exposed. After that we start resecting 2/3 left great omentum of the transverse colon. Ultimately, we detached the right colon and the hepatic flexure completely from the lateral peritoneal attachment.

Laparoscopic radical rectectomy: we dissected mesentery along with the right iliac artery surface up to the bifurcation, and separate mesentery along the abdominal aorta to expose inferior mesenteric artery. And then we separated the mesentery along Toldt fascia surface to the opposite side to expose and protect the left ureter. Next the sigmoid mesentery was separated at the root and lateral ligament of the rectum were divided. According to the total mesorectal excision principle, the rectum was freed along Denonvilliers fascia until at a distance of 3 cm from the distal margin of the carcinoma and divided the rectum.

Specimen extraction and anastomosis: the gastric specimen was then taken out from the abdomen through the trocar about 5 cm in size around the umbilicus. Taking out the right hemicolon through the incision around the umbilicus, divided and removed it, then an ileotransversostomy was performed by the linear stapler and strengthened by suturing. Put back the colon and took out the rectum, freed the sigmoid colon mesentery and divided the sigmoid colon about 10 cm above the tumor. The stapler head was extracorporeal placed and repositioned into the abdomen. After that, the jejunum was took out from the same incision by pulling the labeled thread and then a Braun anastomosis was performed in the proximal 10 cm and the distal 50 cm away from the Treitz ligament. Next, the afferent loop was occluded 10 cm far from the jejunojejunostomy place with linear stapler (uncut). After that, put back the small intestine into the peritoneal cavity and reestablish pneumoperitoneum. Sigmoidorectostomy was performed by stapler through anus. The last step was performing laparoscopic gastrojejunostomy at a point 2 cm distance to the blocking place.

Results

The whole operation took about 305 min with bleeding of about 300 mL. The postoperative pathologic finding showed an early gastric myxoadenocarcinoma (T1bN0M0, stage IA), colon adenocarcinoma (T4aN0M0, stage IIB), and rectal adenocarcinoma (T2N0M0, stage I). The patient discharged from hospital on the 12th day without any complication.

Discussion

Multiple primary malignant neoplasms are two or more malignancies in an individual without any relationship between the tumors. Synchronous tumors are defined as ≥2 primary tumors occurring within 6 months after diagnosing the first primary tumor. If the time interval was more than 6 months, the tumors were considered to be metachronous (2).

Both gastric and colorectal cancers are common tumor worldwide, while the morbidity of multiple synchronous primary tumors are really rare, which has been reported to vary from 0.7% to 11.7% (3). And triple synchronous primary cancers are considered has a rarer incidence. A previous study indicated that the incidence of multiple synchronous primary cancers in China is about 3.13% (4), which is similar to foreign countries. In all gastric cancer patients, Lee *et al.* reported that the frequency of synchronous malignant tumors is about 3.4% in 3,291 cases (5).

With the improvement of medical examination technology, more multiple synchronous primary cancers patient can be diagnosed. Nevertheless, diagnose error and misdiagnosis rate are still quite high. Therefore, when diagnosing a cancer patient, firstly, we should take synchronous primary cancers into consideration. Secondly, we should be caution when differentiating diagnosis of synchronous primary cancers from metastatic cancer, because their therapies are totally different.

Currently, there is no guideline for the treatment of multiple synchronous primary cancers. The most common treatment is surgery associated with adjuvant treatment (6). In resectable multiple synchronous primary cancers, radical surgery with or without chemotherapy is the preferred treatment (7,8). In the present synchronous triple primary stomach, colon and rectal cancers patient, we have several questions. For example, how to choose the way of operation, open or laparoscopic? If we choose laparoscopic operation on this patient, how we select the position of trocars so that we can carry out the procedure favorably and smoothly. Meanwhile, which is the optimal resection order in the present synchronous triple primary stomach, colon and rectal cancers patient? And which is the best reconstruction way for laparoscopic distal gastrectomy in this patient? Considering the relative early cStages of the three primary tumors in the present patient, we selected laparoscopic surgery and the exactly process of the operation was described detailed in the procedure part. According to our operation plan, the procedures were completed successfully, and lymph nodes dissection was sufficient, with no metastases in total 68 lymph nodes. Besides that, we made use of the essential single umbilical incision which was used to take out specimens to perform ileotransversostomy, jejunojejunostomy and occlude the afferent loop. Then laparoscopic sigmoidorectostomy and gastrojejunostomy were performed after reestablishing pneumoperitoneum. This minimally invasive operation brought the patient quickly recovery. In this case, we chose uncut Roux-en-Y reconstruction after laparoscopic distal gastrectomy with D2 lymph node dissection, because it is reported that uncut Roux-en-Y technique, would preserve unidirectional intestinal myoelectrical activity and diminish Roux Stasis Syndrome (9,10). And nine months follow-up post-operation indicates that the patient recovers well without any symptoms of Roux Stasis Syndrome.

Uncut Roux-en-Y anastomosis after laparoscopic distal gastrectomy with D2 lymph nodes dissection is a relatively complicated operation. Performing the three laparoscopic operations in one patient simultaneously is more difficult. Therefore, the laparoscopic surgery therapy for multiple primary malignant neoplasms should be performed by surgeons who are rich in experiences of laparoscopy surgical techniques.

Conclusions

In resectable multiple synchronous primary cancers, radical surgery is the preferred treatment, but weather choose the laparoscopic surgery and how to design the resection order is depending on the primary tumors' stages and surgeons' experience. More attempts should be done on the laparoscopic resection of multiple synchronous cancers.

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Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

Ethical Statement: The study was approved by the Ethics Committee of the First Affiliated Hospital of Nanjing Medical University (Nanjing, Jiangsu, China). Written informed consent was obtained from the patient. A copy of the written consent is available for review by the Editor-in-Chief of this journal.

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Vessel-centered laparoscopic total mesorectal excision via medial approach

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Introduction

Total mesorectal excision (TME) is currently the standard treatment for rectal cancer. This procedure provides significant oncological benefits by reducing local recurrence and increasing 5-year survival. Laparoscopic surgery for colorectal cancer has been steadily developing since its introduction in 1990, and laparoscopic TME (lap TME) is an ideal minimally invasive surgical technique for rectal cancer. Compared with laparotomy, laparoscopic surgery has similar safety, completeness of resection, and prognosis (1,2).

The primary principle of rectal TME is to find an anatomical plane to ensure the integrity of visceral layer of the rectum during the surgery. Therefore, laparoscopic lateral and medial approaches are developed based on the membrane anatomy. Experienced surgeons may adopt the lateral approach to reach the correct plane; however, entering the posterior renal space by mistake is common. At present, the medial approach is more widely used; that is, the dissection starts at the level of iliac crest or the root of the mesenteric artery and then travels upwards along the abdominal aorta to cut open the sigmoid mesocolon and thus find an appropriate anatomical plane; subsequently, the root of mesenteric blood vessel is skeletonized to remove lymph nodes. Another principle of the radical surgery for tumors is to prioritize the handling of blood vessels, including dissection of perivascular lymphatic adipose tissue and transection of blood vessels, during which the veins are transected first, followed by the transection of arteries, so as to lower the risk of tumor metastasis via the blood stream during the surgery. During TME, the inferior mesenteric artery (IMA) and its accompanying vessels should be skeletonized, and the inferior mesenteric vein (IMV) should be transected first. In addition, under the premise of ensuring the radical treatment of tumors, the nourishing vessels (e.g., the left colonic artery) of the anastomosis of the intestine should be carefully protected. An increasing number of evidences have shown that the transection of the left colonic vessels may increase the risk of postoperative anastomotic leak. TME via the conventional laparoscopic medial approach typically follows the order of layer-vessel, which may result in the dissociation of mesangium due to early separation of the Toldt's space behind the mesorectum, the exposure of left colonic blood vessels and IMV, and difficulty in the dissection of lymph nodes at the root of IMA. Therefore, when following the principles of TME, we altered the order of layer-vessel in conventional medial approach based on the need for vessel handling and lymph node dissection in rectal cancer patients and proposed the concept of handling vessels before expanding layers; that is, the vascular pathway is dissected first, and then the posterior rectal layer is extended, which is known as the vessel-centered laparoscopic TME via medial approach. The advantages of this procedure include: (I) it completely follows the principles of radical treatment of tumors, minimizing the risk of tumor metastasis via blood stream; (II) compared with the layer-vessel practice, the vessels are relatively fixed since the posterior vascular space has not been mobilized, and dissection along the blood vessels can easily expose the IMA trunk, left colonic vessels,

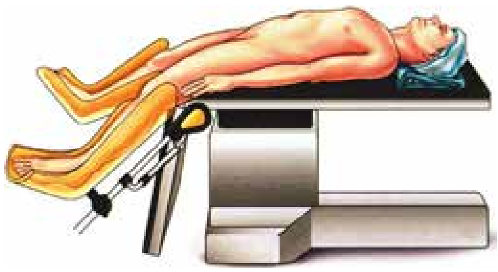


Figure 1 Body position of the patient.

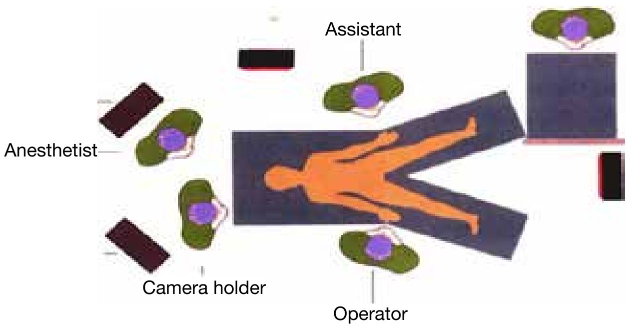


Figure 2 Positions of the operator and the assistants.

and IMV; (III) the full exposure of the blood vessels is conducive to the dissection of inter-vascular lymph nodes, especially the No. 253 lymph node; (IV) it is conducive to the preservation of left colonic vessels; and (V) it simplifies the surgical process and shortens the operation. The specific operation steps of this procedure are as follows.

Indications and contraindications

Indications

Preoperative rectal MRI and/or intrarectal endoscopic ultrasonography reveal clinical cT_1-cT_3 stage and N-negative rectal cancer or lower sigmoid colon cancer. Preoperative rectal MRI and/or intrarectal endoscopic ultrasonography reveals suspiciously positive circumferential resection margin (CRM) and/or N-positive middle to lower rectal cancer that is ≤12 cm away from the anal margin. Neoadjuvant radiochemotherapy followed by surgery is recommended.

Contraindications

Tumor-related contraindications: with positive or suspiciously positive CRM, including severe infiltration of organs around the rectal cancer, massive pelvic tumors, and intestinal obstruction that can not be adequately decompressed; patient-related contraindications: poor systemic conditions; accompanied by other severe diseases; and/or unable to tolerate anesthesia and surgery.

Anesthesia, surgical position, trocar sites, and positions of medical staff

Anesthesia

Tracheal intubation under general anesthesia is performed, and continuous epidural anesthesia may be added.

Surgical position

The patient is placed on a lithotripsy position, with right hip joint held at 45° of extension and abduction and knee joint at 30° of flexion. The hips are raised, and the lower limbs are lower than the hips. The right upper limb is adducted, and the left upper limb is adducted or abducted, when necessary. After surgery begins, the position is adjusted to feet higher than head by 30-degree angle, with the body tilted to the right by 15-degree (*Figure 1*).

Trocar placement

A 10-mm trocar is placed on the upper edge of the umbilicus, and the laparoscope is placed as an observation port after the trocar is inflated. A second 12-mm trocar is placed in the right lower abdomen (intersection between right midclavicular line and the connecting line of bilateral anterior superior iliac spines) under the laparoscope and used as the main operating port. A 5-mm trocar is placed at the left midclavicular line at the level of the umbilicus as the auxiliary operating port. A second 5-mm trocar is placed at intersection between left midclavicular line and the connecting line of bilateral anterior superior iliac spines as the auxiliary operating port (*Figures 2* and *3*).

Surgical steps and key points

(I) After the trocars are inserted, the assistant moves to the left side of the patient, above the operator. The patient's position is adjusted feet higher than head by 30-degree angle and tilted by 15–20 degrees. This allows the small intestine to move to the

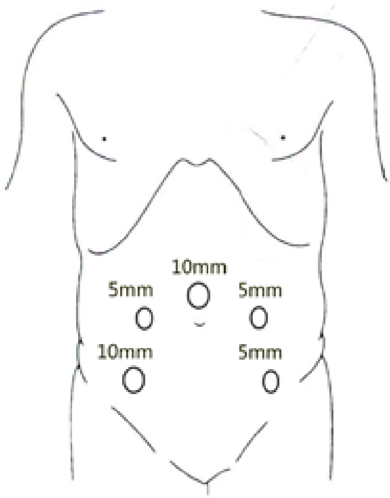


Figure 3 Trocar locations.

Figure 4 Expose the root of small-bowel mesentery.

Figure 5 Use gauze to fend off the small intestine.

upper abdominal cavity, exposing the root of the small-bowel mesentery (*Figure 4*). Gauze is used to fend off the small intestine (*Figure 5*).

(II) The sigmoid colon and rectum are pulled leftwards and upwards to expose the right mesentery of the rectum, creating a groove-like space between the inferior mesenteric vascular pedicle and the posterior peritoneum. The posterior peritoneum is cut open along this line, up to the lower edge of the mesenteric attachment of the small bowel and down to the sacrum (*Figures 6* and *7*).

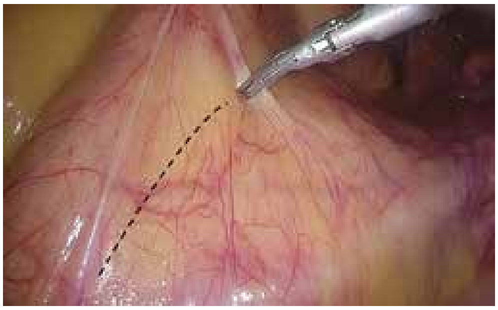


Figure 6 The space (indicated by dotted line).

Figure 7 Dissection along the space.

(III) After the peritoneum in front of the abdominal aorta is cut open, raise the peritoneum to separate adipose tissue until the white sheath of IMA becomes visible. After the traveling of IMA is confirmed, the adipose and lymphoid tissues are dissociated to the distal end along the vascular sheath (*Figures 8-11*).

(IV) Separation toward the distal portion till the site where the IMA gives off the left colic artery (LCA), which travels towards the left upper proximal end. Dissection towards the proximal end continues along the LCA, during which No. 253 lymph node that exists among LCA, IMA, and abdominal aorta is removed (*Figures 12-15*).

(V) Dissection continues towards the distal end along the LCA and IMA planes. Typically, the IMV travels along the lower or lateral side of LCA. Dissection

Figure 8 Separate the peritoneum in front of the root of IMA. IMA, inferior mesenteric artery.

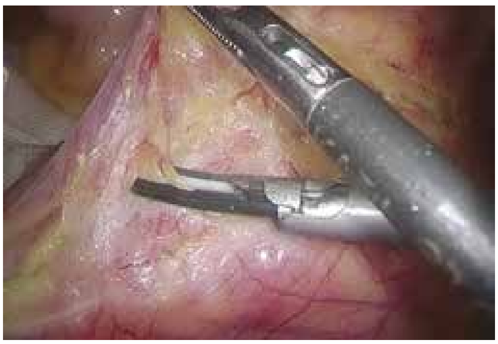


Figure 9 Remove the lymphatic and adipose tissues in front of IMA. IMA, inferior mesenteric artery.

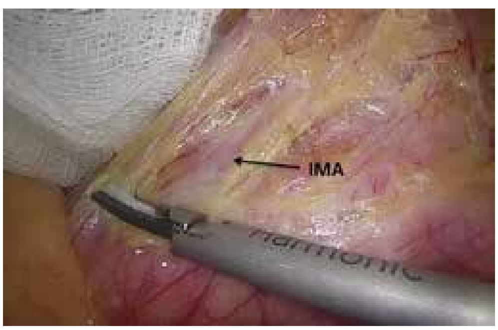


Figure 10 Expose the root of IMA. IMA, inferior mesenteric artery.

along this plane allows the dissociation of superior rectal artery (*Figures 16* and *17*).

(VI) The space behind the IMA is isolated, during which the scalpel should be close to the vessel and the superior hypogastric plexus (SHP), left ureter,

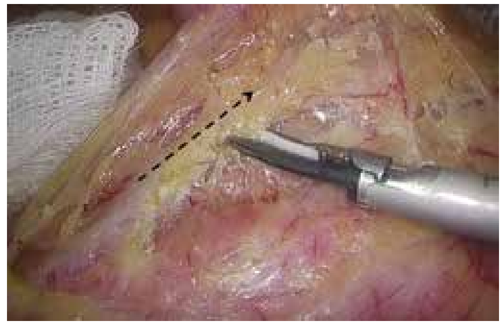


Figure 11 Dissociate the lymphatic and adipose tissues along IMA (indicated by dotted arrow). IMA, inferior mesenteric artery.

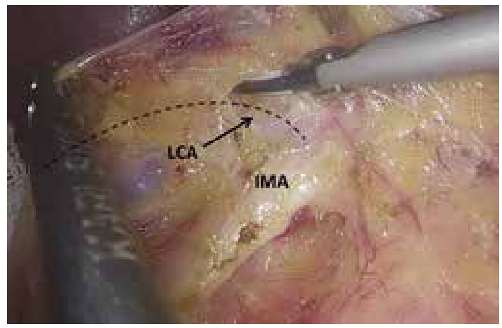


Figure 12 The curved mark is the traveling of the left colic artery (LCA) (indicated by dotted line). IMA, inferior mesenteric artery.

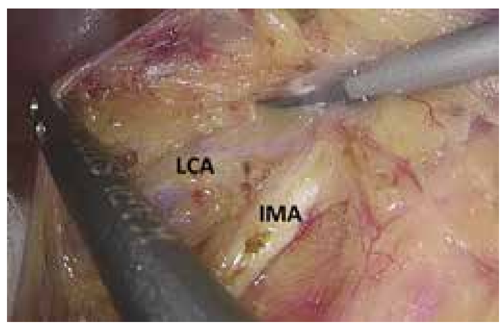


Figure 13 Dissociation of vessels along LCA. LCA, left colic artery; IMA, inferior mesenteric artery.

and left reproductive vessels should be carefully protected (*Figures 18* and *19*).

(VII) Transection of inferior mesenteric vein and superior rectal artery: when the Toldt's space behind the rectum can be clearly seen and the left ureter and genital vessels become visible, dissection continues laterally till the left lateral paracolic

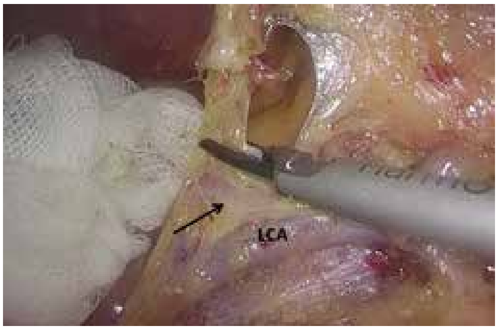


Figure 14 Dissociate LCA till its lower branch. LCA, left colic artery. Arrow shows lower branch of LCA.

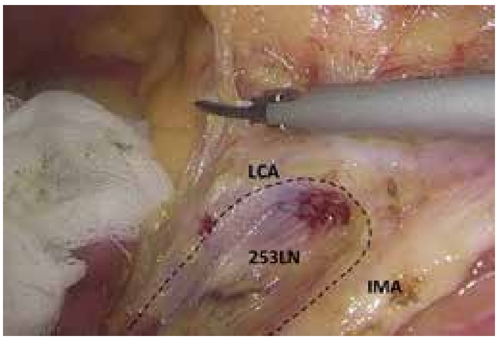
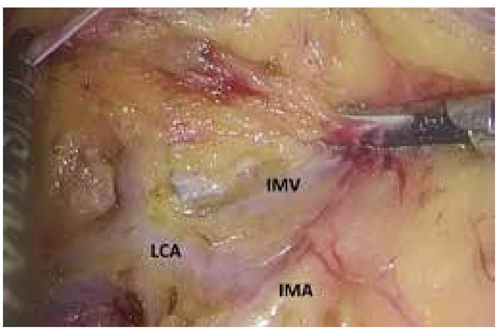
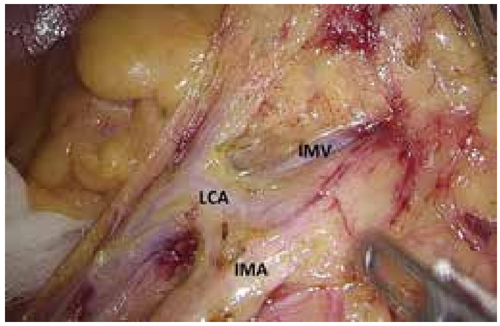


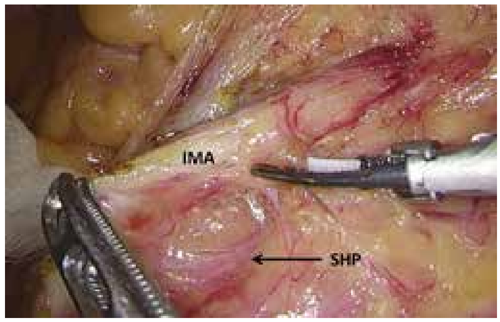
Figure 15 Dissection of the No. 253 lymph node between IMA and LCA. IMA, inferior mesenteric artery; LCA, left colic artery.



Figures 16 Dissection towards the distal end along the IMV and IMA planes. IMA, inferior mesenteric artery; LCA, left colic artery; IMV, inferior mesenteric vein.



Figures 17 Relationship between left colic artery and inferior mesenteric artery/vein. IMA, inferior mesenteric artery; LCA, left colic artery; IMV, inferior mesenteric vein.



Figures 18 Isolation of the space behind inferior mesenteric artery. IMA, inferior mesenteric artery; SHP, superior hypogastric plexus.

Figures 19 The surgical procedures should be close to the vessel to preserve SHP, left ureter. SHP, superior hypogastric plexus.

gutter, during which the superior hypogastric plexus should be protected (*Figures 20-23*).

(VIII) Dissection of the retrorectal space: the retrorectal space, also known as Holy space, is an avascular plane between visceral fascia and parietal fascia. It contains a small amount of loose connective tissue and autonomic nerve that governs the pelvic organs, with the sacrococcygeal ligament as its lower boundary and the lateral ligament as the lateral side. The root of the transected blood vessel is raised and the rectum is pulled forwards and

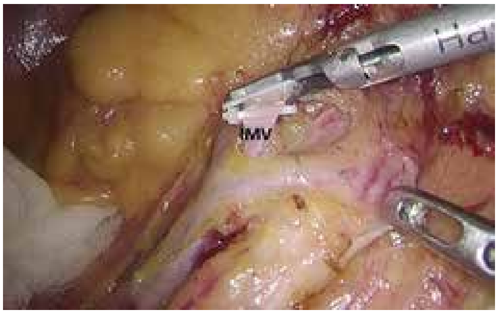


Figure 20 Transection of inferior mesenteric vein. IMV, inferior mesenteric vein.

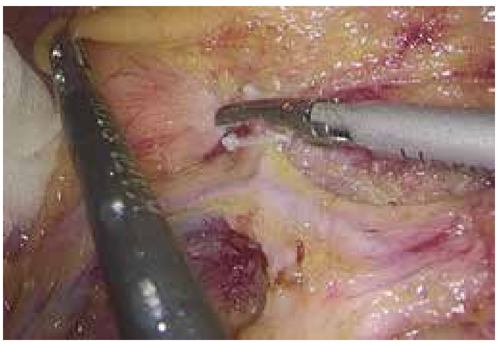


Figure 21 Transection of the branch vessels of sigmoid colon.

Figure 22 Transection of superior rectal artery.

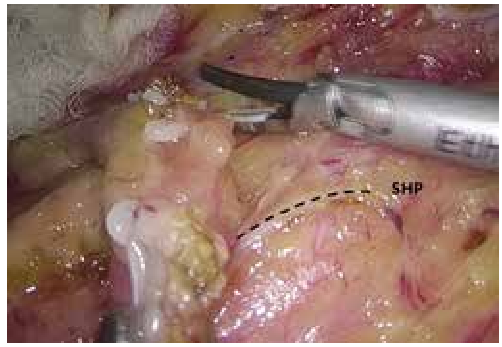


Figure 23 Protection of superior hypogastric plexus (SHP) (indicated by dotted line).

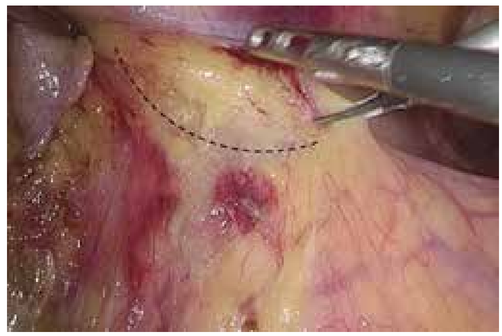


Figure 24 The retrorectal space (indicated by dotted line).

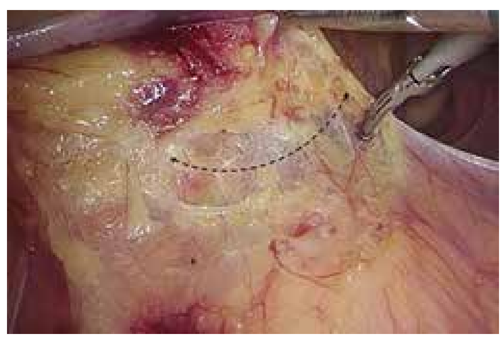


Figure 25 Dissection along the space (indicated by dotted arrow).

towards the head side. After the sharp dissection and separation between visceral fascia and parietal fascia of mesorectum, the retrorectal space (between the hypogastric nerve and the intrinsic fascia of the rectum) can be precisely entered (*Figures 24-26*). The retrorectal space and the lateral wall of rectum are isolated alternately, gradually towards the lower side. The dissection continues along the rectum, followed by “Tunnel” isolation; then, the dissection is extended to the outer side and division is performed along the marking line (*Figures 27-31*).

(IX) Separation of lateral rectal space: open the lateral peritoneum along the yellow-white junction and extend the lateral peritoneum incision. The assistant pulls the rectum toward the head side and the reverse side. The good traction between the

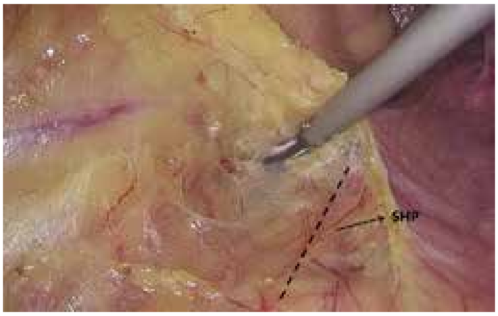


Figure 26 Protection of iliohypogastric nerve (indicated by dotted line).

Figure 27 Lateral dissociation along paracolic sulcus and peritoneal reflection (indicated by dotted line).

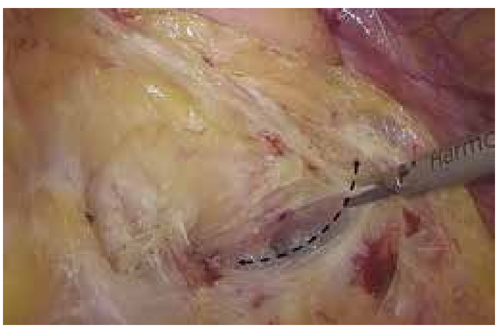


Figure 28 "Tunnel" isolation along the space (indicated by dotted arrow).

operator and the assistant enables the maintenance of adequate tension. Attention should be paid to protect the lateral pelvic nerves (*Figures 32-35*).

(X) Separation of the superior space of levator ani: separate downwards the peritoneal reflection till the level of retrorectal space; when there is a sense of resistance, it means the rectosacral fascia has been reached. At this point, the dense sacrorectal fascia needs to

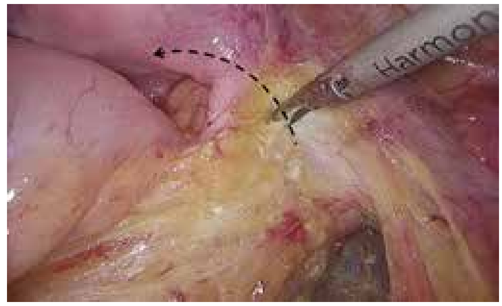


Figure 29 Isolation towards the midline along peritoneal reflection (indicated by dotted arrow).

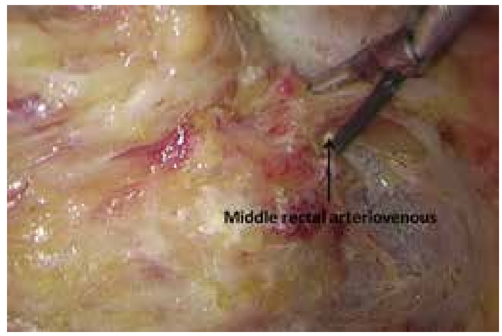


Figure 30 Transection of the middle rectal vessels in lateral rectal ligament.

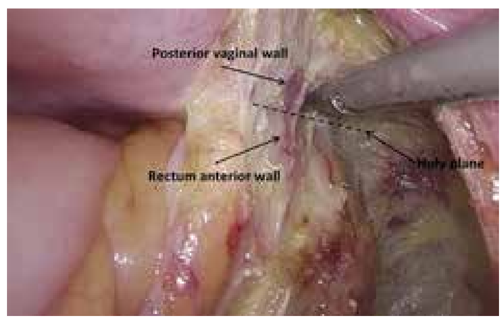


Figure 31 When the dissection reaches the anterior wall, the Holy space between rectum and vagina is visible; avoid damaging the posterior wall of the vagina when dissection along this space. Dotted line shows Holy plane.

be cut open, which allows the entering of a loose space (the superior space of levator ani). Dissection continues towards the anal side till the vertical plane of the levator ani. After the presacral space is entered and isolated, pampiniform presacral venous plexus is visible, which should be carefully protected.

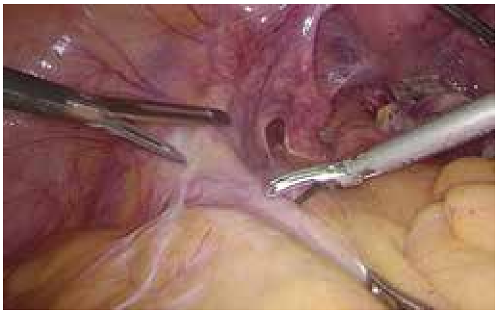


Figure 32 Open the lateral peritoneum along the yellow-white junction.

Figure 33 Cut open the left lateral peritoneum along peritoneal reflection (indicated by dotted line).

Figure 34 Separation and transfixion of the posterior side.

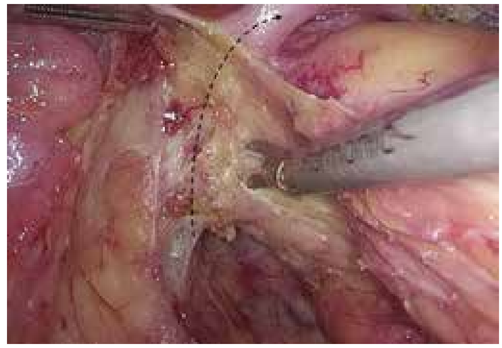


Figure 35 The lateral ligament at the left side of rectum is transected after the dissection along the left peritoneal reflection (indicated by dotted line).

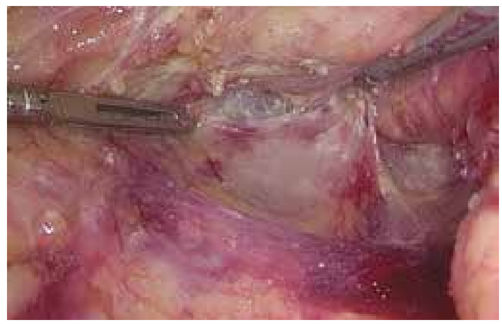


Figure 36 Dissect along the presacral space.

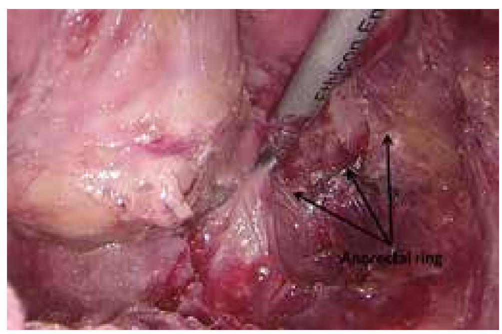


Figure 37 Dissect till the puborectalis sling.

The posterior and lateral sides of the rectum are separated till the edge of the hiatus of levator anus muscle, which its landmark being the puborectalis that surrounds the rectum. Then, the puborectalis is thoroughly mobilized (*Figures 36* and *37*).

(XI) Isolation of prerectal space: peritoneum is usually cut open along a curved line 1.0 cm above the peritoneal reflection and isolated in front of Denonvilliers' fascia. In males, the Denonvilliers' fascia is cut open at the bottom of seminal vesicle. In females, since there is no obvious anatomic landmark, a full-thickness dissection of Denonvilliers' fascia performed near the distal

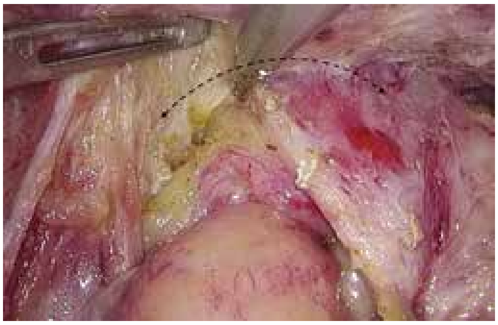


Figure 38 Dissection of bilateral peritoneum meets at the peritoneal reflection (indicated by dotted line).

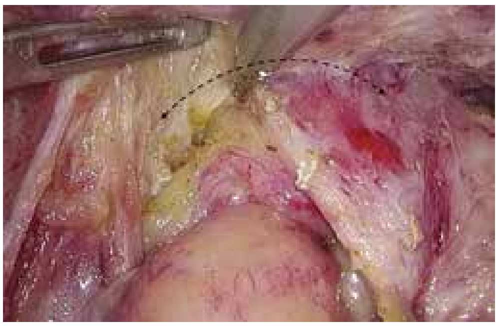


Figure 39 Full-thickness dissection of Denonvilliers' fascia (indicated by dotted arrow).

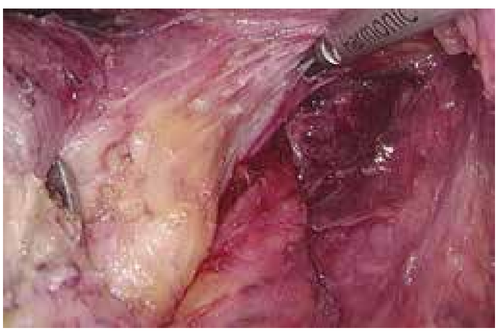


Figure 40 Separate the mesangial tissue at the terminal portion of rectum.

mesorectum (*Figures 38* and *39*).

(XII) Rectal transection: the lower edge of the tumor can be identified by rectal examination and then marked with a titanium clip. The distal resection margin is approximately 2–3 cm above the lower edge of the tumor. Carefully isolate the mesorectum on the lateral and posterior walls of rectum and avoid any

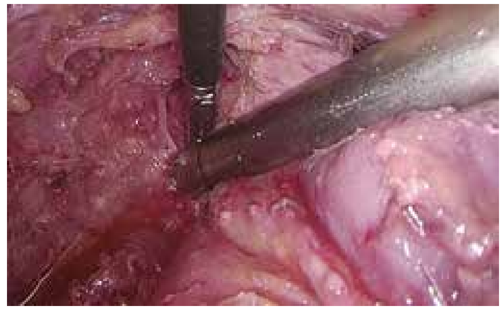


Figure 41 Close the terminal portion of rectum with the stapler.

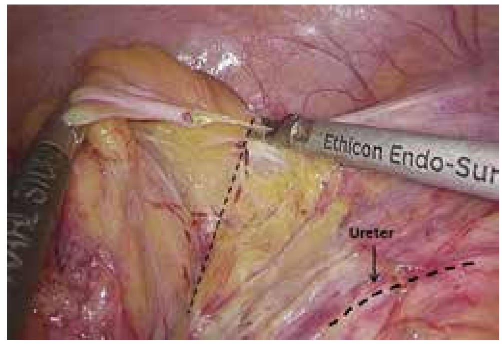


Figure 42 Dissociate the rectal stump towards the proximal side along the Toldt's line. Dotted line shows Toldt's line.

injury or penetration of the intestinal wall. After anal irrigation, a rotatable cutter-stapler is placed through the main operating trocar. The angle of the cutter-stapler is adjusted after the intestinal wall is clamped. The assistant standing at the distal side assists in completely placing the intestine into the cutting range of the cutter-stapler by using a pair of noninvasive pliers. The bowl is then stapled; typically, two closures are required, during which there must be an overlapping area between these two closures to ensure complete closure of the stump (*Figures 40* and *41*).

(XIII) Mobilize and clip the mesorectum to be resected: lift the rectal stump and dissociate it towards the proximal side along the Toldt's line. After the sigmoid and parts of the descending colon are thoroughly mobilized, lift the distal and proximal portions of the rectum and the transected rectal vascular pedicles to form a triangular plane (as shown in the figure). Mobilize the mesorectum along the pre-cut line (*Figures 42* and *43*).

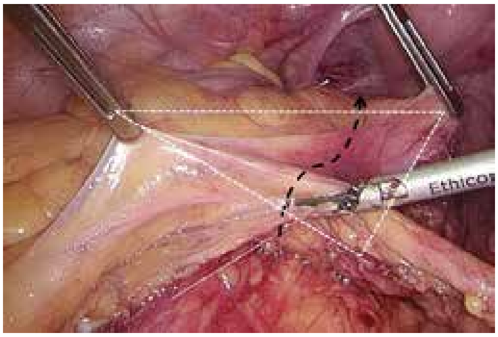


Figure 43 Clip the mesorectum. Black dotted arrow shows the pre-cut line, white dotted lines show triangular plane.

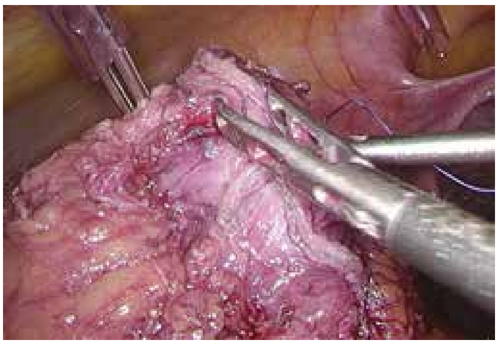


Figure 44 Suture the rectal stump, with the suture end reserved; draw the suture out from the main operating port to facilitate traction.

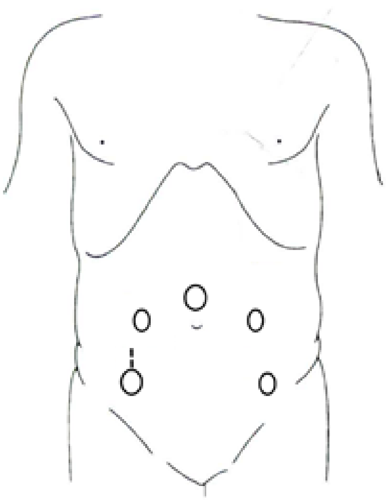


Figure 45 The right main operating port is enlarged as the incision (the dotted line).

Figure 46 The right main operating port is enlarged (the dotted line).

Figure 47 Transection of the intestinal canal at the site 10 cm away from the upper edge of the tumor.

(XIV) Harvest the specimen: typically, a 4–5-cm incision is made under the umbilicus. For patients requiring preventive colostomy, the colostomy incision (i.e., the right main operating port) can be fully utilized. The incision can be enlarged and appropriately extended, via which the specimen is mobilized. The intestinal canal is transected about 10 cm away from the proximal side of the tumor to remove the specimen (*Figures 44-47*).

(XV) Rectal anastomosis: a 29–33-mm stapler is inserted after the anus is dilated. The puncture site should be at the intersection of two closures to minimize the risk of postoperative anastomotic leakage. Check the presence of any bowel volvulus before stapling. An air leakage test may be performed after the stapling. After the abdominal and pelvic cavities are rinsed with dilute iodophor, a dual cannula is placed at the low-posterior portion of the rectum (*Figures 48-50*). If the serous surface of the tumor is involved (as judged during the operation) or

Figure 48 The site where the puncture awl penetrates outwards.

Figure 49 Check the anastomotic site after the anastomosis.

Figure 50 A dual cannula is placed at the low-posterior portion of the rectum.

intraperitoneal implantation is highly possible, 2–3 doses of raltitrexed (3 mg/m^2) were routinely administered after rinsing. The drug is dissolved in 200 mL of normal saline for intraperitoneal chemotherapy. The drainage tube is clamped for 1–2 h before reopening.

Comments

Rectal TME is recognized as the "gold standard" in the radical treatment of rectal cancer and can effectively reduce the local recurrence of rectal cancer. It emphasizes the following principles: (I) to dissect along the roots of the tumor draining blood vessels to maximize lymph node removal; and (II) to find and maintain the surgical plane based on human embryology and anatomy to ensure that the visceral fascia is smooth and complete, without defects. Laparoscopic TME also needs to follow the basic principles of open TME and meanwhile has higher requirements on the knowledge of the anatomy of organs and tissues around the rectum.

First, the scope of blood vessel handling and lymphatic dissection must be decided. There are two ways to handle the IMA during rectal TME: one is high ligation, which refers to ligation at the start of the IMA from the abdominal aorta; and the other is low ligation, which refers to the ligation at the start of the left colonic artery. During the laparoscopic TME, surgeons tend to mobilize the IMA and perform high ligation at its root. By doing so, they can simply and effectively dissect deep lymph nodes and quickly find correct anatomical spaces for TME (3,4). However, simplicity is not the only justification for a surgical procedure; rather, the following two factors should also be considered: (I) the necessity of deep lymph node dissection; and (II) the need for the preservation of left colonic vessels.

Lymph nodes at the root of IMA are the station 3 nodes of rectal cancer. Two independent studies have demonstrated the correlation between the metastasis to station 3 nodes and the tumor T stage. The rates of metastasis to station 3 nodes were 0%, 0.4%, 2.6%, and 2.9% for stages T1, T2, T3, and T4 tumors in study A (5) and 0%, 1.0%, 2.6%, and 4.3% in study B (6). The corresponding data in Fudan University Cancer Hospital were 0%, 0.95%, 5.22%, and 6.12%, suggesting the degree of lymph node metastasis along the IMA is associated with the local infiltration of tumors, and the metastasis to station 3 nodes mainly occurs in T3 and T4 tumors. In addition, station 3 is the only affected station in about 6% of the rectal cancer patients, which is known as the skipped metastasis to station 3 nodes (7). Therefore, for T1 and T2 rectal cancers, theoretically low ligation is sufficient to achieve the radical resection of the tumors. However, the problem is that there is currently no way to accurately assess preoperative and intraoperative tumor T stage to guide the resection range of lymph nodes (8), not to mention the possibility of skipped metastasis and micrometastasis.

Therefore, it is highly necessary to dissect the station 3 nodes during the surgical treatment of resectable rectal cancer.

After high ligation of the IMA, the blood supply to the descending colon and sigmoid colon entirely comes from the mid-colon artery and the marginal arterial arch (9,10). While some studies suggest that the blood supply from the mid-coital artery and the peripheral arterial arch is sufficient to maintain the survival of distal colon and anastomosis (11), most studies have demonstrated that high ligation of the IMA significantly reduces blood supply to the distal colon and anastomosis (12,13). Seike *et al.* found in their intraoperative measurements that approximately one-fifth of patients experienced significant reduction in anastomotic blood supply after high ligation, especially among elderly males and in patients who had received lower anterior resection, and preservation of the left colonic artery could alleviate this condition (14). We had the same finding by using indocyanine green angiography: the blood flow at the proximal colonic anastomosis and the marginal arterial arch was significantly reduced after blocking the left colonic vessels. In addition, because of the absence of collateral circulation between superior mesenteric artery and IMA in some patients, severe anastomotic ischemia may occur after surgery, which may further lead to anastomotic stricture and anastomotic leak (15). Therefore, preservation of the left colonic vessels during surgery will help reduce the incidence of anastomotic leak, especially in elderly males or in patients with low anastomosis.

After the weighing of pros and cons, surgeons have developed a modified surgical procedure for rectal cancer: the IMA is ligated at the site below the origin of the LCA, followed by the dissection of adipose and lymphatic tissues (No. 253 lymph node) between the LCA and the IMA (5). It has been confirmed that the number of lymph nodes collected during LCA-preserving station 3 lymph node dissections was not significantly different from the number of lymph nodes harvested during high ligation (16). Notably, compared with high ligation, laparoscopic LCA-preserving D3 radical resection requires longer operative time (17). The development and popularization of this procedure require higher surgical skills and a simpler and more reasonable surgical approach.

A lateral approach and a medial approach have been applied in laparoscopic TME. The lateral approach is adopted from open surgery; however, it is seldom used because the operator may mistakenly operate on the posterior renal space during surgery. The medial approach is more commonly applied. In 2004, the European Association for Endoscopic surgery (EAES) formally identified it as the recommended approach for laparoscopic colorectal resection (18). The classic medial approach is as follows: first, enter the Toldt's space from the midline side (i.e., behind the IMA) to expose the nerve plexus, ureter, and reproductive system vessels behind the mesentery; second, mobilize and expand this level to the congenital adhesion of the lateral peritoneum; third, mobilize and ligate the root of the blood vessel; fourth, mobilize the mesentery and dissect lymph nodes; and finally, mobilize all the intestinal parts. As a plane-vessel technique, this procedure has many advantages including fully exposed surgical field, clear anatomical plane, and less blood loss. The length of the resected intestine, the length of the tumor's inferior resection margin, and the number of lymph nodes removed are comparable to those in the open surgery group. However, left colic blood vessel-preserving D3 dissection remains a challenging task in clinical settings. For example, early isolation of the Toldt's space behind the rectum may cause the mesangial detachment and the distortion of the local anatomic landmarks, which may result in difficulty in exposing the LCA; as a result, it is impossible to preserve the left colic vessels and carry out effective dissection of No. 253 lymph node.

Following the principle of TME and based on the needs for lymphatic dissection, we changed the surgical sequence from plane-vessel to vessel-plane; that, the vascular path is dissected first, and the plane at the retrorectal space is extend when handling the vessels. This is the concept of vessel-centered laparoscopic TME via medial approach. First, the retroperitoneum is opened with an ultrasonic scalpel at the sigmoid mesocolon and retroperitoneal reflection; however, instead of entering and expanding the Toldt's space at this time, the peritoneum is opened at the projecting root of the IMA and the inferior mesenteric arterial sheath is exposed. Dissection along the vascular sheaths continues till the root of LCA is exposed. The surgical plane is expanded upwards and downwards along the root of LCA and IMA. Since the posterior vascular space has not been mobilized, the local anatomical plane is relatively fixed; thus, it is relatively easy to expose the left colic vessels, No. 253 lymph node, IMV, superior rectal vessels, and sigmoid branch vessels. After vascular skeletonization, the No. 253 lymph node was removed, followed by the successive transection of IMV and superior rectal artery. After the above operations were completed, the assistant lifts the stumps of distal mesangial vessels, and

Figure 51 Dr. Xinxiang Li.

the Toldt's space behind the rectum can be clearly visible. The remaining TME operation steps are completed along this space.

Compared with the traditional medial approach, this procedure has the following advantages: (I) the blood vessels are handled first, which is in line with the principles of oncology and can minimize the risk of bloodborne metastasis; (II) since the vessels are relatively fixed since the posterior vascular space has not been mobilized, and dissection along the blood vessels can easily expose the IMA trunk, left colonic vessels, and IMV; (III) the exposure of blood vessels in the drainage area is conducive to the dissection of the adipose and lymphatic tissues, especially the No. 253 lymph node; (IV) the preferential exposure of the left colic vessels can increase the probability of preserving these blood vessels and help reduce the incidence of anastomotic leakage after operation; (V) dissection and transection of blood vessels, dissection of lymph nodes, and exposure of the posterior space are all performed in front of the posterior subperitoneal fascia, thus obviously reducing the risk of injuring the retroperitoneal vessels, ureters, and autonomic nerves; and (VI) it simplifies the surgical process, and the whole process of exposure and dissection requires only 10–15 minutes.

In summary, with the use of high-definition and 3D camera systems, precise dissection and skeletonization of blood vessels can be better performed, which increases the accuracy of surgeries. As a result, a reasonable approach and dissection sequence have become increasingly important for high-quality TME. The vessel-centered laparoscopic TME via the medial approach, as a simplified and safe procedure, is more consistent with the principles of radical treatment for tumors and deserves further application in clinical settings.

About the author

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Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

Informed Consent: Written informed consent was obtained from the patient for publication of this manuscript and any accompanying images.

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Autonomic nerve preserving in laparoscopic total mesorectal excision

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Abstract: Since the introduction of total mesorectum excision and combined modality therapy has dramatically improved the oncologic outcome for the patients with rectal cancer, the quality of functional outcome has been increasingly important. Urogenital dysfunctions due to intraoperative inadvertent pelvic autonomic nerve damage are well-recognized. Pelvic autonomic nerve preservation may be limited and challenged by the anatomical constrains of the curved narrow pelvis. Laparoscopic technology with the advantages of direct illumination and magnification may enable better visualization and facilitate pelvic autonomic nerve preservation. There are a few key zones at risk of nerve injury and a proper surgical technique with step-by-step checklist at the critical points should be carried on. The increased experience with laparoscopic and understanding of the pelvic nerve anatomy may relate to the improving functional outcomes. Here, we discuss the current understanding of anatomy, key zones at risk and tips and tricks of our experience of nerve preservation during the laparoscopic total mesenteric excision (TME).

Keywords: Laparoscopy; rectal cancer; total mesorectum excision; pelvic autonomic nerve preservation

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Introduction

The adoption of total mesenteric excision (TME) and combined modality therapy has dramatically improved the oncologic outcome for the patients with rectal cancer during the last 3 decades (1,2). Nonetheless, the improved survival was constantly in company with high incidence of organ dysfunction which might severely compromise quality of life (3,4). In addition to the anterior rectal syndrome, urogenital dysfunctions due to intraoperative inadvertent pelvic autonomic nerve damage are well-recognized complications after rectal cancer surgery (5). The incidence of urinary dysfunction including difficulty emptying the bladder and urinary incontinence has been reported from 0% to 35% (4,6). Male sexual dysfunction includes erectile and ejaculatory problems may reach as high as 79.8% and 72.2%, respectively. For females, sexual dysfunction in relation to dyspareunia, difficulty to achieve orgasm and insufficient vaginal lubrication, is plagued but poorly defined and likely neglected in clinical practice (7,8).

Pelvic autonomic nerve preservation under direct visualization and sharp dissection may be limited and challenging by the anatomical constrains of the curved narrow pelvis, especially for the android pelvis with hypertrophic mesorectum. Laparoscopic technology with the advantages of direct illumination and magnification may enable better visualization and thereby hypothetically help to improve pelvic autonomic nerve preservation. As in previous studies, two multicenter randomized control trails comparing laparoscopic with open surgery have reported worse sexual function in laparoscopic surgery (4,9). While, the later studies showed no differences in outcomes or

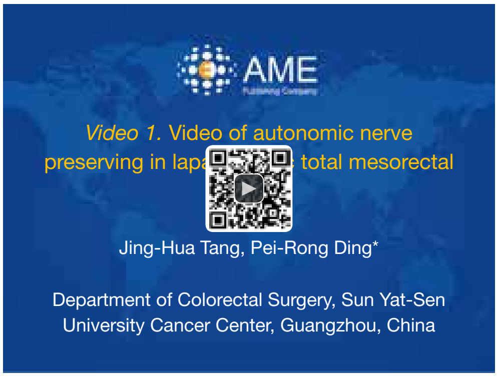

Figure 1 Video of autonomic nerve preserving in laparoscopic total mesorectal excision (14).
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even in favor of laparoscopic to compare with open surgery (10,11). The increased experience with laparoscopic and understanding of the pelvic nerve anatomy may relate to the improving functional outcomes. A trend towards fewer incidences of urogenital dysfunctions is noticeable with the practice of pelvic autonomic nerve preservation adherence to the TME principles (5,10,12,13).

We believe that favorable urinary and sexual function could be achieved with enhanced vision, adequate traction and countertraction during the laparoscopic TME. Here, we discuss the current understanding of anatomy, key zones at risk and tips and tricks of nerve preservation during the laparoscopic TME (*Figure 1*).

Pelvic autonomic nerve anatomy

Superior hypogastric plexus (SHP) and hypogastric nerves (HN)

The SHP is a network of pre- and post-ganglionic nerves overlying the abdominal aorta. The plexus is located anterior of the fifth lumbar vertebrae, starts underneath of the inferior mesenteric artery (IMA), run over the sacral promontory and then bifurcates into the right and left HN (15,16). The paired HN run about 2 cm medially to the ureter, move obliquely along the posterolateral wall of the pelvis and finally end as afferent fibres of inferior hypogastric plexus (IHP). The SHP comprises sympathetic nerves, which is originated from the sympathetic trunks alongside the tenth thoracic to the third lumbar vertebrae. Injury to the SHP or HN may result in troubles of ejaculation, decreased orgasm and urinary incontinence (16).

IHP and pelvic splanchnic nerves (PSN)

Besides the sympathetic fibres from the HN, the IHP also receives pelvic parasympathetic fibres from the PSN. The splanchnic nerves arising from the ventral roots of S2–S5 enter the pelvis through sacral foramina, running immediately ventral to the piriform muscles, together with the HN forming the IHP that lies laterally on the pelvic wall at the level of the lower third of rectum. Some branches of the splanchnic nerves run medially to the rectum via the so called "lateral ligaments" and make up the medial segment of the IHP. The lateral ligaments are thought to be condensation of fascia on the dorsolateral side of rectum and connect the rectum to the pelvic parietal fascia. Some suggest the ligaments do not exist and the small, inconstant and frequently unilateral middle rectal artery cross the mesorectum independent of any structure (16-18). The anterior portion of the IHP innervates the bladder and sexual organs. In women, fibers from the IHP travel through underneath the intersection of the ureter and uterine artery to the vesicovaginal and rectovaginal septum forming branches to the bladder, the vagina and the uterus (19). In men, these run in the neurovascular bundles (NVB) incline anteriorly at the lateral corners of the seminal vesicles in the 2 o'clock and 10 o'clock direction. These nerves run laterally outside the Denonvillier's fascia and continue on the periprostatic plexus supplying branches to the prostate, seminal vesicles, cavernous bodies, and the vas deferens (16,20).

Key zones at risk

Origin of the IMA

The SHP is vulnerable to intercepted during high ligation of the IMA which is intended to achieve complete removal of regional lymph nodes. The SHP fibres lie in front of the aorta and are located in a wide area of dissection. The preaortic plexus injured if the IMA pedicle is ligated flush with the aorta (20). The left trunk of the SHP travels along the left side of the aorta and is very close to the IMA at its origin. So mass clamping of the IMA may increase the risk of damage to the left trunk of the plexus.

Posterior rectum

Although there is still controversy about the facial structures (21), posterior dissection of the rectum should carried out at the avascular plane of loose areolar tissue

Figure 2 The SHP is a network of pre- and post-ganglionic nerves overlying the abdominal aorta. By opening the IMA sheath and ligating the pedicle at a distance of 1.5–2 cm from the aorta, Avoiding mass clamping of the IMA, the SHP fibres lying in front of the aorta are preserved. SHP, superior hypogastric plexus; IMA, inferior mesenteric artery.

between the fascia propria anteriorly and the parietal fascia containing the HN posteriorly. A further loose areolar tissue layer could be easily created posterior to the HN. If dissection is too posterior and the HN appears to run into the mesorectum, both the HN and the presacral vein are at risk of damaging. The major risk is to enter the wrong plane at the transition of the mesosigmoid to the mesorectum or not following the correct plane during dissection.

Lateral rectum

At the high level lateral dissection of the mesorectum, the HN is vulnerable to injury if dissection starts or opens the laterorectal reflection of the peritoneum too laterally. During the low lateral dissection, the IHP is vulnerable to injury. The so called "lateral ligament" is a dense connective tissue between rectum and pelvic parietal fascia. The IHP is rarely seen in patients with high body mass index and bulky and fat mesorectum. Injury can occur if the lateral ligament bleeding is not control and blunt dissection is used or excessive medical traction and non-anatomical dissection.

Anterior rectum

There is a very narrow space between the mesorectum and the seminal vesicles and prostate or vaginal. The Denonvillier's fascia is displaced anterior to the mesorectum and posterior to the seminal vesicles and prostate or vaginal. The NVB lie laterally anterior to the Denonvillier's fascia and then go down to the urethra at the apex of the prostate. Excessive traction on the rectum "moves" the NVB in the dissection field on the lateral edges. Blind mass clamping if bleeding is not controlled contributes the damage of the NVB. There is no consensus concerning the proper anterior anatomical plane but if the tumor is anterior, the dissection should carry out anterior to the Denonvillier's fascia, which presents a high risk of nerve damage.

Tips and tricks of nerve preservation in laparoscopic total mesorectal excision

In laparoscopic total mesorectal excision there are a few key zones at risk of nerve injury as mentioned above. To ensure the preservation of pelvic autonomic nerve, a proper surgical technique with step-by-step checklist at the critical points should be carried on without compromise of oncological outcome.

Laparoscopic TME usually starts with a peritoneal incision at the surface of the sacral promontory, dissection from medial to lateral and extend up underneath the duodenum, and then meet the first key area for injury of the IHP. The key of nerve preservation is finding the plane by maintaining sufficient tension. With the help of the assistant lifting the pedicle of the IMA, dissection of the posterior of the IMA could be easy. Under the magnified laparoscopic view, the SHP is visualized covered with ventral fascia. By opening the artery sheath and ligating the pedicle at a distance of 1.5–2 cm from the aorta, the SHP fibres lying in front of the aorta are preserved. Avoiding mass clamping of the IMA and preserving the Gerona's fascia is needed for the left trunk of the SHP running along the left side of the aorta (*Figure 2*).

After the dissection of the left Toldt's space and complete the mobilization of the sigmoid and descend colon, the transition from mesosigmoid to mesorectum is the second zone of iatrogenic nerve injury for the HN. Kinugasa suggest the pre- hypogastric nerves (pre-HGN) fascia anterior to the HN is evident based on historical examination in the retrorectal multilaminar structure. Posterior dissection should be performed at the loose areolar layer between the rectal proper fascia and the pre-HGN fascia (*Figure 3*). The superior rectal artery is situated just anterior to the rectal propria fascia, which could be used as a landmark to find the plane. Surgeons should follow the plane but not create a new plane, use left hand to counter-traction to keep sufficient tension and keep fascia of rectum clear from other tissue (*Figure 4*).

Going all the way down to the level of the forth sacral vertebral will meet the so-called rectosacral fascia which

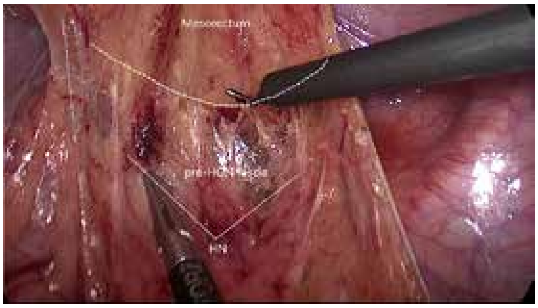

Figure 3 The pre-HGN fascia is anterior to the HN. Dissection should be performed at the loose areolar layer between the rectal proper fascia and the pre-HGN fascia along the dotted line. HGN, hypogastric nerve.

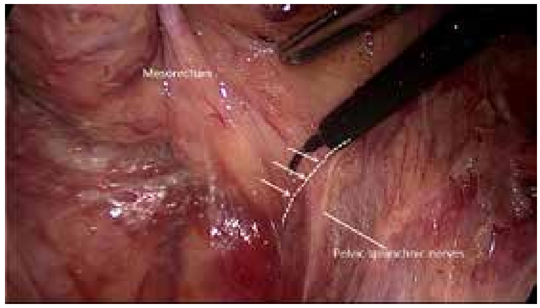

Figure 5 The inferior hypogastric plexus receives fibres from the pelvic splanchnic nerves. There is always a Triangle space lying below rectal fascia and nerve plexus and extending laterally along the line through the triangular space.

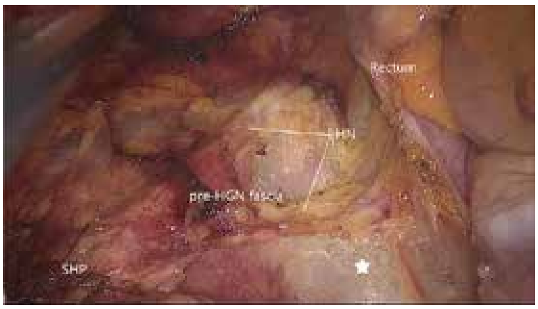

Figure 4 Dissection is too posterior and the pre-HGN fascia is opened. Both the HN and the presacral vein are at risk of damaging. Pentagram shows the wrong plane. HGN, hypogastric nerve.

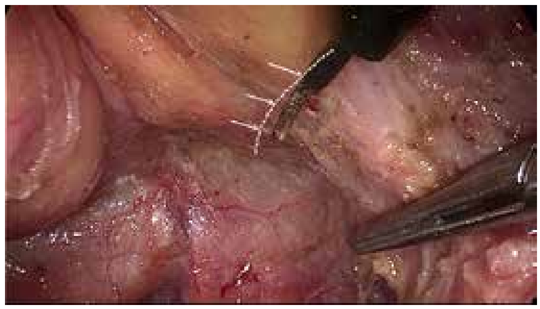

Figure 6 Dissection along the fascia propria and extending laterally along the line through the triangular space is more appropriate.

was thought to be a surgical artifact in Kinugasa's study (21). A sharp incision though this plane will be another loose areolar layer without any risk of nerve damage. The lateral dissection is the third risk zone for injury of the HN and IHP. The lateral dissection is done after the posterior midline dissection has gone as far down to the anorectal junction as possible. Lateral dissection moves from the posterior midline to the left and right posterolateral pelvic wall (*Figure 5*). Some authors suggest under the illumination and magnification of the laparoscopic technology, the autonomic nerves can serve as the landmark and develop a novel concept of nerve-oriented mesorectal excision. However, The IHP is covered by parietal fascia and rarely seen in obese patients (22). Dissection along the fascia propria may be more appropriate (*Figure 6*). Identification of the site where fascia of rectum and IHP merge together is needed. Typically, there is a triangle space lying below rectal fascia and nerve plexus. Extending laterally along the line through the triangular space, the IHP attaching to rectal fascia is effectively shrunk. Dissection need be cautious not to break into the mesorectum or the nerve plexus and always keep good tension and small bite. Using the tips mentioned above, the adherent nerves can be slightly teased and peeled off the rectal fascia. After open the laterorectal reflection of the pararectal peritoneum, dissection to the supra-levator space and anterior plane is one of the most vulnerable parts of mesorectum and nerve plexus. Mesorectum stretching out laterally like a coconut rather than cylinder (*Figure 7*). In order to avoid leftover of mesorectum, dissection should always follow the arc of pelvic floor from posterior to lateral and from known to unknown. After fully mobilization, a clear coconut-like structure can be seen and mesorectum is completely removed.

After complete mobilization of the supra-levator space and lateral part of mesorectum, peritoneum is incised about 0.5 cm anterior to the peritoneal reflection. Here we

Figure 7 Coronal CT image demonstrates the mesorectum stretching out laterally like a coconut rather than cylinder. Dissection should always follow the arc of pelvic floor from posterior to lateral.

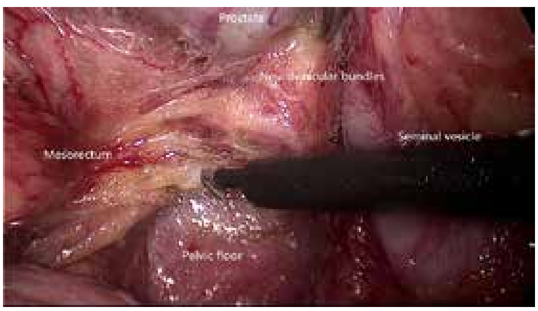

Figure 8 The NVB lie laterally anterior to the Denonvilliers fascia. Transect the Denonvilliers fascia at the base of seminal vesicle, then dissection is along the propria fascia. Fully mobilization of posterior and lateral mesorectum greatly facilitates the preservation of NVB. NVB, neurovascular bundle.

enter the space anterior to Denonvillier's fascia and meet a new risk area of autonomic never injury. Although Heald suggest the Denonvillier's fascia forms the anterior surface of the mesorectum, most opinions recommend dissecting in front of Denonvillier's fascia only when the tumor located anteriorly or there is a risk of compromised circumferential margin. For posterior and lateral tumors, our experience is to transect the Denonvillier's fascia at the base of seminal vesicle, then dissection is along the propria fascia. Fully mobilization of posterior and lateral mesorectum greatly facilitates the preservation of NVB. Dissection just follows the groove and uses the hook parallel but not vertically to the rectal fascia. In some cases, it looks like there is a shining envelope containing the NVB when it is well preserved (*Figure 8*).

The adoption of TME and combined modality therapy has improved the oncologic outcome greatly in the patients with rectal cancer. Urogenital dysfunctions due to intraoperative inadvertent pelvic autonomic nerve damage are well-recognized. Surgeons should be familiar with the pelvic autonomic nerve anatomy especially the key zones at risk and take advantage of laparoscopic technique in order to improve the functional outcomes of TME.

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Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

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High ligation of inferior mesenteric artery in laparoscopic resection of rectal cancer: is it safe or dangerous?

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Nowadays anterior resection and abdominoperineal excision for rectal cancer have been well standardized in laparoscopic approach. But there are still arguments about the level of the ligation of the inferior mesenteric artery (IMA) (1). Some surgeons tie the IMA at its origin from the aorta (high ligation). Others tie the IMA below the origin of the left colic artery (LCA) (low ligation). It is not clear if there is different incidence rate of anastomotic leakage and survival period between these two different levels of ligation of the IMA after radical resection of rectal cancer.

As everyone knows, the colon has two main sources of blood supply: the superior mesenteric artery (SMA) and the IMA. The main branches of the SMA include the ileocolic artery (ICA), the right colic artery (RCA) and the middle colic artery (MCA), which supplies the cecum, the ascending colon, and the transverse colon. The main branches of IMA include LCA, the sigmoid artery (SA) and the superior rectal artery (SRA), which supply the descending colon, the sigmoid colon and the up-half rectum.

In laparoscopic resection of rectal cancer, high ligation of the IMA appears easier to achieve than low ligation. The other advantage of high ligation is to reduce the tension of anastomosis (2). In theory, the descending colon ischemia and necrosis will not happen after high ligation of IMA in anterior resection for rectal cancer because there are some arterial arches between the MCA from the SMA and the LCA from the IMA. But is high ligation of the IMA really safe?

It is usually considered that there are two arterial arches between the MCA and the LCA, which maximally keep the blood supply for the descending colon after high ligation of the IMA. One is the marginal arterial arch, also known as the artery of Drummond. The other is Riolan's arch.

The artery of Drummond (*Figure 1*) is composed of arterial branches which supply the colon and runs in the mesentery close to the colon as part of the vascular arcade that connects the SMA and IMA. It is named by Hamilton Drummond [1882–1925], an English physician. But because of congenital developmental defects, the artery of Drummond is perhaps incomplete especially at the splenic flexure of colon, where is the site of watershed anastomosis of midgut and hindgut in the embryonic stage of development. This point is also called Griffiths' point (3). At the Griffiths' point, the anastomosis of the artery of Drummond may be substantial, tenuous, or absent (*Figure 2*). Angiographic studies show that anastomosis at Griffiths point is present in 48%, poor or tenuous in 9%, and absent in 43% (3). It means that the proportion of poor development of the artery of Drummond at the Griffiths' point reaches as high as 50%. This has relevance in radiology, as it explains why the splenic flexure watershed site is the most common location for ischaemic colitis.

Riolan's arch represents an important collateral circulation between the SMA and the IMA upon which the descending colon may be dependent. But the definition of Riolan's arch, which named by Jean Riolan [1580–1657], a famous 17th century French anatomist, is deliberately vague. In general, Riolan's arch refers to a distinguishing anatomical entity connecting the MCA with the LCA, additional to the artery of Drummond (*Figure 3*) (4). There are also many other interpretations and synonyms of Riolan's arch (*Table 1*). The rate of emergence of Riolan's

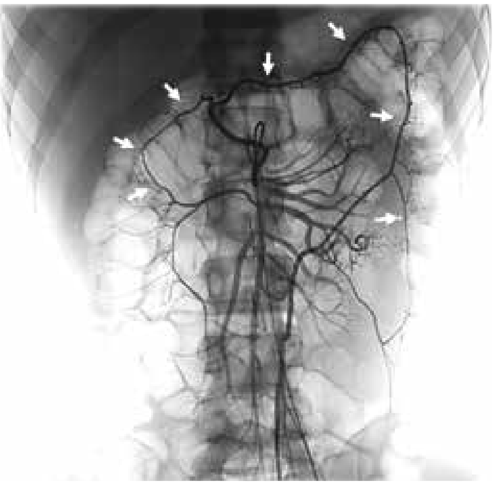

Figure 1 Digital subtraction angiography of SMA shows the artery of Drummond (white arrows). SMA, superior mesenteric artery.

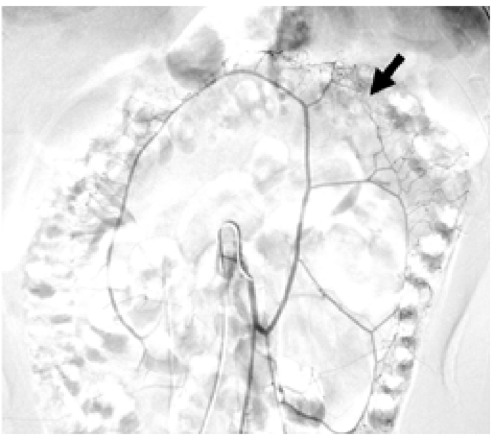

Figure 2 Digital subtraction angiography of IMA shows the absence of the artery of Drummond at Griffiths' point (black arrow). IMA, inferior mesenteric artery.

arch is very different because of the difference of definition, race, research method and sample size in different reports. A book edited by the Chinese Society for Anatomical Sciences reports that the incidence rate of Riolan's arch is 6.19%±1.13% in Chinese people. It illustrates that Riolan's arch is usually in the state of no or only having a little blood flow. Some authors even think that the incidence of Riolan's arch means there is severe stenosis in the SMA or IMA.

Some reports show that the descending colon ischemia or necrosis will happen after high ligation of the IMA. Tsujinaka *et al.* (5) observed that 6 out of 302 patients (2.0%)

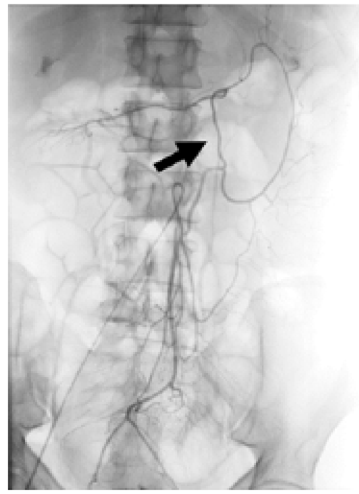

Figure 3 Digital subtraction angiography of IMA shows Riolan's arch (black arrow). IMA, inferior mesenteric artery.

Table 1 Synonyms of Riolan's arch (4)

Central anastomotic artery of colon
Mesomesenteric artery
Middle-left colic collateral
Intermesenteric artery or arcade
Meandering mesenteric artery
Anastomosis (magna) of Riolan
Meandering artery of Riolan
Great colic artery of Riolan
Arch of Treves
Artery of Moskovitch
Artery of Gonzalez
Anastomosis maxima of Haller
Arcus magnus mesentericus

with high ligation of the IMA developed proximal colon necrosis, which were confirmed by secondary surgery. Of these 6 patients, 2 died from associated complications. The results, which are obtained from the univariate analysis showed that advanced age, cerebrovascular disease, and hypertension were significantly associated with colon necrosis. In another report (6), 1,201 patients with sigmoid colon or rectal cancer who underwent high ligation of IMA were analyzed. Ten patients (0.83%) diagnosed

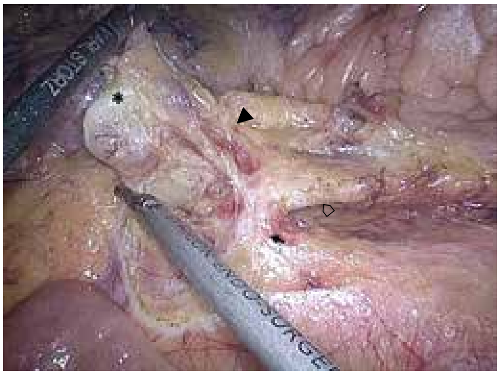

Figure 4 Low ligation of the IMA with dissection the lymph nodes at root of the IMA (→: IMA; ►: LCA; *: the lymph nodes at root of the IMA; ⌂: low lagation point of the IMA). IMA, inferior mesenteric artery.

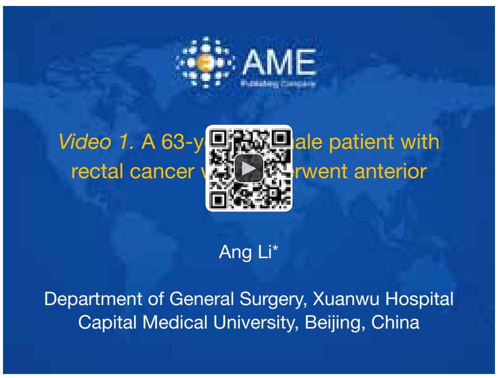

Figure 5 A 63-year-old male patient with rectal cancer who underwent anterior resection (8). The IMA was tied below the origin of the LCA with dissection the lymph nodes at the root of the IMA. IMA, inferior mesenteric artery; LCA, left colic artery. Available online: http://www.asvide.com/articles/1270

postoperative colonic ischemia. Mortality was 10%. The symptoms of postoperative colonic ischemia occurred on the 5th day (range, 2nd–10th day) after operation. Over all, both the artery of Drummond and Riolan's arch may not provide reliable blood supply to the descending colon after high ligation of IMA. But there were different opinions. Boström *et al.* (7) reported that symptomatic anastomotic leakage occurred in 12.3% (41/334) of patients in the high ligation group and in 10.6% (41/388) in the low ligation group. There was no statistical difference between two groups and high ligation was not independently associated with a higher risk of anastomotic leakage.

In conclusion, despite the controversy, the descending colon ischemia and necrosis after high ligation of IMA in anterior resection for rectal cancer should be pay great attention because of the existence of the Griffiths' point and the low incidence rate of Riolan's arch, especially for the patients with advanced age, cerebrovascular disease, and hypertension. Low ligation of the IMA with dissection the lymph nodes at the root of the IMA (*Figures 4,5*) perhaps is another choice. But that issue requires further study.

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Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

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Laparoscopic anterior resection of rectal cancer with lymph node dissection around the inferior mesenteric artery with preservation of the left colic artery (LAR-LND-PLCA)

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Background: Laparoscopic anterior resection of rectal cancer with lymph node dissection around the inferior mesenteric artery (IMA) with preservation of the left colic artery (LAR-LND-PLCA) is a highly difficult operation. According to our rich experiences of laparoscopy surgical techniques recent years, we can proficiently master the surgical techniques and difficulties of LAR-LND-PLCA base on the anatomy of blood vessels and the interfacial space.

Methods: A 59-year-old patient who was diagnosed as rectal cancer underwent LAR-LND-PLCA. Combined with this case, we share the surgical technology of LAR-LND-PLCA base on our experience.

Results: The length of operation was 120 min with bleeding of about 50 mL. The patient recovered well postoperation and discharged from hospital on the 7th day.

Conclusions: LAR-LND-PLCA is effective and safe for the rectal cancer. Because it is too difficult, so it must be done in the rich experienced hospital.

Keywords: Rectal cancer; laparoscopy; preservation of the left colic artery

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Introduction

Colorectal carcinoma is the second most commonly carcinoma in females and the third in males. In 2012 there are about 1.4 million new cases and 693,900 deaths (1). And approximately one third of all colorectal carcinoma are rectal cancer.

The anatomy of rectum is complex, and we need a good understanding of the anatomy of the rectum, good psychological quality, excellent surgical technique and the operation team with the tacit understanding to complete the laparoscopic anterior resection of rectal cancer with lymph node dissection around the inferior mesenteric artery (IMA) with preservation of the left colic artery (LAR-LND-PLCA). Here (*Figure 1*), we share the LAR-LND-PLCA surgical skills by a case of rectal cancer.

Methods

Surgical indications

LAR-LND-PLCA is suitable for the cancerous lesion located within 12 cm of the anal verge by rigid proctoscopy.

The contraindications of LAR-LND-PLCA are as follows: patients with severe cardiopulmonary in sufficiency, T4b, obstruction or tumor >6 cm in size.

In the video, the patient is a 59-year-old man diagnosed to be moderately differentiated rectal cancer after CRT, and preoperative tumor staging was ycT3N1M0 by MR (*Figure 2*).

Figure 1 LAR-LND-PLCA (2). LAR-LND-PLCA, laparoscopic anterior resection of rectal cancer with lymph node dissection around the inferior mesenteric artery with preservation of the left colic artery. Available online: http://www.asvide.com/articles/1203

Figure 2 Abdominal MRI scan.

Surgical position

After anesthesia, the patient is placed in lithotomy position and Trendelenburg position. In the operation room, there are two monitors placed right above the head and between the patient's legs. The surgeon stands on the right side of the patient. The first assistant stands on the left side of the patient. The second assistant stands on the left side of the surgeon.

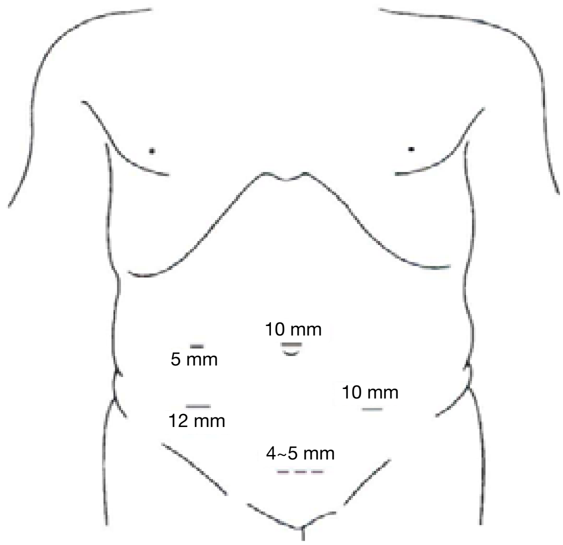

Figure 3 Trocars position.

Surgical procedures

In this operation, we need five trocars, of which two 12-mm and three 5-mm trocars. Above of the navel we puncture into 12 mm trocar and put in 30 degree laparoscopy. Pneumoperitoneum was established with carbon dioxide (CO_2) and the intra-abdominal pressure was maintained at a constant 12 to 15 mmHg. Other trocars were placed in position to see *Figure 3*. The first step is laparoscopic exploration to determine whether there was distant metastasis or spread.

And then we performed a central way to open the right side of the rectum ditch and separated the left Toldt's fascia.

At the same time, we should dissect the lymph nodes along IMA, vein and their branch and preserved the left colic artery. After branching the left colic artery of IMA, we ligated the IMA and IMV (*Figures 4,5*).

Then we can free the interspaces around the rectum and cut rectum according to the TME principle.

We extended the right side abdomen 12 mm trocars hole to about 5 cm. Through this incision, we took out the rectal cancer specimens and cut the colon in the cancer proximal 10 cm, then made an end-to-end anastomosis through the

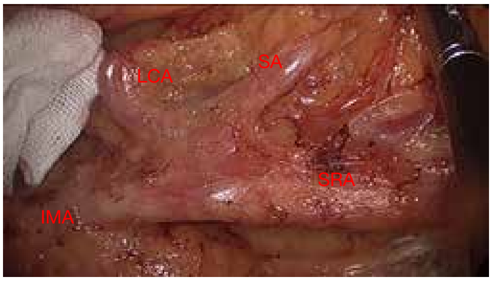

Figure 4 The branch of IMA. IMA, inferior mesenteric artery.

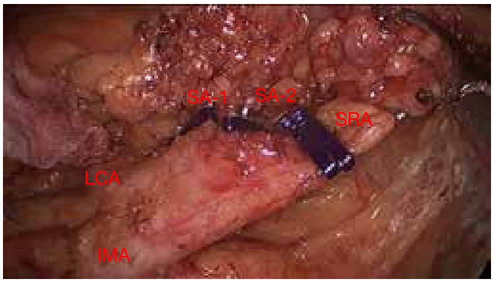

Figure 5 Ligating the IMA. IMA, inferior mesenteric artery.

Figure 6 Pathological specimens of rectal cancer.

anus using the anastomosis staplers.

At last, we made prophylactic ileostomy and suture the trocar holes and the incision.

Results

Operation time was 120 minutes, and the amount of bleeding was 50 mL. The postoperative pathological results showed that the poorly-differentiated adenocarcinoma with

Figure 7 Pathological specimens of rectal cancer.

ypT2N1aM0 (IIIA) stage among which 1/14 lymph node-positive (*Figures 6,7*). The patient recovered well without complications and discharged from hospital 7 days after surgery.

Discussion

Some studies shows that laparoscopy is associated with the same short-term and long-term outcomes with comparing the open operations (3,4). Some scholars reported that LAR had the advantages of less bleeding, faster recovery and shorter hospital stay in the short-term endpoints (5,6). And locoregional recurrence and disease-free and overall survival are the same between laparoscopic-assisted and open operation (3,4,7,8). So LAR may be considered based on some principles in NCCN Guidelines for Rectal Cancer Version 2.2016.

Curative resection of rectal cancer included "high tie" and "low tie" of the IMA. "Low tie" included preservation of the LCA and lymph nodes dissection over the root of IMA (*Figure 8*). But it was controversial whether a high or low ligation of the IMA was superior. Some experts believed that there were no significant differences in the complication rate, operative time, the amount of blood loss, the number of days and OS and RFS rates between "low tie" and "high tie" with LND (9). But some scholars thought high tie may increase anastomotic leakage, because it reduced intestinal blood supply (10).

LAR-LND-PLCA LAR is a very difficult surgery and need skilled surgical techniques. So if it is difficult to deal with the problems in the laparoscopic surgery, please consult a rich experienced surgeon or change to open surgery.

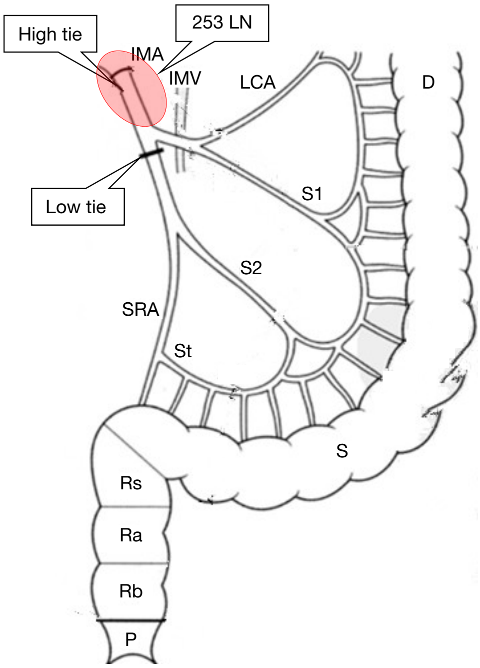

Figure 8 "High tie" and "low tie".

Conclusions

LAR-LND-PLCA is effective and safe for the rectal cancer. Because it is too difficult, so it must be done in the rich experienced hospital.

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None.

Footnote

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Laparoscopic approach for retrorectal tumors—results of a series of 11 cases

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Background: Retrorectal tumors (RRTs) are infrequent entity. They originate from totipotential cells located in the retrorectal space, which allows the development of an important diversity of tumors with different potential of malignancy. Their anatomical location can make difficult the surgical approach, and in the recent years, minimally invasive surgical approach has been proposed. The aim of the present study is to analyze the results by laparoscopic approach in a series of 11 cases treated in a 19-year period.

Methods: From 1998 to 2016, 11 patients (4 males, 7 females, mean age 54 years) with RRT were treated by laparoscopy and retrospectively reviewed. The tumor size ranged from 5 to 11 cm.

Results: The mean operative time was 160 minutes. Conversion to open surgery was observed in one case. Among complications were observed two pelvic abscesses and one surgical wound infection. The mean postoperative hospital stay was 7.5 days. Definitive histology included fibrous tumor [1], neurofibroma [2], hamartoma [2], teratoma [1], schwannoma [2], tail gut [1], salivary gland [1], glomus tumor [1]. At a mean follow-up of 48 months, no recurrences were observed.

Conclusions: The minimally invasive approach, for the treatment of RRTs in any site, is a satisfactory option.

Keywords: Retrorectal tumors (RRT); laparoscopic surgery; minimally invasive approach

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Introduction

Retrorectal tumor (RRT) is infrequent entity in the daily surgical practice. Its incidence is not well known (1), although some authors report an incidence between 2 and 6 cases per year in reference centers (2,3).

They are located in the retrorectal space (*Figure 1*), between the presacral fascia, posteriorly, and the rectum, anteriorly, with the Waldeyer fascia and the peritoneal reflection as well as the inferior and superior verge, respectively. This space contains tissues from different embryological origins (vessels, nerves and mesenchymal tissue). This justifies the heterogeneity of observed tumors, originated from different etiological strains, with different possibilities of malignancy (1). Its anatomical location justifies the possible difficulties in the surgical approach.

Different RRT classifications are reported in literature (*Table 1*), the Uhlig and Johnson modified by Dozois (1) and Pappalardo *et al.* (4) classifications are both most used.

The RRTs are usually asymptomatic, and are often diagnosed routinely in gynaecological controls. If they are not early detected they can achieve a considerable volume, which will determine a series of typical symptoms based on their location: constipation, chronic abdominal pain, perianal abscess, faecal/urinary incontinence or sexual dysfunctions (1,5). Most commonly these tumors are diagnosed in female patients between 40 and 60 years (6).

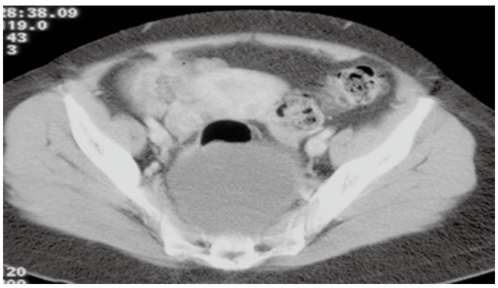

Figure 1 RRT at CT scan. CT, computed tomography; RRT, retrorectal tumor.

The diagnosis of RRTs is usually achieved by imaging test such as ultrasound (US), abdominal computed tomography (CT) scan (*Figure 1*) or magnetic resonance imaging (MRI), and the radiological characteristics can guide on the possible origin of the lesion (5-7). Histologic diagnosis is usually postoperative. Diagnostic biopsy should be avoided due to the difficult access and possible complications, such as the infection (8) or potential neoplastic spreading (1,2).

Usually, the perineal or abdominal surgical approach is chosen based on the level of the lesion. The line connecting the pubis with the sacral vertebrae S3–S4, is employed as anatomical landmark, according to the so-called Woodfield's algorithm (9) (*Figure 2*). The abdominal or perineal approach are performed based on the relationship between the RRT and the S3 vertebra, based on involvement of different organs and on the lesion size (*Figure 3*).

The introduction of laparoscopy, and its application in low rectal surgery, allowed to extend the indication of the

Table 1 RRT classifications reported in literature

Uhlig and Johnson, modified by Dozois	Pappalardo *et al*.	Lev. Chelouche *et al*.
Congenital (60–70%)	Retrorectal space: tail gut, teratoma, dermoid, epidermoid, rhabdomyosarcoma, liposarcoma, unclassifiable	Benign congenital
Neurogenic (10%)	Sacral spinal cord: meningocele, Ewing's tumor, neurofibroma, neurofibrosarcoma, neurilemoma, chondrosarcoma, osteogenic sarcoma	Malignant congenital
Miscellanea (10%)	Rectum: rectal duplication, leiomyosarcoma, lymphoma	Benign acquired
		Malignant acquired

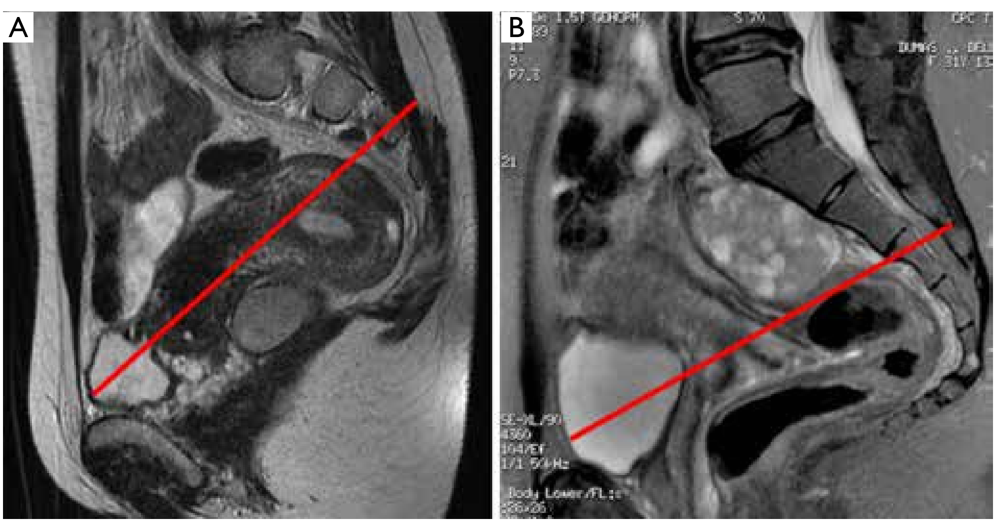

Figure 2 RRT under (A) and upper (B) the line connecting the pubis with the sacral vertebrae S3, according to Woodfield's algorithm.

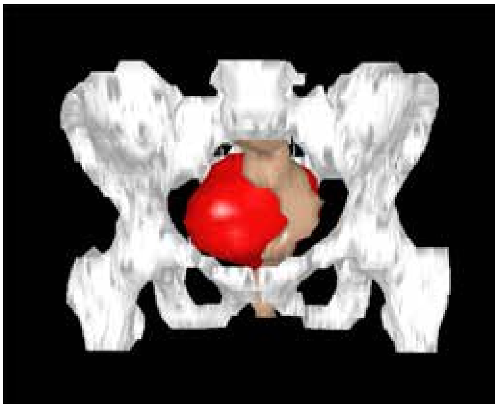

Figure 3 Reconstruction of RRT with CT scan. CT, computed tomography; RRT, retrorectal tumor.

Figure 4 Trocars position.

approach for the treatment of RRT, and questioning about the Woodfield's algorithm validity (9).

The aim of the present study is to report the authors' experience with the laparoscopic approach for the treatment of RRT, technically difficult to access.

Methods

This study is a retrospective analysis of prospectively collected data of the Service of Surgery of the Hospital de Sant Pau, Barcelona, Spain, of patients underwent surgery for RRT from 1998 to 2016. Institutional review board (IRB) approval was obtained. Since 1998, 11 patients were treated by laparoscopy for RRT. This study is an update, of a previously published analysis regarding the first 4 patients (10).

Patients' preoperative clinical and demographic data (age, sex, previous surgery RRT lesion, exploration performed, diagnostic orientation), intraoperative data (operative time, conversion rate, blood loss) and postoperative data (complications, re-intervention) were extracted. Abdominal CT scan was performed periodically to early diagnose potential recurrences.

Surgical technique

Resection of RRT was performed as previously described (10). Preoperative mechanical bowel preparation, the use of elastic stockings and heparin for thrombosis prophylaxis were recommended before surgery.

Surgery was performed with patient supine and in extreme Trendelenburg position, as well as in case of laparoscopic approach of the rectum. The first 10 mm optical trocar is inserted at the umbilicus site, one 5 mm and one 12 mm operating trocars are located in the right flank and iliac fossa, respectively, and the last 12 mm trocar is placed in left flank for the assistant (*Figure 4*). Sometimes a 5 or 11 mm trocar in hypogastrium may be useful to use the retractor or the aspirator (10).

The lesion located at the level of the lower pelvis usually protrudes through the peritoneum that is divided to access in the retrorectal space. This maneuver allows to achieve a wide dissection plane. The blunt dissection is performed with the aim to enucleate the lesion. Sometimes, specially in case of large cystic tumors, it is possible the incidental open the lesion, or to perform a deliberate aspiration, to reduce the tumor size and to facilitate the dissection. In case of cystic lesions, puncture-aspiration of the contents and the tumor capsule extraction by bag, through one of the trocar site, or through a small suprapubic incision such as Pfannenstiel, is performed (10).

A 30° optic is also a useful tool for the surgeon, allowing a better visualization of the small operative field, specially in case of male patients' narrow pelvis. An essential maneuver, during surgery, is the control of the rectal wall integrity. In fact rectal perforation is considered the most important complication. To avoid this one, a careful technique, adequate traction and exposure of the rectum and digital intra-rectal control during dissection, are required (10).

Results

From 1998 to 2016, 11 patients (4 males, 7 females, mean age 54 years, range 32–86 years) with RRT (*Table 2*) underwent surgery in authors' Hospital.

Preoperative diagnosis was performed radiologically in all cases. MRI was the most useful diagnostic test, providing

Table 2 Patients' characteristics and intraoperative and postoperative data

Age (years)	Gender	Symptoms	Approach	Operative time (minutes)	Size (cm)	Complications	Recurrences	Definitive histology	LOS (days)
33	Female	Gynecological examination	Laparoscopic	90	7.5-5-4.4	–	–	Fibrous tumor	6
59	Female	Sciatica	Laparoscopic	75	6-5-3	Abscess	–	Neurofibroma	10
38	Female	Gynecological examination	Laparoscopic	145	11-5.5-3.5	–	–	Hamartoma	5
84	Male	Abdominal pain	Laparoscopic	180	7-6-4	–	–	Teratoma	6
86	Female	Obstructed defecation	Laparoscopic	190	7-7-3.6	–	–	Hamartoma	8
63	Male	Lumbar pain	Laparoscopic	200	5-6-4	Abscess	–	Schwannoma	11
35	Male	Abdominal pain	Laparoscopic	250	10-6-1.5	Wound infection	–	Schwannoma	7
32	Female	Perianal abscess	Combined laparoscopic/ perineal	190	7-4-2	–	–	Tail gut: cystic hamartoma	5
43	Female	Incidentally by CT scan	Laparoscopic	120	–	–	–	Salivary gland	6
69	Male	Incidentally by MRI	Laparoscopic	–	–	–	–	Glomus tumor	7
38	Female	Radiological exam	Laparoscopic/ converted to open surgery	210	3-5-6	–	–	Neurofibroma	11

LOS, length of hospital stay; CT, computed tomography; MRI, magnetic resonance imaging.

information regarding the diagnostic orientation and the anatomical lesions relationships (1). Puncture biopsy is not considered mandatory in any case, based on the debate that exists about it clinical use. Moreover in any case, determines a change about surgical indication or approach. In all cases, the preoperative diagnostic orientation was benign lesion, without specifying the origin. All treated RRT were primary diagnoses.

One patient affected by a recurrent hamartoma and previously operated perineally, was treated satisfactorily by the abdominal approach.

Laparoscopic approach was employed in all cases, with mean operative time of 160 minutes (range 75–250 minutes). In one patient, with a presacral neurinoma, previously treated by a total proctocolectomy and ileoanal reservoir by laparotomy, the procedure was converted in open surgery. No intraoperative complications were observed. In all cases, a radical tumor excision was achieved. Blood loss was negligible.

Postoperative complications were observed in two cases (17%): 1 wound infection and 1 pelvic abscess treated by intravenous antibiotic therapy (grade I and II according to Dindo Classification, respectively). In both cases, for easier management during surgery, due to the lesions diameter, an evacuation of lesions contents was performed. Mean postoperative hospital stay was 7.5 days (range 5–11 days).

Mean size of excised lesion was 6 cm (range 5–11 cm). Definitive histology was benign in all cases. *Table 2* shows the histological characteristics of the present series. At mean follow up of 4 years (range 1–10 years), recurrences were not observed.

Discussion

The most common and the best treatment established, was surgery by open abdominal or perineal approach or combined. However, these options result in a significant morbidity. A logical development is the laparoscopic approach, after achieving good results with rectal cancer, prolapse and prostate surgery. The laparoscopic option has confuted the traditional Woodfield's algorithm that recommended in case of upper lesions, above S3, the transabdominal approach, while in case of lower lesion, the perineal route. The laparoscopic approach for these lesions was described for the first time by Sharpe *et al.* in 1995, for the treatment of a benign RRT (dermoid cyst) (11).

We report our experience, with a selected series of 11 patients who underwent surgery in our Service of Digestive Surgery in the last 19 years, treated by laparoscopic approach. This series only included lesions considered

Table 3 Previously published articles about patients treated surgically for RRT

Authors	Mean age (years)	Gender	Lesions size, range (cm)	Mean operative time (minutes)	Conversion, n (%)	Complications	LOS (days)	Definitive histology	Mean follow up (months)	Recurrences
Nedelcu *et al.* (4)	35	7 females, 2 males	3–11.5	–	1 (11.1)	Neurological, hematoma	4.7	All benign lesions	–	–
Duclos *et al.* (13)	55	12 females	3–12	145	2 (16.6) (bleeding, technical difficulty)	Bleeding, urinary infection, rectal injury	8	10 benign and 2 malignant lesions (misdiagnosis)	34	–
Zhou *et al.* (14)	36	6 females, 2 males	6.6–11.8	122±36	–	–	5	All benign lesions	11	–
Present series	54	7 females, 4 males	5–11	160	1 (9.1)	2	7.5	Benign lesions	48	–

LOS, length of hospital stay; RRT, retrorectal tumor.

benign after radiological tests, therefore without affectation of bone and nerve structures, and of size beyond which caused difficulties for their extraction, unless in case of cystic lesions. During this long period no changes regarding surgical technique or approach have been adopted (10).

The most important controversy, in the treatment of RRTs, begins with diagnosis, which is basically radiological. The majority of the authors consider that a biopsy should be performed only in case of well-founded suspicion of malignancy or in cases in which, due to the patients' comorbidity or advanced age, surgery is not suggested and confirmation of benign lesion is required. In our series, all patients underwent surgery after preoperative diagnosis of benign lesions, without preoperative biopsy, and in all cases, definitive histology confirmed benign tumors.

The decision, regarding the most adequate open surgical approach (abdominal versus perineal), is not only determined by the lesion location (Woodfield's algorithm), but also by the potential malignancy, size, histology or adjacent structures invasion (9,12) (*Figures 2,3*). The present series confirms the feasibility and the safety of the laparoscopic approach and provides good outcomes as well as also in other series similar to the present for the sample size (8–12 cases) (*Table 3*) (4,13,14).

An extensive experience in laparoscopic rectal surgery, for surgeon who decides to approach these lesions by laparoscopy, is mandatory, such as the surgeon's familiarity with the laparoscopic dissection of this region, that allows to treat lesions located below S3–S4, for which, following the Woodfield's algorithm, the open abdominal approach is not recommended. In case of large cystic lesions, the opening and aspiration of their contents significantly facilitate the surgery.

In the present series, conversion to open surgery rate was low (1/11, 9%), and was observed in a young female patients with retrorectal neurofibroma and history of previous proctocolectomy and ileal reservoir for ulcerative colitis, due to severe adhesions that did not allow the laparoscopic approach. In contrast, we had the example of a patient with a first perineal approach for the treatment of a hamartoma that was possible to resect in a second attempt laparoscopically, without recurrence so far.

The lesion size (up to 11 cm) in the present study did not complicate the laparoscopic approach, but cystic tumors have required puncture and aspiration to be resected and extracted by a trocar site, protected with an extractor bag. Although, in some cases, suprapubic mini-laparotomy to extract the specimen, was required. In case of leak of benign lesions contents, there is no risk of neoplastic spreading, in fact aspiration and washing can be performed with saline solution and diluted by povidone iodine at 5%.

The advantages of the laparoscopic approach such as less pain, shorter hospital stay and better recovery in working life, are widely known and reported in several studies about rectal or prostatic surgery. It is important to note, that in literature, three articles, about laparoscopic approach, are reported, and due to the rarity of this pathology these series are very small, with 8, 9 and 12 cases (4,13,14), respectively. In a fourth article (15), 4 out of 15 patients underwent laparoscopic surgery, while the other patients underwent surgery by different combinations of open abdominal and perineal approaches. Conversion rate reported in literature is low (11–16%), and it is comparable with the present series (9%). Mean operative time, in this study, was 146 minutes, similar to this reported in literature (122 and 145 minutes) (13,14) such as blood loss and hospital stay.

Other surgical techniques, less employed for their invasiveness, are reported, as well as the Kraske and York Mason transrectal technique, that results in significant morbidity, especially regarding wound infection (2,15). Transanal endoscopic microsurgery (TEM) is also proposed in literature, mostly in case of small lesions (4).

At mean follow up of 48 months, the recurrence rate, in our series, was 0%. Recurrences of these lesions are observed both in case of malignant tumor, due to their nature, or in case of benign tumor due to an incomplete resection. This means that, in the present series, the R0 has been achieved.

In the present series, the complication rate observed was low (18%), without major complications (grade I and II according to Dindo Classification), if compared to those observed in other series (4,13,14), that include major complications such as neurological lesions and the accidental rectal wall opening, that results in a rectal leak late postoperatively. Therefore, adequate training in rectal oncologic surgery is necessary, with the aim to preserve the hypogastric plexus and the integrity of the rectum.

Definitive histology observed is similar to other series (*Table 3*), but, as mentioned above, only patients with suspicion of benign lesions, confirmed at postoperative histology, underwent surgery. The great histological variability, that it is possible to achieve, is reported by Baek *et al.*, in a review published in 2016 (16), in which are reported data from 241 studies for a total of 1,708 patients.

The weaknesses of the present study are its retrospective nature, the small sample of patients and the lack of long-term results.

In conclusion, RRTs are infrequent, despite the poor experience accumulated, and studies with a small sample of patients are reported, laparoscopic approach is feasible and safe (10). An adequate experience with laparoscopic surgery, although in other areas such as rectal cancer, greatly facilitates the decision to approach these lesions. It is important to select adequately the patients who can benefit of the laparoscopic approach, based on the suspicion of benignity/malignancy, locoregional dissemination, type and size of the lesion, and incompatibilities for the laparoscopic approach, such as in case of previous abdominal surgery.

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None.

Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

Ethical Statement: The study was approved by the ethnical committee. Written informed consent was obtained from the patients.

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Single-access laparoscopic rectal resection: up-to-down and down-to-up

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Abstract: Single-access laparoscopy (SAL) took interest in the last decade, due to the attraction to perform minimally invasive surgery (MIS) through the natural orifices, adding enhanced cosmetic outcomes to the general benefits of MIS. SAL for rectal resection has been described as feasible and safe. Obviously the patients' selection and the surgeon's skills are mandatory. Recently, the application of transanal laparoscopy to the surgery of the rectum gained popularity as well. The union between the abdominal SAL and the transanal total mesorectal excision (TaTME) makes sense because the vascular dissection and the colic mobilization can be performed through the SAL, the TME can be realized through the transanal route, and the abdominal access-site can be used for the temporary ileostomy placement at the end of the procedure. In this chapter, the rectal resection with TME through abdominal SAL or abdominal SAL plus TaTME, is described in details.

Keywords: Single-access; single-port; single-incision; laparoscopy; transanal; total mesorectal excision (TME)

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Introduction

Single-access laparoscopy (SAL) took interest in the last decade (1), due to the attraction to perform minimally invasive surgery (MIS) through the natural orifices (2). The main scope was to add enhanced cosmetic outcomes to the general benefits of MIS. The umbilicus, since its embriological scar, has been considered as the main single-access to perform SAL (3). On the other way, in front a large specimen's removal or a temporary stoma's placement, other abdominal sites have been considered, like the suprapubic (4-6) and the right flank (7) accesses.

SAL for rectal resection has been described as feasible and safe (8). It makes sense because it permits to reduce the abdominal wall trauma due to the less number of the trocars, and also to place the temporary stoma at the site of single-access, maintaining improved the cosmetic outcomes. Obviously the patients' selection is mandatory and, especially at the begining of the surgeon's experience, low body mass index and female patients are the favorite candidates for this technique.

Moreover, thanks to the natural orifices translumenal endoscopic surgery (NOTES) (9), the application of laparoscopy through the anus took interest in these last years. This approach was already introduced in 1985 by Buess *et al.* (10) with the transanal endoscopic microsurgery (TEM), and recently it underwent to an evolution with the application of laparoscopy to the surgery of the rectal diseases. Hence, different transanal procedures have been described like the resection of large rectal polyps (11), the total mesorectal excision (TME) (12), and the control of colorectal complications like bleeding, leak and stenosis (13-15). The major benefits of the transanal approach are the exact intraluminal lesion location and the transmural dissection just below, the improved operative field's exposure, the better exposure of the lateral nerves, the specimen's removal through the anus with a reduced incisional hernia rate, and the improved surgeon's ergonomics.

The union between the abdominal SAL and the transanal TME (TaTME) makes sense because the vascular dissection and the colic mobilization can be performed through the SAL, the TME can be realized through the transanal route, and the abdominal access-site can be used for the temporary ileostomy placement at the end of the procedure.

In front of a rectal tumor, the rectal TME is chosen between the only abdominal access (7), the abdominal access plus the transanal access (16), and the pure transanal access (17). The decision is taken considering the tumor's location, the patient's characteristics, the surgeon's familiarity with these techniques. For the cancer of the middle and low rectum, the transanal approach alone or associated to the abdominal access can probably add more benefits. For the cancer of the upper rectum, the abdominal approach alone probably remains the favorite. Anyway so far, proper guidelines have to be still written.

In this chapter, the rectal resection with TME through abdominal SAL or abdominal SAL plus TaTME, is described in details.

Techniques

Up-to-down rectal resection

Patient and team positioning

The patient is placed in a supine position, with the arms alongside the body and the legs apart. The arms, ankles, and legs are secured and protected. These latter are well secured to the operative table, and the left leg is positioned further up.

For the first part of the procedure, the surgeon stands to the patient's right and the camera assistant to the surgeon's right. The scrub-nurse stands between the patient's legs. The video monitor is placed in front of the surgeon and camera assistant.

After the mesocolic mobilization is made, the camera assistant moves to the surgeon's left, and the scrub-nurse to the surgeon's right.

Single-access abdominal laparoscopy

A 3.5-cm transverse skin incision is made in the right flank, adjacent to the right rectus abdominis muscle and between the umbilicus and the superior right iliac spine. The underlying fascia is divided in a pararectal fashion for 1.5 cm, which exposes the rectus abdominis muscle. The muscle is medially retracted and a purse-string suture using PDS 1 is placed in the fascia, going inside and outside respectively at the 5, 7, 9, 11, 1, and 3 o'clock positions. The peritoneal sheet is entered through a 1-cm vertical incision, and a new purse-string suture using Vicryl 1 is placed, going inside and outside respectively at the 5, 7, 9, 11, 1, and 3 o'clock positions. Both sutures are kept externally with a Pean-Rochester curved forceps.

An 11-mm reusable trocar (or a 12-mm non-reusable trocar) is introduced into the peritoneal cavity inside the purse-string sutures, and the pneumoperitoneum is created. The 10-mm, 30º scope is advanced through the 11-mm trocar.

A 6-mm reusable flexible trocar is inserted at 12 o'clock position with the respect to the patient's head, outside the purse-string sutures and on the same vertical line of the previous trocar, for the insertion of the curved reusable instruments according to DAPRI (Karl Storz-Endoskope, Tuttlingen, Germany) (*Figure 1*). The first one is the bicurved grasping forceps (*Figure 1A*), inserted following its curves at 45º with respect to the abdominal wall (*Figure 2*).

Another 6-mm reusable flexible trocar is inserted at the 6 o'clock position with the respect to the patient's head, outside the purse-string sutures and on the same vertical line of the previous trocars, for insertion of other instruments (*Figure 3*), such as the monocurved grasping forceps (*Figure 1B*), the monocurved coagulating hook (*Figure 1C*), the monocurved dissecting forceps (*Figure 1D*), the monocurved bipolar forceps (*Figure 1E*) and scissors (*Figure 1F*), the straight 5-mm clip applier, the monocurved scissors (*Figure 1G*), the monocurved needle holder (*Figure 1H*), the suction and irrigation cannula, and the straight grasping forceps.

The abdominal cavity is explored and examined to rule out the presence of peritoneal metastases, superficial hepatic lesions and free ascites.

The operative room table is placed in an accentuated Trendelenburg position with right-sided tilt.

The small bowel is moved into the right abdominal quadrants and above the right liver lobe using the bicurved and the monocurved grasping forceps.

The ligament of Treitz is identified in order to expose the root of the inferior mesenteric vein. The peritoneal sheet at the root of this vein is incised with the monocurved coagulating hook (*Figure 4*) until the Toldt's fascia is reached. The inferior mesenteric vein is isolated using the monocurved dissecting forceps and clipped by the 5-mm straight clip applier. The left mesocolon is separated from the Toldt's fascia in an avascular plane using the monocurved coagulating hook or the suction cannula (*Figure 5*).

Surgeon works with curved instruments without crossed hands and without conflict with the camera assistant's hand (*Figure 6*).

The peritoneal sheet is incised along the abdominal aorta with the monocurved coagulating hook, reaching the origin of the inferior mesenteric artery (*Figure 7*). The root of the

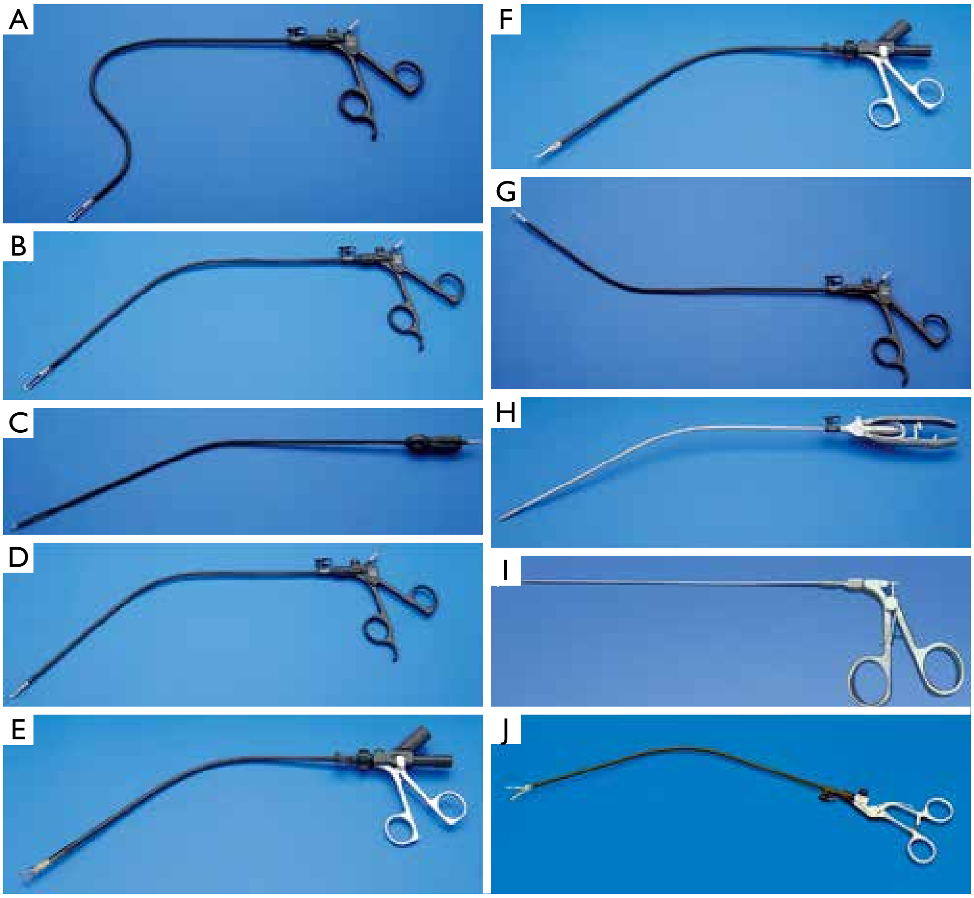

Figure 1 Curved reusable instruments according to DAPRI (Karl Storz-Endoskope, Tuttlingen, Germany): bicurved grasping forceps (A), monocurved grasping forceps (B), monocurved coagulating hook (C), monocurved dissecting forceps (D), monocurved RoBi® bipolar grasping forceps (E), monocurved RoBi® bipolar scissors (F), monocurved scissors (G), monocurved needle holder (H), straight 1.8-mm trocarless grasping forceps (I), monocurved anvil grasping forceps (J).

artery is freed using the monocurved coagulating hook and the monocurved dissecting forceps, clipped by the 5-mm straight clip applier, and divided by the monocurved scissors (*Figure 8*).

If necessary to improve the operative field's exposure, a straight 1.8-mm trocarless grasping forceps (*Figure 11*) can be inserted percutaneously via a skin puncture (created by a Veress needle) in the left suprapubic area. At the end of the procedure, this hole can be used for drain placement.

The left mesocolon is freed from the Toldt's fascia (*Figure 9*), respecting the left Gerota's fascia and going in the direction of the pancreatic tail. The sigmoid and left colon are mobilized from the peritoneal attachments, using the monocurved coagulating hook or scissors (*Figure 10*), until to reach the splenic flexure, which is mobilized by a medial-to-lateral approach.

The procedure is continued with the mobilization of the left mesocolon until the promontory is reached. The upper mesorectum is incised and dissected from the presacral fascia in an avascular plane (*Figure 11*), using the monocurved coagulating hook, and the monocurved bipolar grasping forceps and scissors.

For the rest of the TME, the camera assistant moves to the surgeon's left, and the scrub-nurse to the surgeon's right. The TME is performed from up-to-down, alternatively using the monocurved coagulating hook and the monocurved bipolar grasping forceps and scissors.

To improve the pelvic field's exposure, one or two temporary percutaneous suture using a straight Ethilon 2/0 needle, is passed from the suprapubic area into the uterine

Figure 2 SAL (single-access laparoscopy): insertion of the bicurved grasping forceps at 12 o'clock position.

Figure 3 SAL (single-access laparoscopy): insertion of the other curved instruments at 6 o'clock position.

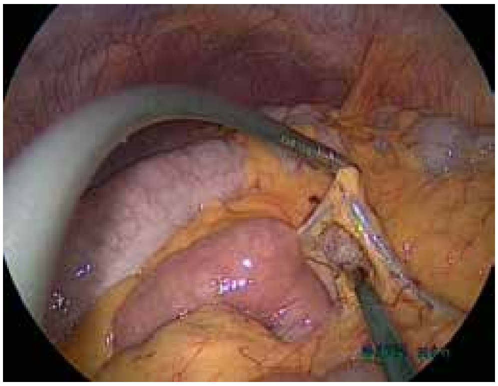

Figure 4 SAL (single-access laparoscopy): inferior mesenteric vein dissection.

fundus (female) (*Figure 12*). Moreover, for the recto-sigmoid colon resection, if the straight 1.8-mm trocarless grasping forceps is already inserted it can be used, otherwise another straight Ethilon 2/0 needle is passed in the pericolic fatty tissue and kept externally by a Pean-Rochester curved forceps.

Once the upper mesorectum is freed, the dissection

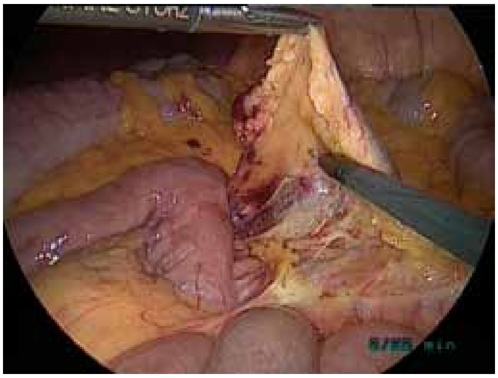

Figure 5 SAL (single-access laparoscopy): separation of the left mesocolon from the Toldt's fascia.

Figure 6 SAL (single-access laparoscopy): surgeon's ergonomics view.

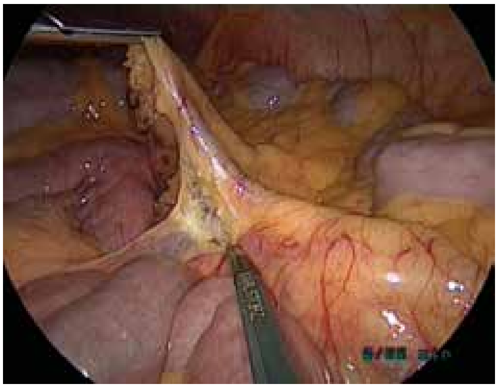

Figure 7 SAL (single-access laparoscopy): peritoneal sheet opening along the abdominal aorta.

continues with the mobilization of the middle and low mesorectum, going first posteriorly (*Figure 13*), then laterally (*Figures 14,15*), and finally anteriorly (*Figure 16*), using both coagulating hook and bipolar instruments. At this step in both male and female patient, a temporary suprapubic percutaneous suture (straight Ethilon 2/0 needle) is passed into the pelvic peritoneal reflexion (*Figure 17*). The plane anteriorly to the rectum and posteriorly to the seminal vesicles/rectoprostatic fascia (male) or uterin cervix/ vagina (female) (*Figure 18*) is dissected with the monocurved coagulating hook.

Once the lower mesorectum is reached, the dissection continues first posteriorly to reach both the levator ani muscles, and then laterally and anteriorly (*Figure 19*). Monocurved bipolar grasping forceps and scissors are contineously used and changed during this step.

The level of the left colon transection is chosen, and the mesocolon is dissected from this level going in the direction of the inferior mesenteric vein root, using the monocurved coagulating hook and bipolar tools.

For the rectal sectioning, the 11-mm trocar is replaced by a reusable 13-mm trocar (if the 12-mm non-reusable trocar is inserted at the beginning, this replacement is not needed), in order to accomodate an articulating linear stapler. The 10-mm scope is switched into a 5-mm, 30º long scope, which is inserted into the 6-mm flexible trocar at the 6 o'clock position (*Figure 20*). The linear stapler encircles the freed low rectum and is fired (*Figure 21*). Usually two-three firings are enough to complete the rectal section.

The specimen is held by the straight grasping forceps and the 6-mm flexible trocar at the 6 o'clock position is retrieved together with the 13-mm trocar and both purse-string sutures. The two fascial openings for the trocars are joined together, enlarging the access. A plastic wall protector is inserted into the peritoneal cavity. The specimen is removed inside the plastic protector (*Figure 22*). The correct level of the left colon transection is found and sectioned by scissors. The anvil of circular stapler is inserted into the lumen, and a Prolene 2/0 purse-string suture is used to close the colic lumen aorund the anvil spike.

The anvil is introduced into the abdominal cavity, and the peritoneal sheet as well as the muscular fascia, are partially closed by Vicryl 1 sutures, permitting introduction of the 11-mm trocar into the abdominal cavity. The 10-mm scope is reused.

The circular stapler is introduced through the anus into the rectum, and the stapler spike is pushed out the rectal stump, staying in the middle of the previous staple line. The bicurved grasper is used to fit the anvil into the circular stapler; the stapler is closed and fired (*Figure 23*).

The suction and irrigation cannula is introduced and the pelvis is immersed under physiologic solution. Leak-test of the anastomosis, using insufflated air through the anus, is performed.

The temporary percutaneous sutures are removed. The parietal pelvic peritoneum is closed and attached to the left colon by Vicryl 2/0 running sutures (*Figures 24,25*), using the monocurved needle holder and the bicurved grasping forceps. The left mesocolic window is closed as well by a Vicryl 2/0 running suture. If necessary, a suprapubic drain is placed into the pelvis.

The operative room table is positioned without any Trendelenburg and tilt, and the small bowel is gently moved out of the right abdominal quadrants and over the left colon.

The distal bowel loop as well as the ileo-caecal valve are searched. A loop, roughly 20 cm before the ileo-caecal valve, is grasped and extracted at the level of the abdominal access, together with the trocars' removal. A temporary ileostomy is realized, placing the ileum outside the access (*Figure 26*), and closing the fascia and the peritoneal sheet by Vicryl 1 sutures. The ileum is open, and muco-cutaneous sutures using Vicryl Rapid 3/0 are positioned. An ileostomy set is finally placed.

Post-operative care

One gram paracetamol is given i.v. at the end of the surgical procedure. Postoperative analgesia is given following the WHO visual analog pain scale (VAS). In the recovery room, the following scheme is followed: for VAS between 1 and 3, 1 g paracetamol i.v. is administered; for VAS between 4 and 8, 100 mg tramadol i.v. is used; for VAS greater than 8, 1 mg piritamide i.v. is incremented.

The arterial catheter is removed in the recovery room.

Once the patient leaves the recovery room, pain is assessed every 6 h, with 1 g paracetamol administered i.v. if VAS is between 1 and 3, and 100 mg tramadol administered i.v. if VAS is between 4 and 8.

Antibiotic prophylaxis is prescribed if necessary and TVP prophylaxis until the discharge of the patient from the hospital. The urinary catheter is removed after 5 days. The patient is allowed to drink water after 24 hours, and to tolerate a light diet from the 3rd postoperative day. The management of the ileostomy is started after 48 hours. If there are no complications, the patient is discharged on the 6th postoperative day, after the abdominal drain (if used) and central line have been removed.

Upon discharge, 1 g paracetamol perorally or 50 mg tramadol perorally are prescribed only if needed.

Office visits are scheduled at 10 days, 1 and 2 months.

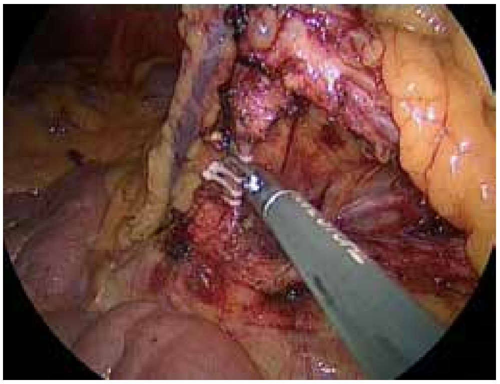

Figure 8 SAL (single-access laparoscopy): inferior mesenteric artery section.

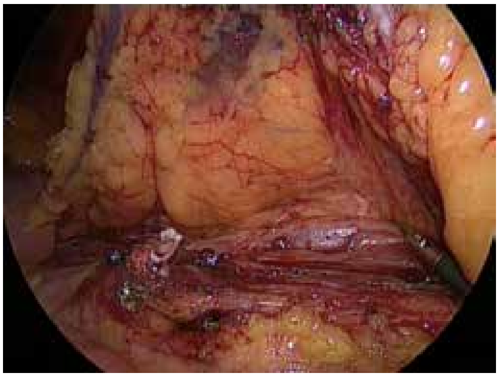

Figure 9 SAL (single-access laparoscopy): mobilization of the left mesocolon from the Toldt's fascia.

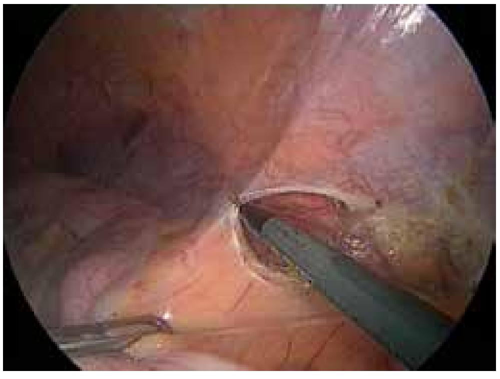

Figure 10 SAL (single-access laparoscopy): mobilization of the sigmoid and left colons from the peritoneal attachments.

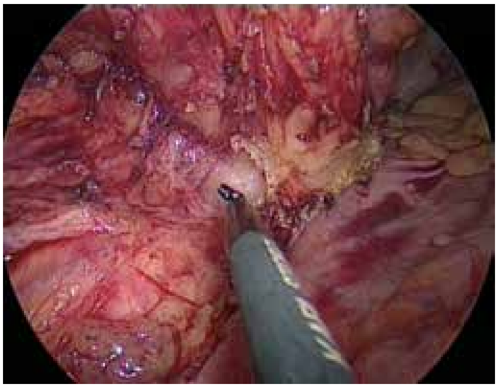

Figure 11 SAL (single-access laparoscopy): mobilization of the upper rectum from the presacral fascia in an avascular plane.

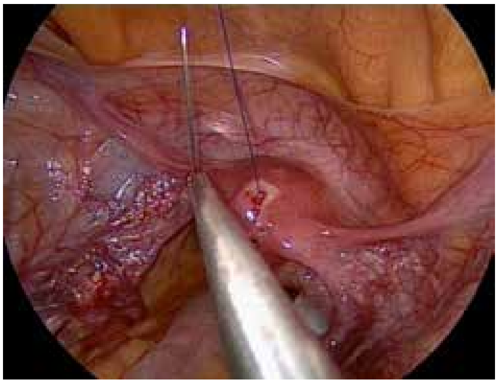

Figure 12 SAL (single-access laparoscopy): temporary percutaneous suture passed into the uterus to improve the operative field's exposure.

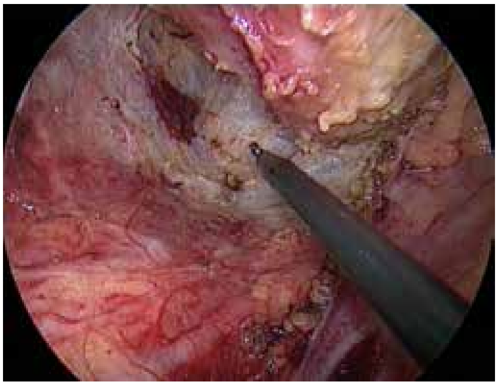

Figure 13 SAL (single-access laparoscopy): posterior mobilization of the middle rectum.

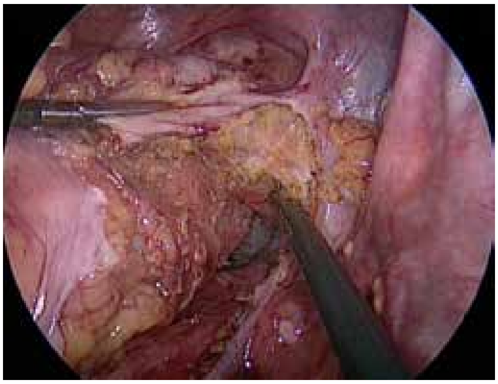

Figure 14 SAL (single-access laparoscopy): right lateral mobilization of the middle rectum.

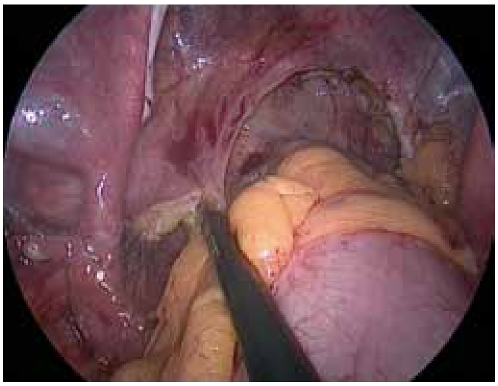

Figure 15 SAL (single-access laparoscopy): left lateral mobilization of the middle rectum.

Figure 16 SAL (single-access laparoscopy): anterior incision of the Douglas' pouch.

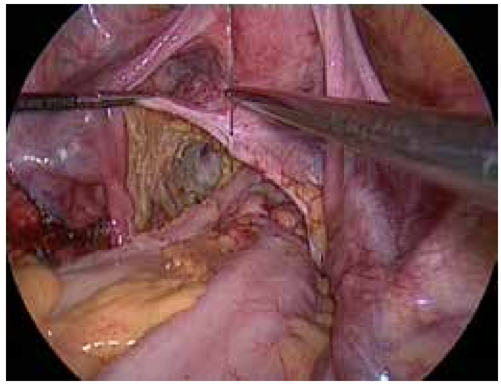

Figure 17 SAL (single-access laparoscopy): temporary percutaneous suture passed into the pelvic peritoneal reflexion.

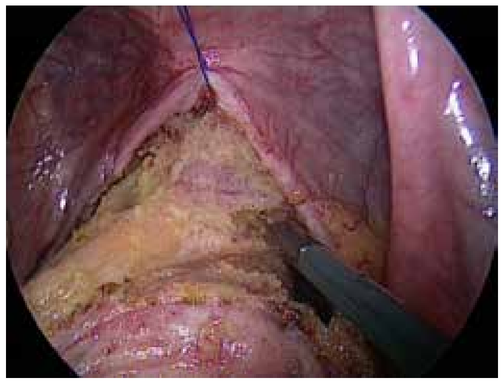

Figure 18 SAL (single-access laparoscopy): anterior dissection of the rectum from the vagina.

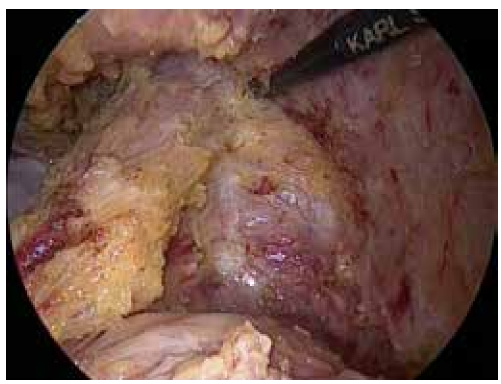

Figure 19 SAL (single-access laparoscopy): anterior mobilization of the low rectum.

Figure 20 SAL (single-access laparoscopy): introduction of the linear stapler under 5-mm scope.

Figure 21 SAL (single-access laparoscopy): placement of the linear stapler around the low rectum.

Figure 22 SAL (single-access laparoscopy): specimen's removal through the single-access.

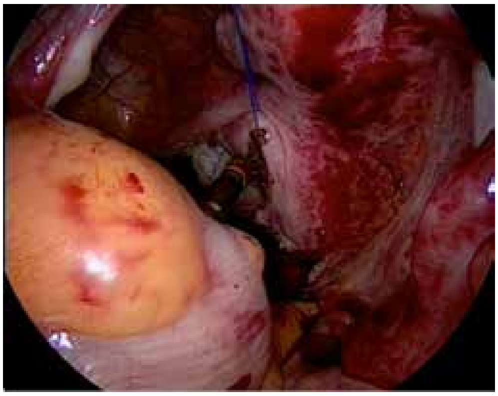

Figure 23 SAL (single-access laparoscopy): ultralow circular mechanical colorectal anastomosis.

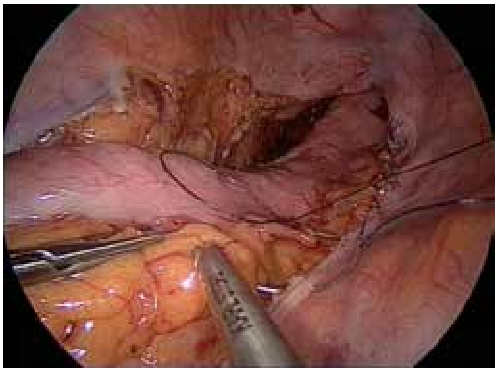

Figure 24 SAL (single-access laparoscopy): right parietal pelvic peritoneum closure.

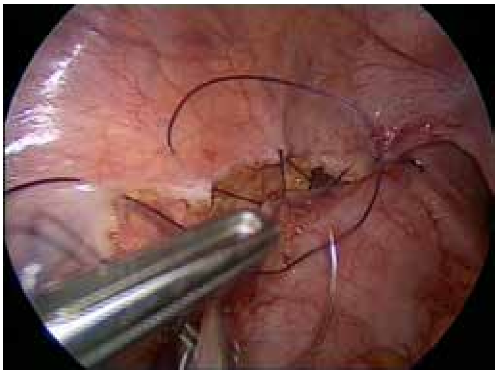

Figure 25 SAL (single-access laparoscopy): left parietal pelvic peritoneum closure.

Usually the patient is scheduled for the closure of the temporary ileostomy after 2 months. Then, the patient is followed-up by the surgeon and the gastroenterologist/oncologist.

Down-to-up rectal resection

Patient and team positioning

The patient is placed in a supine position, with the arms alongside the body and the legs apart. The arms, ankles, and legs are secured and protected. These latter are well secured to the operative table, and the left leg is positioned further up.

For the first part of the procedure, the surgeon stands to the patient's right and the camera assistant to the surgeon's right. The scrub-nurse stands between the patient's legs. The video monitor is placed in front of the surgeon and camera assistant.

After the mesocolic mobilization is made, the camera assistant moves to the surgeon's left, and the scrub-nurse to the surgeon's right.

During the perineal resection, the surgeon stands between the patient's legs, the camera assistant to the surgeon's right and the scrub-nurse to the surgeon's left. The video monitor is placed in front of the surgeon and camera assistant.

Single-access abdominal laparoscopy

A 3.5-cm transverse skin incision is made in the right flank, adjacent to the right rectus abdominis muscle and between the umbilicus and the superior right iliac spine. The underlying fascia is divided in a pararectal fashion for 1.5 cm, which exposes the rectus abdominis muscle. The muscle is medially retracted and a purse-string suture using PDS 1 is placed in the fascia, going inside and outside respectively at the 5, 7, 9, 11, 1, and 3 o'clock positions. The peritoneal sheet is entered through a 1 cm vertical incision, and a new purse-string suture using Vicryl 1 is placed, going inside and outside respectively at the 5, 7, 9, 11, 1, and 3 o'clock positions. Both sutures are kept externally with Pean-Rochester curved graspers.

An 11-mm trocar is inserted into the peritoneal cavity inside the purse-string sutures, and the pneumoperitoneum is created. The 10-mm, 30° scope is advanced through the 11-mm trocar.

A 6-mm reusable flexible trocar is inserted at the 12 o'clock position with respect to the patient's head, outside the purse-string sutures and on the same vertical line as the previous trocar, for insertion of the bicurved grasping forceps (*Figure 1A*). This grasping forceps is inserted following its curves at 45° with respect to the abdominal wall (*Figure 2*).

Another 6-mm reusable flexible trocar is inserted at the 6 o'clock position with respect to the patient's head, outside the purse-string sutures and on the same vertical line as the previous trocars, for the insertion of other instruments (*Figure 3*), such as the monocurved grasping forceps (*Figure 1B*), the monocurved coagulating hook (*Figure 1C*), the monocurved dissecting forceps (*Figure 1D*), the monocurved bipolar forceps (*Figure 1E*) and scissors (*Figure 1F*), the straight 5-mm clip applier, the monocurved scissors (*Figure 1G*), the monocurved needle-holder (*Figure 1H*), the suction and irrigation cannula, and the straight grasping forceps.

The abdominal cavity is explored and examined to rule out the presence of peritoneal metastases, superficial hepatic lesions and free ascites.

The operating room table is placed in an accentuated Trendelenburg position with right-sided tilt.

The small bowel is moved into the right abdominal quadrants and above the right liver lobe using the bicurved and monocurved grasping forceps.

The ligament of Treitz is identified in order to expose the root of the inferior mesenteric vein. The peritoneal sheet at the root of this vein is incised with the monocurved coagulating hook (*Figure 4*) until the Toldt's fascia is reached. The inferior mesenteric vein is isolated using the monocurved dissecting forceps and clipped by the 5-mm straight clip applier. The left mesocolon is separated from the Toldt's fascia in an avascular plane using the monocurved coagulating hook or the suction cannula (*Figure 5*).

The surgeon works with curved instruments without crossing hands and without interference with the camera assistant's hand (*Figure 6*).

The peritoneal sheet is incised along the abdominal aorta using the monocurved coagulating hook (*Figure 7*), until the origin of the inferior mesenteric artery is reached. The root of the artery is freed using the monocurved coagulating hook and the monocurved dissecting forceps, clipped by the 5-mm straight clip applier, and divided using the monocurved scissors (*Figure 8*).

If necessary to improve the operative field's exposure, a straight 1.8-mm trocarless grasping forceps (*Figure 1I*) can be inserted percutaneously via a skin puncture (created by a Veress needle) in the left suprapubic area. At the end of the procedure, this hole can be used for drain placement.

The left mesocolon is freed from the Toldt's fascia (*Figure 9*), respecting the left Gerota's fascia and going in the direction of the pancreatic tail. The sigmoid and left colons are moved away from the peritoneal attachments (*Figure 10*) using the monocurved coagulating hook or scissors until reaching the splenic flexure, which is downloaded using a medial-to-lateral approach.

The procedure is continued by moving the left mesocolon until the promontory is reached. The upper mesorectum is incised and dissected from the presacral fascia in an avascular plane until 1 cm down the promontory (*Figure 27*), using the monocurved coagulating hook and the monocurved bipolar grasping forceps and scissors. The level of the left colon transection is chosen and the mesocolon is dissected from this level going in the direction of the inferior mesenteric vein root, using the monocurved coagulating hook and bipolar tools.

In female patients, a temporary percutaneous suture, using a straight Ethilon 2/0 needle, is placed in the uterine fundus to improve the operative field's exposure (*Figure 12*).

The procedure continues with the TME performed from down-to-up. The operating room table is placed in a reduced Trendelenburg position and reduced right-sided tilt.

Transanal dissection, specimen's extraction & colorectal anastomosis

Both patient's legs are positioned upwards (gynecologic positioning). The D-port (*Figure 28*) is inserted into the anal canal and fixed to the skin by four silk 0 sutures. A 10-mm, 30° scope is inserted in the middle opening of the D-port (*Figure 29*), and the rectal lumen is checked to identify the rectal tumor. A gauze pad is pushed beyond the rectal tumor. The monocurved grasping forceps (*Figure 1A*) and the monocurved anvil grasping forceps (*Figure 1J*) are inserted at the 9 o'clock opening of the D-port (*Figure 30*). The other instruments, such as the straight grasping forceps, the monocurved needle-holder (*Figure 1H*), the monocurved scissors (*Figure 1G*), the monocurved coagulating hook (*Figure 1C*), the monocurved bipolar forceps and scissors (*Figure 1E,F*), the suction and irrigation cannula, are inserted at the 3 o'clock opening of the D-port (*Figure 31*).

A safe margin distally from the tumor is chosen, and a purse-string suture using Prolene 2/0 is placed into the rectal mucosa, using the monocurved grasping forceps and the monocurved needle holder (*Figure 32*). The suture is tight extracorporeally, the knot is pushed intraluminally and cut by the monocurved scissors. Then, the mucosa just under the purse-string suture is incised until to pass the entire rectal wall (*Figure 33*). The TME is performed from bottom to top, going first posteriorly (*Figure 34*). Then, the mobilization of the rectum is completed, going laterally on the left (of the patient) (*Figure 35*) and right side (of the patient) (*Figure 36*). The dissection is finally performed anteriorly, taking care to dissect the correct plane between the rectum and the prostate (male), or the vagina (female) (*Figure 37*). The dissection is continued up, respecting the presacral fascia posteriorly, until reaching the seminal vesicles (male) or the uterin cervix (female) anteriorly, using both monocurved coagulating hook and monocurved bipolar scissors. Finally, the transanal dissection joins the previous dissection started at the level of the promontory through the laparoscopic abdominal access, opening the Douglas' pouch (*Figure 38*).

The rectal-sigmoid colon is encircled by a plastic protector and removed transanally, after having removed the D-port (*Figure 39*). The level of the colic transection is found, the left colon is sectioned, and the specimen removed. The anvil of the circular stapler is introduced into the colic lumen, closing this latter with a Prolene 2/0 purse-string suture. The colon and anvil are pushed inside the pelvis and the D-port is repositioned. The rectal stump is closed transanally with a Prolene 2/0 purse-string suture, using the monocurved grasping forceps and the monocurved needle-holder (*Figure 40*). Then, the monocurved anvil grasping forceps keeps the anvil transanally (*Figure 41*), while the suture is tight by extracorporeal knot, pushed intraluminally and cut by the monocurved scissors. The D-port is removed again, and the circular stapler is introduced transanally (*Figure 42*). The anvil is attached to the circular stapler by the monocurved anvil grasping forceps, under abdominal laparoscopic control. The stapler is closed and fired.

Through the abdomen, the suction and irrigation cannula is introduced and the pelvis is immersed under physiologic solution. A leak-test of the anastomosis, using insufflated air through the anus, is performed.

Transanal dissection, specimen's extraction and coloanal anastomosis

Both patient's legs are positioned upwards (gynecologic positioning). A gauze pad is inserted in the anal canal to avoid potential fecal contamination. The anal retractor is positioned and the anal mucosa is injected with Lidocaine 1%. The pectineal line is incised using the monopolar electrode (*Figure 43*). Once freed circumferentially, the anal mucosa is closed by a silk 0 purse-string suture. The anal canal is dissected until to reach the low rectum into the

Figure 26 SAL (single-access laparoscopy): temporary ileostomy placement.

Figure 27 SAL (single-access laparoscopy): abdominal mesorectal dissection stopped at 1 cm down the promontory.

pelvis.

The D-port is inserted and fixed to the skin by four silk 0 sutures. A 10-mm, 30° scope is inserted in the middle opening of the D-port (similar to *Figure 29*). The monocurved grasping forceps (*Figure 1B*) is inserted at the 9 o'clock opening of the D-port (similar to *Figure 30*). The other instruments, such as the monocurved coagulating hook (*Figure 1C*), the monocurved bipolar forceps and scissors (*Figure 1E,F*), the suction and irrigation cannula are inserted at the 3 o'clock opening of the D-port (similar to *Figure 31*).

The lower rectum is mobilized circumferentially from down-to-up, going first posteriorly (similar to *Figure 34*), to the left side (of the patient) (similar to *Figure 35*), to the right side (of the patient) (similar to *Figure 36*) and, finally anteriorly (similar to *Figure 37*), using the monocurved coagulating hook and the monocurved grasping forceps. The dissection is performed anteriorly finding the correct

Figure 28 TaTME (transanal total mesorectal excision): reusable transanal D-Port according to DAPRI (Karl Storz-Endoskope, Tuttlingen, Germany).

Figure 29 TaTME (transanal total mesorectal excision): placement of the D-Port and 10-mm scope in the middle opening.

Figure 30 TaTME (transanal total mesorectal excision): placement of the monocurved grasping forceps at 9 o'clock opening.

Figure 31 TaTME (transanal total mesorectal excision): placement of the other monocurved instruments at 3 o'clock opening.

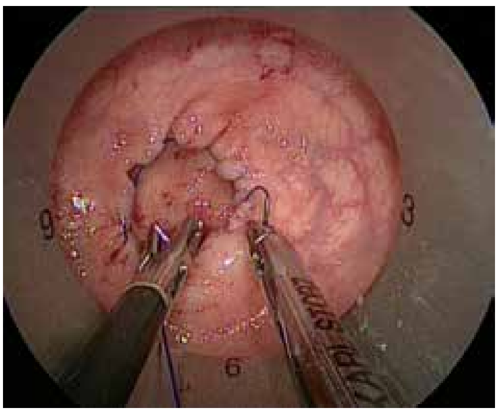

Figure 32 TaTME (transanal total mesorectal excision): endoluminal rectal closure.

Figure 33 TaTME (transanal total mesorectal excision): transrectal incision.

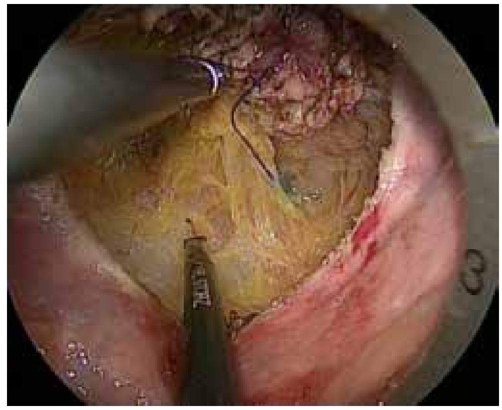

Figure 34 TaTME (transanal total mesorectal excision): posterior TME.

Figure 35 TaTME (transanal total mesorectal excision): left (of the patient) lateral TME.

Figure 36 TaTME (transanal total mesorectal excision): right (of the patient) lateral TME.

plane between the rectum and the prostate (male), or the vagina (female).

The middle rectum is freed, taking care to respect the presacral fascia posteriorly, and to find the correct plane between the rectum and the seminal vesicles (male), or uterin cervix (female) anteriorly. Both the monocurved coagulating hook and the monocurved bipolar scissors are used. Finally, the transanal dissection joins the previous dissection started at the level of the promontory through the laparoscopic abdominal access, opening the Douglas' pouch (similar to *Figure 38*).

The rectal-sigmoid colon is encircled by a plastic protector and removed transanally, after having removed the D-port (similar to *Figure 39*). The level of the colic transection is found and the left colon is sectioned, removing the specimen. A coloanal anastomosis is created using Vicryl Rapid 3/0 sutures (*Figure 44*). The anal retractor is taken out.

Figure 37 TaTME (transanal total mesorectal excision): anterior TME.

End of both procedures and temporary ileostomy

Through the abdomen, the pelvic parietal peritoneum is closed and attached to the left colon by Vicryl 2/0 running sutures (*Figures 24,25*), using the monocurved needle holder and the bicurved grasping forceps. Then, the temporary percutaneous suture (female) is removed. The left mesocolic window is closed as well by a Vicryl 2/0 running suture. If necessary, a suprapubic drain is placed into the pelvis.

The operating room table is positioned without any Trendelenburg and tilt, and the small bowel is gently moved out of the right abdominal quadrants and over the left colon.

The distal bowel loop together with the ileo-caecal valve are searched. A loop, roughly 20 cm before the ileo-caecal valve, is grasped and extracted at the level of the abdominal access, together with the trocars' removal and purse-string sutures. A temporary ileostomy is performed, placing the ileum outside the access (*Figure 26*), and closing the fascia and the peritoneal sheet by Vicryl 1 sutures. The ileum is open, and muco-cutaneous sutures using Vicryl Rapid 3/0 are positioned. An ileostomy set is finally placed.

Post-operative care

One gram paracetamol is given i.v. at the end of the surgical procedure. Post-operative analgesia is given following the WHO visual analog pain scale (VAS). In the recovery room,

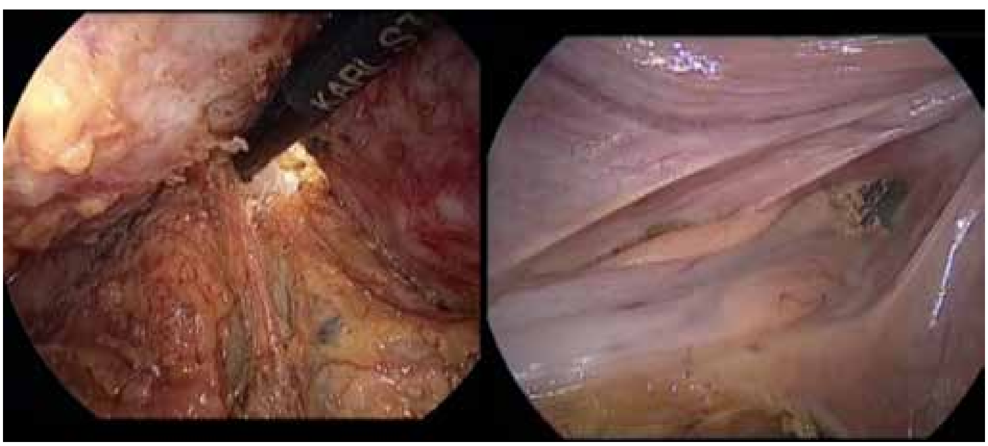

Figure 38 TaTME (transanal total mesorectal excision): opening of the Douglas' pouch. On the left: transanal view; on the right: transabdominal view.

Figure 39 TaTME (transanal total mesorectal excision): specimen's extraction.

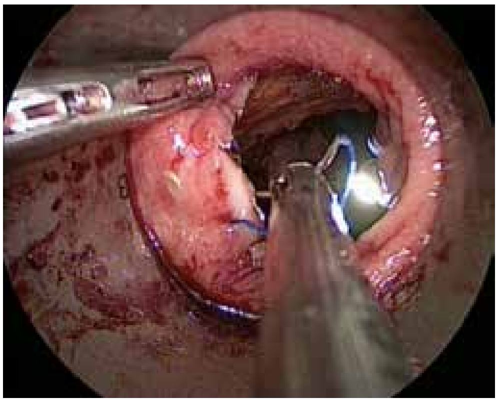

Figure 40 TaTME (transanal total mesorectal excision): rectal stump closure by purse-string suture.

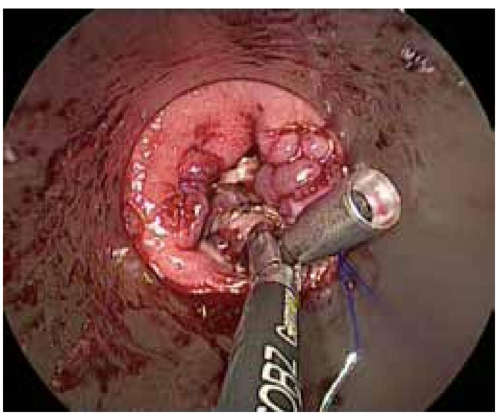

Figure 41 TaTME (transanal total mesorectal excision): anvil kept with the monocurved anvil grasping forceps.

Figure 42 TaTME (transanal total mesorectal excision): transanal insertion of circular stapler.

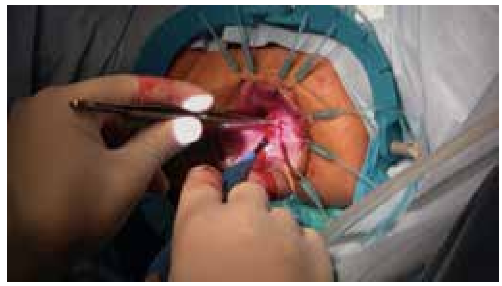

Figure 43 TaTME (transanal total mesorectal excision): anal mucosa dissection.

Figure 44 TaTME (transanal total mesorectal excision): coloanal anastomosis.

the following scheme is followed: for VAS between 1 and 3, 1 g paracetamol i.v. is administered; for VAS between 4 and 8, 100 mg tramadol i.v. is used; for VAS greater than 8, 1 mg piritamide i.v. is incremented.

The arterial catheter is removed in the recovery room.

Once the patient leaves the recovery room, pain is assessed every 6 h, with 1 g paracetamol administered i.v. if VAS is between 1 and 3, and 100 mg tramadol administered i.v. if VAS is between 4 and 8.

Antibiotic prophylaxis is prescribed if necessary and

TVP prophylaxis until the discharge of the patient from the hospital. The urinary catheter is removed after 5 days. The patient is allowed to drink water after 24 hours, and to tolerate a light diet from the 3rd post-operative day. The management of the ileostomy is started after 48 hours. If there are no complications, the patient is discharged on the 6th post-operative day, after having removed the abdominal drain (if used) and the central line.

Upon discharge, 1 g paracetamol perorally or 50 mg tramadol perorally are prescribed only if needed.

Office visits are scheduled at 10 days, and 1, 2 months. Usually the patient is scheduled for closure of temporary ileostomy after 2 months. Then, the patient is followed-up by the surgeon and gastroenterologist/oncologist.

Conclusions

SAL rectal resection with TME can be performed with safety, although the patients' selection and the surgeon's experience remain mandatory. For the middle and low rectal cancer, SAL has to be joined to the transanal approach, getting the other benefits.

Acknowledgements

None.

Footnote

Conflicts of Interest: The author is consultant for Karl Storz-Endoskope, Tuttlingen, Germany

Informed Consent: Written informed consent was obtained from the patients for publication of this article and any accompanying images.

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Laparoscopic modify extralevator abdominoperineal resection for rectal carcinoma in the prone position

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Contributions: (I) Conception and design: All authors; (II) Administrative support: None; (III) Provision of study materials or patients: K Ye; (IV) Collection and assembly of data: J Lin; (V) Data analysis and interpretation: K Ye; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

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Background: Laparoscopic technique applying for low rectal Carcinoma excision and the extralevator technique applying for abdominoperineal resection are involved with emerging technologies. The aim of this study was to introduce a modified approach of a direct visible resection: the levator muscles with laparoscopic technique and the alteration of patient's position to a PJK position for the perineal resection of T3–T4 low rectal carcinoma.

Methods: A 54-year-old woman with rectal carcinoma within 4 cm of the anal verge, the pathology confirmed adenocarcinoma. The enteroscopy showed that a cauliflower-like carcinoma was seen in the back of rectum. MRI and ERUS showed that the carcinoma of the lower rectum infiltrate muscular rand no enlarged lymph node around the rectum be noted. Preoperative TNM-staging was T3NxM0, and the patient was underwent an modified approach of a direct visible resection: the laparoscopic technique and the alteration to PJK position.

Results: The operation cost 180 min with bleeding of about 50 mL. The patient recovers well postoperation and discharged from hospital on the 7th day.

Conclusions: Laparoscopic modify extralevator abdominoperineal excision (ELAPE) for rectal carcinoma can be safely performed without the occurrence of short-term complications.

Keywords: Abdominoperineal resection (APR); LELAPR; PJK position; rectal carcinoma

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Introduction

Conventional abdominoperineal excision for low rectal carcinoma, because of retained the levator muscles, due to rectal perforation or the positive circumferential resection margin (CRM), which induced the main risk of higher local recurrence and lower survival (1,2), however, an extralevator abdominoperineal excision (ELAPE) may be more feasible through en bloc resection of the levator muscles covering the distal mesorectum and removing of more tissue in the distal rectum, but this technique may increase the incidence of postoperative perineal wound complications, urinary and sexual dysfunction, and the occurrence of chronic pain in regio perinealis (3). We performed a modify ELAPR with transabdominal transection of the approach of a direct visible resection: the laparoscopic technique and the alteration to PJK position. A laparoscopic approach to the resection can bring the lower postoperative complication, and the modify ELAPR reduced the perineal complications, simplified the operation and accelerated patient recovery.

Figure 1 Laparoscopic modify extralevator abdominoperineal resection (6). Available online: http://www.asvide.com/articles/1139

Methods

Surgical indications

It was considered that patients with rectal tumours located within 4 cm of the anal verge and the plane between the tumour and the levator ani muscles was not clear were suitable for laparoscopic abdominoperineal excision (LELAPE) (4). And the patients with cT3+ and/or lymphatic metastasis need the neoadjuvant chemoradiotherapy (5).

In the present video (*Figure 1*), the patient is a 54-year-old woman who was diagnosed moderately differentiated adenocarcinoma of lower rectum tumours located within 4 cm of the anal verge by coloscope and histological test. The tumor stage was assessed to be cT3N0M0 by MRI scan preoperation.

Surgical procedures

LELAPE was followed the principles of total mesorectal excision. Patients were placed in the improving lithotomy position and a modified five-hole method was performed. From medial to lateral, the sigmoid colon and rectum was dragged from retroperitoneal structures. Along the left Toldt's space, the operation need well protected ureter and pelvic autonomic nerves, cut the inferior mesenteric artery from its origin, dissect the lymph nodes near the artery.

Pelvic dissection proceeds alternating posterior, both sides and anterior between visceral and parietal endopelvic fascia. Between the mesorectal fascia and the Waldeyer's presacral fascia, hypogastric nerve and the parasympathetic sacral nerve roots from S2 to S4 is well preserve. Anteriorly, dissection would start at the level of rectovaginal septum in female, and the plane above the seminal vesicle in male, Laterally, dissection should well preserve the hypogastric plexus and neurovascular bundle. The mesorectum was separated from the levator ani muscles downward as far as its origin. And the clearly defined tissue such as the neurovascular bundle laterally, the upper part of the vagina/seminal vesicles anteriorly and the coccyx posteriorly was found thought laparoscopically.

In our operation, extralevator resection has been modified. The dissection external of the levator ani muscles should depend on the location and invasion direction of tumor, and the coccyx bone has been preserved. The levator muscles in tumor side are arc and vertically cut down under direct laparoscopic visualization, and the other sides mostly reserved. The dissection lines along the rectum meet at the apex of the coccyx bone. the R0 resections and no CRM involvement are required in the operation, we defined it as extralevator resection.

A laparoscopic linear stapler was used to cut off the sigmoid colon, and pulled out the proximal colon to make a colostomy incision. And altered the patient's position to a PJK position for the perineal resection, dissection begun firstly on the posterior side, dissection is performed behind the coccyx bone, as levator muscles have been transected by laparoscopic transabdominal approach. The dissection plane is relatively easy to find, lateral dissection follow the levator ani muscle stump .the distal rectum is anteriorly polled out from the pelvic cavity through the perineal wound. The approach could identify boundary of the anterior rectal wall, vagina or seminal vesicles/prostate with excellent visualization. And limited dissection is performed on the anterior, it must preserve the urethra in males and the posterior vaginal wall in females (perineal body). Therefore it's removing the anal canal, levators and low mesorectum altogether with "*en bloc*".

Since the dissection extent of the levator ani muscles have been modified, the pelvic and perineal incisions can easily close by suturing subcutaneous tissue and the skin, and suturing the residue of the levator muscles is necessary.

Results

It took about 150 min to finish the whole operation with bleeding of about 50 mL. The pathology outcome after the surgery shows it the moderately differentiated adenocarcinoma with 1/15 lymph nodes positive staging T3N1M0 (IIIB). And the proximal margin, the distal margin and the CRM was no tumor residual. The patient recovers well postoperation without sexual dysfunction, perineal wound breakdown any and discharged from hospital on the 7th day.

Discussion

Conventional abdominoperineal resection (cAPR) for rectal cancer has been found the relatively high rate of positive CRMs and intra-operative perforations, as well as the higher local recurrence. As a consequence, the extralevator APR (ELAPR) is increasingly used, which through removal of more tissue in the distal rectum to reduce the rate of intraoperative perforation, and CRMs involvement (1,7). But ELAPR has the disadvantages of perineal complications, urinary and sexual dysfunction, aggressive trauma, and reconstruction of the pelvic defect and laparoscopic surgery (LS) has made the rectal surgery revolutionize.

LS for colorectal cancer has been considered to be oncologically equivalent to open surgery, in addition to short-term postoperative benefits such as pain less, recover quicker and scar less (8).

We performed LELAPR with transabdominal transection of the levator muscles and the perineal part resection in a PJK position. Pelvic dissection and rectal mobilization must be performed according to TME principles. Laparoscopic mobilization of the mesorectum is as far as downward the origin of the levator ani muscles. And the clearly defined tissue such as the neurovascular bundle laterally, the upper part of the vagina/seminal vesicles anteriorly and the coccyx posteriorly was found thought laparoscopically. LELAPR well protect the pelvic nerves and vascular structures along the lateral pelvic wall under direct visualization. It reduced the high rate of urinary retention in male cases and patient-reported impotence. A further question in ELAPE surgery are perineal reconstruction, the majority of cases in our hospital have high quality preoperative imaging, pathology reporting and neoadjuvant therapy. We present the less aggressive procedure being an appropriate treatment for most LELAPE operations. With division of the levator ani muscles at their origins has been modified individually, the dissection external of the levator ani muscles should depend on the location and the invasion direction of rectal tumor. The extra-excised levator muscles in the tumor side to reduce the CRM positivity, with a controlled excision of the levator muscles and preserved the coccyx, the healthy tissue left will make it easier to close the pelvic incision.

The majority of shortcoming of Lloyd-Davies position is related to the limited vision to the surgical site, which lead the dissection to be mostly blind and blunt, and did not follow the principle of tumor-free technique. The prone jackknife position enables a sharp, standardized, and direct vision resection of the rectal stump, which ensuring en bloc excision of the primary tumor, lesser CRM positivity, and lower perforation rates (9,10). Since the levator ani muscles have been resection by laparoscopic, the perineal phase of prone jackknife position became easy, also this modify technique reduce blood loss and operative times, and the benefits oncologically equivalent to the ELAPR.

Conclusions

Modify LELAPR with the best oncological approach of laparoscopic technique and the alteration of patient's position, enables to achieve a cylindrical specimen, and an acceptable perioperative and pathological outcomes such as minimally invasive, oncological acceptable and easily performed procedure.

Acknowledgements

None.

Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

Ethical Statement: The study is approved by the institutional ethical committee of Second Affiliated Hospital of Fujian Medical University (No. 2013051) and obtained the informed consent from every patient.

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Reduced-port laparoscopic surgery for rectal cancer

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Abstract: Although laparoscopic surgery for rectal cancer was less invasive than open surgery, there were several puncture holes and one small assisted incisions. This paper introduced the reduced-port laparoscopic surgery (RPLS) for rectal cancer, without increasing the difficulty of the operation, reducing the trauma and improving cosmesis.

Keywords: Reduced-port laparoscopic surgery (RPLS); rectal cancer

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Introduction

Laparoscopic surgery for rectal cancer has developed rapidly in recent 10 years because of its low invasiveness, good short-term and long-term outcomes, good cosmesis, and cost-effectiveness (1-3). Conventional laparoscopic surgery need 4–5 puncture holes and one 3–4 cm assisted incision and will leave 5–6 surgical scars. To reduce surgical invasiveness and improve cosmesis, surgeons proficient in conventional laparoscopic and endoscopic surgery have recently developed more advanced single-port laparoscopic surgery (SPLS) techniques as well as natural orifice transluminal endoscopic surgery (NOTES). NOTES has not been widely used in clinical practice because of the limitation of operative approach, incision closure and special equipment. Since 2008, Bucher (4) and Remzi (5) firstly used single port laparoscopic technology in the field of colorectal cancer. SPLS for colorectal cancer has become a hot spot for research because of its more prominent minimally invasive advantages and better cosmetic results. But SPLS for rectal cancer also has not been widely used in clinical practice because the operation of SPLS for rectal cancer was difficult and the abdominal cavity drainage tube could not be placed or placed through the incision which leaded to poor drainage effect and increased the incidence of incision infection and incision hernia. Reduced-port laparoscopic surgery (RPLS) for rectal cancer which had one incision and one port concentrated multiple punctures of conventional laparoscopic surgery into the auxiliary incision and retained the right lower abdomen port. RPLS had less invasive than conventional laparoscopic surgery and was easier to master than SPLS. The peritoneal drainage tube could place through the right lower abdomen port. So RPLS was accepted by more clinicians and was one of the options for rectal cancer (6,7).

Clinical summary

The patient was female, 42 years old, height 166 cm, weight 53 kg and BMI 19.2. She presented with hematochezia for five days. The tumor was rectal adenoma canceration. Tumor size was about 1.5 cm × 1.5 cm. The distance of tumor from the anal verge was 6 cm. Chest, upper and lower abdomen, enhanced CT did not find distant metastasis. Pelvic MRI showed a thickening of the rectal, mild reinforcement.

Preoperative assessment

The case should be carefully selected in the early stage of RPLS. We routinely select patients with moderate to lean body size (BMI <23) and with a higher demand for cosmesis. T stage of tumor should be less than T3, and the tumor size should not be too large. The patient had no abdominal and pelvic operation history, no cardiopulmonary dysfunction and no other traditional laparoscopic surgery

Figure 1 The location of the trocar.

contraindications.

Anesthesia, patient position, incision and port placement and operation procedure

The umbilicus or lower abdomen median longitudinal incision was 3 cm long. The retractors were placed in incision.

General anesthesia was adopted. The patient was placed in the supine position, with moderate legs separated, the right arm fixed on the right side of the body and the left arm abducted 90 degrees. The patient was put in the Trendelenburg position at 30° and tilted right side-down at an angle of 15°. The umbilicus or lower abdomen median longitudinal incision was 3 cm long. The retractors were placed in incision. The surgical sterile rubber glove was fixed to the outer ring of the incision retractor and the 5, 12, 5 mm trocars entered the abdominal cavity via thumb, middle finger, pinkie finger of the surgical sterile rubber glove respectively (*Figure 1*). After pneumoperitoneum by CO_2 gas, the peritoneal cavity was examined to determine whether RPLS was possible and to ensure that there were no peritoneal metastasis. The 12 mm trocar was placed in the right lower abdomen. When dissecting the inferior mesenteric vessels, the surgeon stood on the right side of the patient, the assistant stood on the left side and the second assistant stood between the legs of the patient (*Figure 2*). After dissecting the inferior mesenteric vessels, surgery and assistant position unchanged, the second assistant stood on the side of the patient's head (*Figure 3*). After getting sufficient distal margin, the rectum was divided using an Endo GIA Stapler. The bowel was extracted through the incision retractor, after removing the covering glove. After delivery of the specimen, anastomosis was made with a 28 mm stapling device. The pelvic drainage tube was placed through the right lower abdomen port (*Figure 4*).

Figure 2 The position of the surgeon.

Postoperative management

Anastomotic leakage is one of the most serious and major complication in rectal surgery. The pelvic drainage tube was very important in the early diagnosis of anastomotic leakage. The drainage tube should be kept unobstructed, and the volume and character of the drainage fluid were closely observed after the operation. The patient was semi supine 6 hours after the operation and began ambulation on first days after the operation.

Comment

The average age of colorectal cancer patients in china was 10 years younger than that of European and American countries, and about 40% patients were younger than 40 years old (8). We need to pay attention to the radical cure for rectal cancer patients, also the cosmesis.

RPLS that we carried out for rectal cancer concentrated multiple punctures of conventional laparoscopic surgery

Figure 3 The position of the surgeon.

Figure 4 The position of Incision and drainage tube.

into the auxiliary incision and retained the right lower abdomen port, reduced the puncture hole and damage and had good cosmetic effect. The operation was easier than SPLS due to the retention of the right lower quadrant 12 mm port. The pelvic drainage tube that placed through the right lower abdomen port was appropriate and conducive to the early discovery and treatment of the anastomotic fistula. The operation was completed by conventional laparoscopic instruments, so that it was easy to spread. RPLS was safe, feasible and one of the options for rectal cancer.

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Footnote

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Laparoscopic total mesorectal excision (TME) with electric hook for rectal cancer

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Abstract: Procedures of laparoscopic total mesorectal excision (TME) with electric hook for rectal cancer are described. Laparoscopy requires cooperation between the surgeon, first assistant surgeon and second assistant surgeon, in order to recognize the inferior mesenteric artery (IMA), the inferior mesenteric vein (IMV), the neurovascular bundle (NVB), and the fibrous tissues between the mesorectum and the surrounding tissues or organs. Some important organs, such as the autonomic nerves, left ureter, left gonadal vessels, and pancreas, should be avoided being injured. Comparing with ultrasound knife, the advantage of electric hook is obvious. Less smog will be produced if the electric hook is used within 2 seconds, and clearer dissectible layer will appear during the TME surgery with electric hook.

Keywords: Rectal cancer; total mesorectal excision (TME); laparoscopic; electric hook

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Positions of the patient, cannulas and the surgical team

The patient should be in steep Trendelenburg position and tilted right side down. The surgeon stands on the patient's right side, the first assistant on the left side, and the second assistant (camera operator) on the left side of the surgeon. The main monitor is placed near the patient's left shoulder, and the second monitor is placed behind the surgeon. Five cannulas (2 mm × 12 mm, 3 mm × 5 mm) are placed as shown in *Figure 1*.

Procedures

The small bowel loops are placed in the right side to expose the duodenum and the inferior mesenteric vein (IMV) (*Figure 2*).

Surgeon must identify the tumor location firstly. The assistant should grasp the pedicle of superior rectal vessels and use an intestinal grasper to push the rectum ventrally and laterally. The promontory should be confirmed, so the surgeon can use the hook to incise the peritoneum at the level of promontory (*Figure 3*).

The surgeon should move to cephalad dissection. While

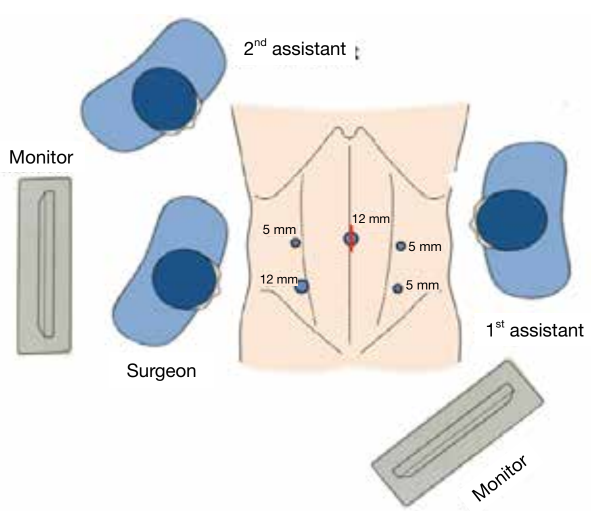

Figure 1 Positions of the cannulas and the surgical team.

Figure 2 To expose the inferior mesenteric vein (IMV).

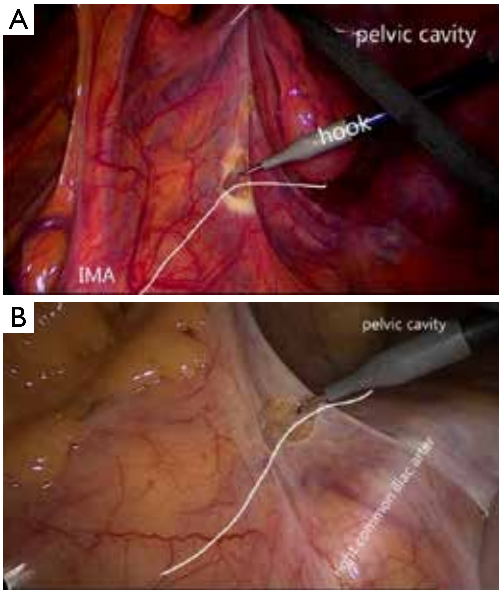

Figure 3 The surgeon can use the hook to incise the peritoneum at the level of promontory.

Figure 4 To cut the subperitoneal connective.

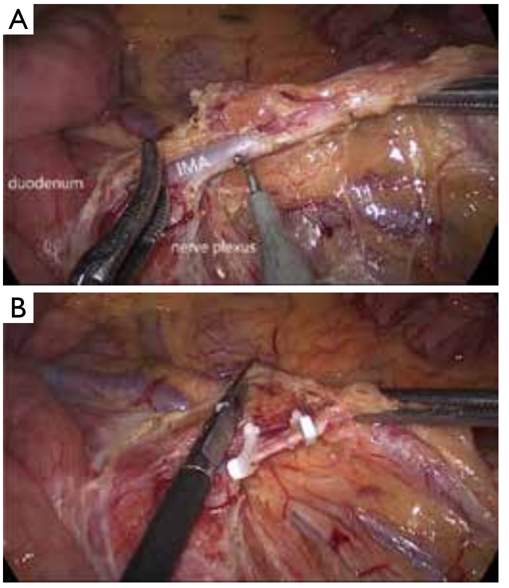

Figure 5 Incision of peritoneum is continued up to the origin of the inferior mesenteric artery (IMA).

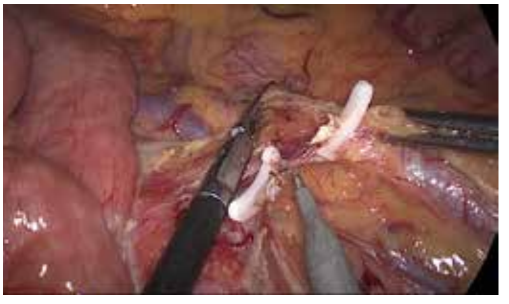

Figure 6 The inferior mesenteric artery (IMA) should be cut between two clips.

cutting the subperitoneal connective, you should avoid damaging the hypogastric nerves (*Figure 4*).

Incision of peritoneum is continued up to the origin of the inferior mesenteric artery (IMA). The surgeon and the assistant should recognize the nerves, the ureter, and the gonadal vessels, and you should also prevent the injuries to them (*Figure 5*). Two absorbable clips are required to occlude the origin of IMA, and then the IMA should be cut between these two clips (*Figure 6*).

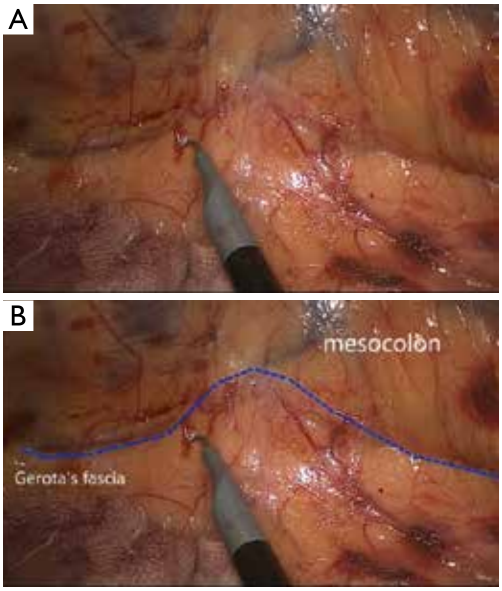

Figure 7 The dissection between the mesocolon and the retroperitoneum.

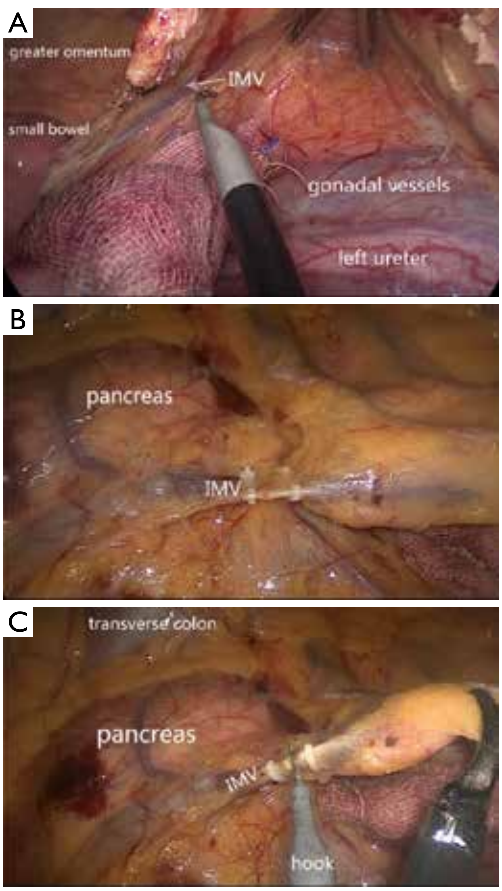

Figure 8 To find the inferior mesenteric vein (IMV) and occlude it.

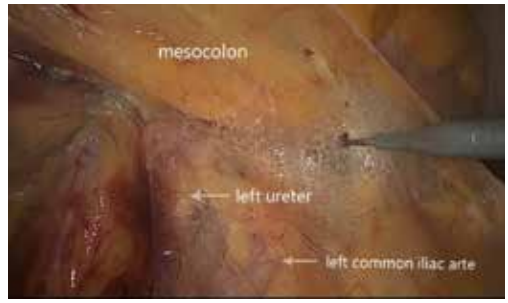

Figure 9 The posterior dissection of the rectum.

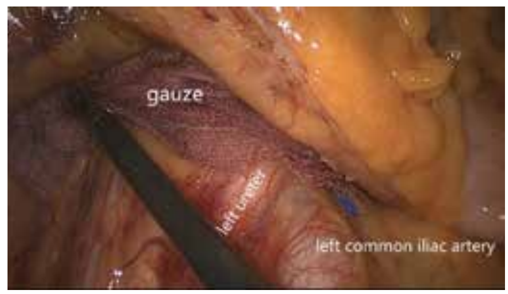

Figure 10 A gauze can be stuffed into the gap as a sign.

The dissection between the mesocolon and the retroperitoneum is advanced laterally and cephalad. Continuing to divide the adipose tissues, in order to create the Gerota's fascia, which is a fibrous membrane covering the left kidney (*Figure 7*). Then the IMV and the pancreas will arise (*Figure 8A*). As same as the IMA, the adipose tissues surrounding the IMV need to be cleaned carefully, and two or more clips are required to occlude the IMV (*Figure 8B,C*).

Following the cephalad dissection, you come back to the posterior dissection of the rectum. Surgeon and assistant should avoid doing harm to the left ureter and the left common iliac arte (*Figure 9*).

Once you have separated the mesocolon and the left common iliac arte, a gauze can be stuffed into the gap between them, in order to be the sign in the next step (*Figure 10*).

The assistant picks the paracolic sulci peritoneum by the left hand and the surgeon picks the mesocolon, in order to keep the tension (*Figure 11*). Traction is very important. Surgeon must be patient and careful to avoid damaging the left common iliac arte and the left ureter. Continuing cutting the paracolic sulci peritoneum until the gauze appears (*Figure 12*), and incision of peritoneum is continued

Figure 11 To divide the colon from the left lateral abdominal wall.

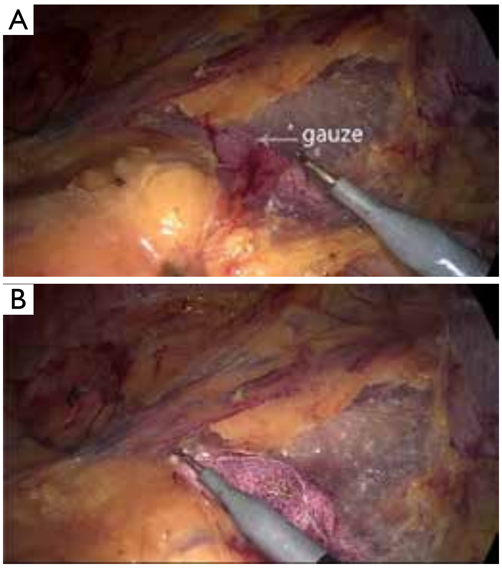

Figure 12 Continuing cutting the paracolic sulci peritoneum until the gauze appears.

up to the splenic flexure (*Figure 13*).

Then the surgeon can move to the posterior dissection of the rectum. The assistant should extend the fibrous tissues between the mesorectum and the retroperitoneum, in order to keep the sufficient traction. The rectal fascia propria can be created so that the surgeon can continue the following dissection. The prehypogastric nerve on both sides, the median or lateral sacral vessels should be protected (*Figures 14,15*).

The lateral dissection on the left side and the right side is similar (*Figures 16,17*). The surgeon now incises the peritoneum carefully, avoiding damaging the pelvic nerve plexus, the neurovascular bundle (NVB) and the seminal vesicle.

The surgeon could use the hook to open the peritoneal

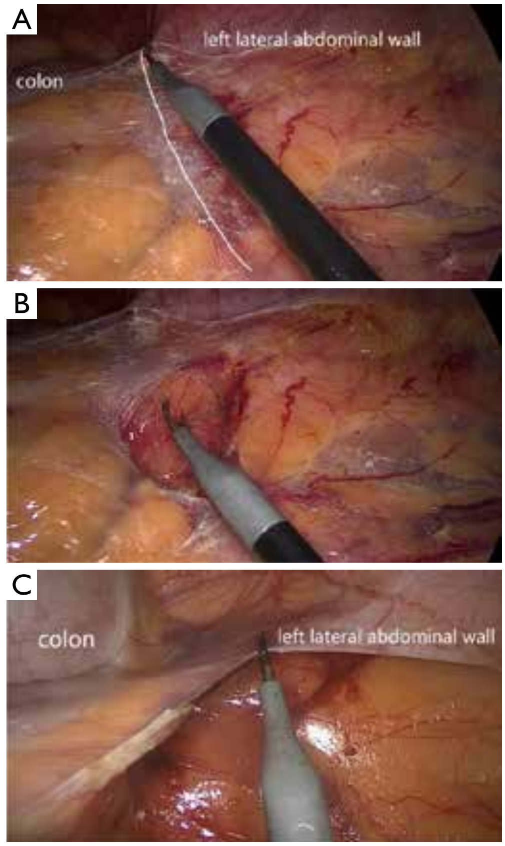

Figure 13 Incision of peritoneum is continued up to the splenic flexure.

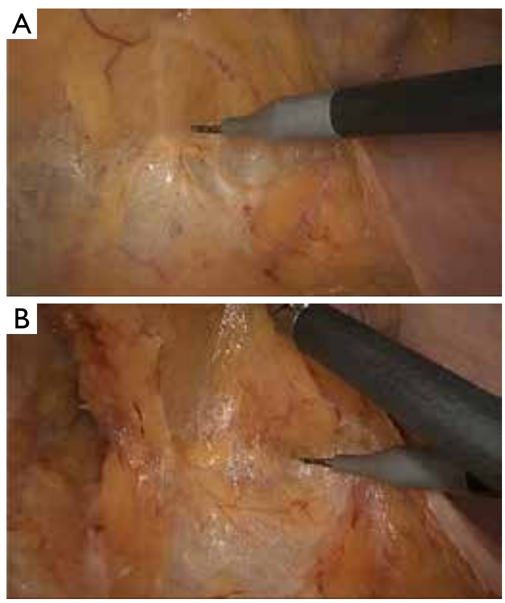

Figure 14 The posterior dissection of the upper rectum.

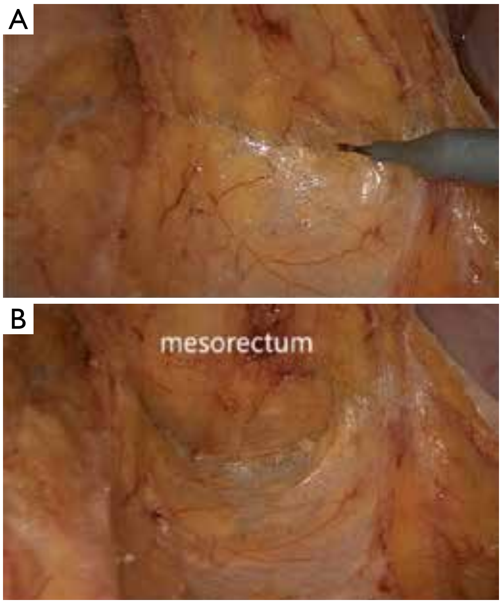

Figure 15 The posterior dissection of the rectum.

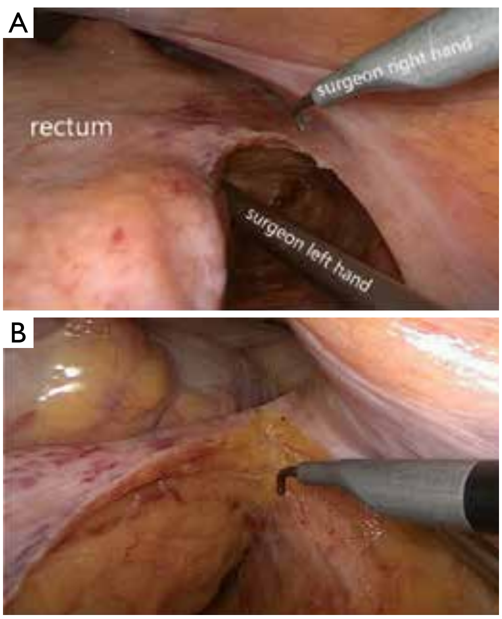

Figure 16 The lateral dissection on the right side.

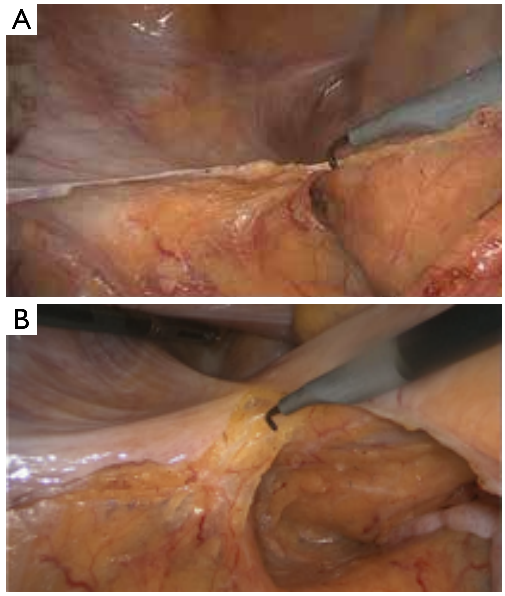

Figure 17 The lateral dissection on the left side.

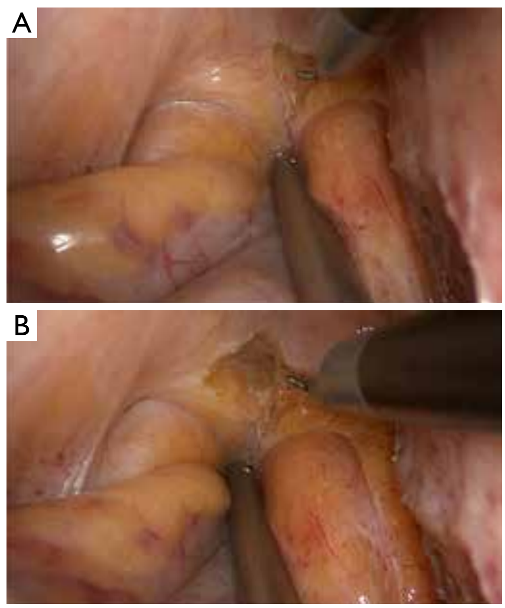

Figure 18 The peritoneal reflection is opened.

reflection. The assistant should push up the urinary bladder by one of his hand, to avoid the damage with bladder. The surgeon should try his best to extend the fibrous tissues between the seminal vesicle and the rectum (*Figure 18*).

There is a fascia called "Denonvilliers' fascia", the fibrous tissues between the rectum and the seminal vesicles, the prostate, and the NVB (*Figure 19*).

The surgeon and assistant should pay attention to the NVB on the both side, preventing to enter into them. The NVB must be everted from the rectum (*Figures 20,21*).

The dissection reaches the pelvic floor, and the so-called lateral ligament is created both in left and right anterolateral

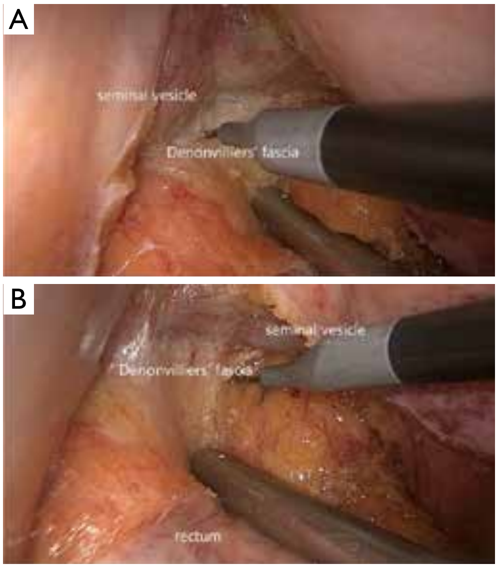

Figure 19 To find the Denonvilliers' fascia.

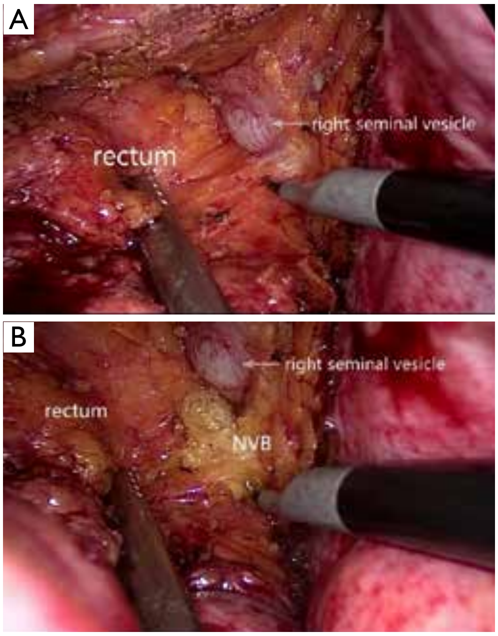

Figure 20 The neurovascular bundle (NVB) on the right side.

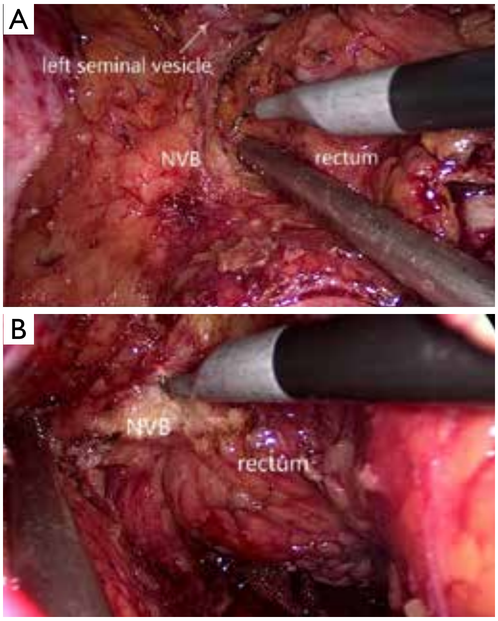

Figure 21 The neurovascular bundle (NVB) on the left side.

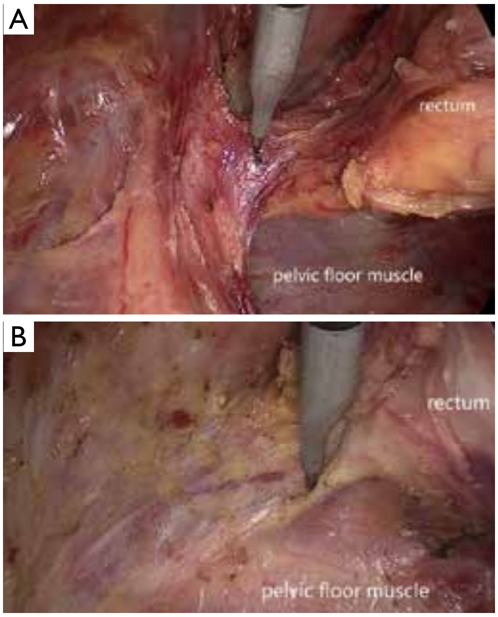

Figure 22 The dissection reaches the pelvic floor.

corner (*Figure 22*). Cut them off and clean the mesorectum to advance it to obtain a sufficient distal margin (*Figure 23*).

Once the surgeons have finished the dissection, some medical instruments can be used to divide the rectum (*Figure 24*). Then we can see the rectal stump and check it (*Figure 25*). Following to take the tumor from the abdomen, anastomosis is performed with either a double-stapling technique.

Conclusions

Laparoscopic total mesorectal excision (TME) with electric

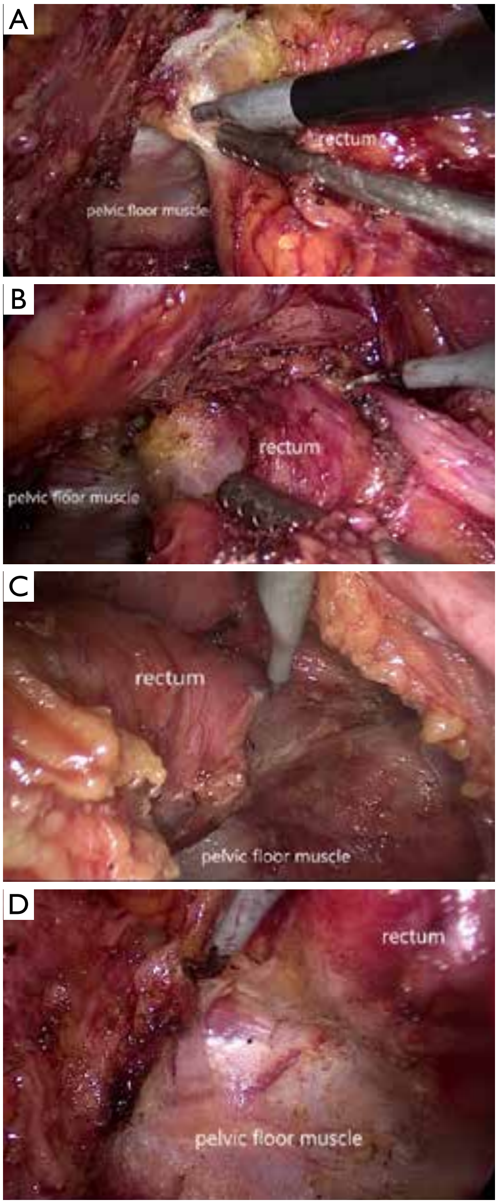

Figure 23 Clean the mesorectum to advance it to obtain a sufficient distal margin.

hook for rectal cancer is described. Comparing with ultrasound knife, the advantage of electric hook is obvious. Firstly, less smog will be produced if the electric hook is used within 2 seconds. Secondly, by using the electric hook, surgeon and assistants can find the clearer dissectible layer. Last but not least, tissue could be mobilized with the electric hook by sharp dissection instead of blunt dissection so that surgeon can prevent some unnecessary damage, such as hemorrhage and perforation.

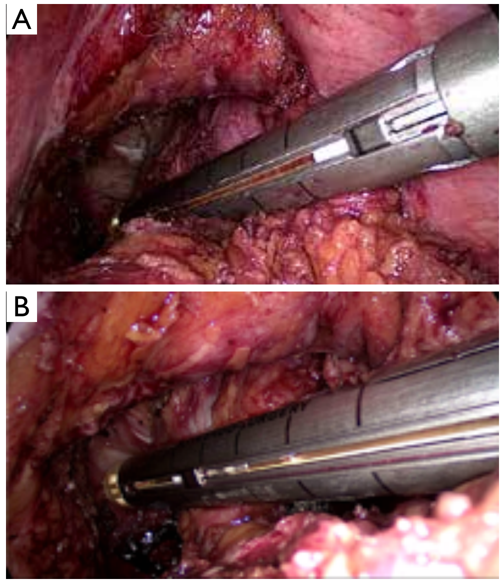

Figure 24 The rectum is divided by an instrument.

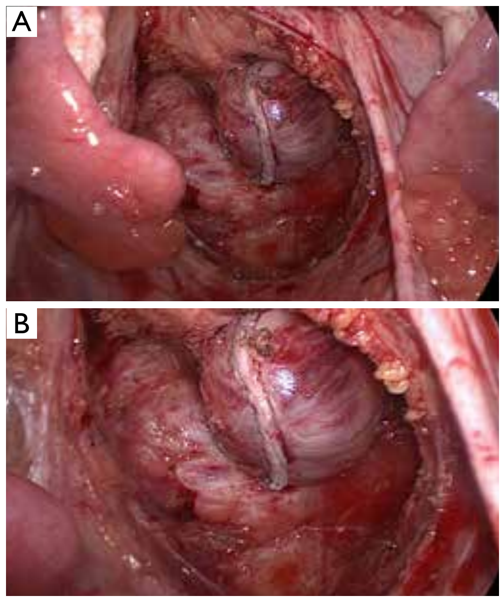

Figure 25 There is the rectal stump.

Laparoscopy surgery with electric hook requires cooperation between the surgeon, first assistant surgeon and second assistant surgeon. Keeping the sufficient traction is important and necessary, which could help the surgeon recognize the correct layer and the organs, including the IMA, the IMV, the autonomic nerves, left ureter, left gonadal vessels, and pancreas (*Figure 26*).

Figure 26 Laparoscopic total mesorectal excision (TME) for rectal cancer (1).
Available online: http://www.asvide.com/articles/1514

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None.

Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

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Laparoscopic *vs.* robotic colorectal resections: new insights from the American College of Surgeons National Surgical Quality Improvement Program

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Provenance: This is an invited Commentary commissioned by Editor-in-Chief Minhua Zheng (Department of General Surgery, Ruijin Hospital, Shanghai Jiaotong University School of Medicine, Shanghai Minimal Invasive Surgery, Shanghai, China).

Comment on: Feinberg AE, Elnahas A, Bashir S, *et al*. Comparison of robotic and laparoscopic colorectal resections with respect to 30-day perioperative morbidity. Can J Surg 2016;59:262-7.

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We read with interest the article by Feinberg *et al.* (1) reporting the short-term results for colorectal resections performed by laparoscopy or Da Vinci System®. Data from of 8,864 colorectal resections performed in 2013 in hospitals participating at the American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) were retrieved concerning preoperative, intraoperative, and 30-day outcome data. For each robotic colorectal procedure there were about 18 laparoscopic resections, 472 robotic (5.6%) *vs.* 8,392 laparoscopic overall. Rectal resections were 1,449, 79 robotic (5.4%). These preliminary findings show that the use of the Da Vinci System® was not dependent to rectal *vs.* colonic localizations and maybe is more related to the habits of each institution, where in some hospitals robotic surgery is employed both for colon and rectal resections and the same is true for laparoscopy.

Although there are not solid data from randomized trials, surgeons performing robotic rectal surgery are aware that it is easier than laparoscopy which is characterized by steep learning curve. It was recently calculated that the mean number of cases required for the surgeon to be classed as an expert in robotic rectal surgery was 39 patients (2). The study showed two main findings. The first one was that the robotic cohort had a lower incidence of unplanned intraoperative conversion (9.5% *vs.* 13.7%, P=0.008). The second was that in the subgroup of rectal resections the employment of the robot resulted in a lower incidence of postoperative ileus than laparoscopy (3.8% *vs.* 11.18%, P=0.039). The only randomized control trial that was implemented [robotic versus laparoscopic resection for rectal cancer (ROLARR)] (3) had as primary end-point the conversion rate and after the completion of the enrolment failed to show a significant reduction rate of unplanned conversion in the robotic group overall. The subgroup analysis supported a benefit with the robotic approach for male patients, obese patients and those with lower tumors. The third interesting result is that there was no difference in duration of surgery between laparoscopic and robotic procedures. This is relatively new in the literature where robotic surgeries are reported to be more time consuming. There are two possible explanations. In the paper by Feinberg *et al.* a great amount of data were reported in a short time interval and in a recent year [2013], so that many institutions dealing with robotic surgery since early 2000s' have reached their plateau in the learning curve. Moreover, the same reason bringing a similar rate of robotic surgeries in colon and rectal cancer may account for a similar duration of surgery for laparoscopic and robotic procedures where institutions employing robotic surgery are committed to perform as many robotic procedures as possible, shortening the length of surgery. Focusing on colonic resections interesting data are coming out regarding the possible advantage of the Da Vinci system in performing right colectomies with a modified complete mesocolic excision technique (mCME). In a recent study (4), the authors confirmed the feasibility and safety of mCME for the treatment of right-sided colon cancer. This technique provided satisfying short-term outcomes with promising 4-year oncologic results.

The problem of increased costs with robotic surgery is well known, however it was not a topic of the study by Feinberg *et al.* However the difference in costs per episode of care penalizing robotic surgery versus other conventional approaches widely ranges among studies (5). Moreover, an accurate analysis based on direct non-medical costs as well as indirect and social costs has never been conducted, and should be the aim for future studies.

Acknowledgements

None.

Footnote

Conflicts of Interest: The author has no conflicts of interest to declare.

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Update on robotic surgery for rectal cancer treatment

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Abstract: Laparoscopic total mesorectal excision (TME) is technically demanding and has a steep learning curve. Moreover, two recent randomized controlled trials have questioned the oncological safety of laparoscopic treatment for rectal cancer. Robotic surgery, thanks to its technical advantages, could potentially overcome the intrinsic limitations of standard laparoscopy. In this paper we will describe the surgical technique of robotic TME and review the recent literature on robotic rectal surgery. Short term, functional and oncological outcomes will be taken into consideration, as well as learning curve and costs. Robotic rectal resection is reported to have lower conversion rates (CRs), better functional outcomes and shorter learning curve, with comparable oncological results. Robotic surgery remains more time consuming and affected by higher costs. The technological advantages provided by the robotic system could probably facilitate the widespread adoption of minimally-invasive TME, that still has a low penetration worldwide. The educational capabilities of the platform, together with structured training programs, could allow novice surgeons to safely approach colorectal surgery.

Keywords: Robotic rectal resection; total mesorectal excision (TME); rectal cancer; circumferential resection margin; low anterior resection; oncological outcomes

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Introduction

While laparoscopic treatment for colon cancer has showed several undisputed short term advantages over the traditional open approach, with equivalent long term oncologic outcomes (1,2), two recently published trials have questioned this assumption for rectal cancer (3,4).

Total mesorectal excision (TME), since it was first described by Heald in 1982 (5), is considered the gold standard treatment for rectal cancer, due to the significant reduction in local recurrence rate (6). The standard and rigid laparoscopic instrumentation, with the camera hold by the assistant surgeon, add complexity to the TME. The pelvis is a confined location, that becomes even more unfavorable in males, and when dealing with bulky tumors or obese patients. Therefore, TME remains a challenging procedure, with high conversion rates (CRs) (7,8) and a steep learning curve (9). Robotic surgery, with its endowristed instruments with 7 degrees of freedom, 3D full HD vision with a stable optical platform, tremor filtering, and motion scaling could overcome some of the technical limitations of standard laparoscopy, reducing the degree of procedural complexity. This could potentially increase the diffusion of minimally-invasive TME, that still maintains a low penetration worldwide (10-12).

This paper aims to describe the surgical technique of robotic TME and to review the recent literature on robotic rectal surgery with a focus on short term results, functional and oncological outcomes, learning curve and costs.

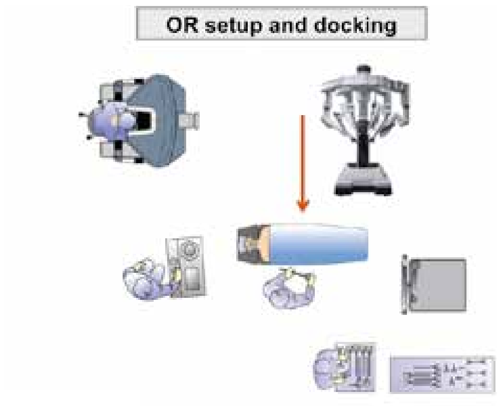

Figure 1 Operative room setup and docking.

Figure 2 Trocar layout.

Robotic TME: surgical technique

Herein we describe the technique for full-robotic TME with the DaVinci Xi surgical platform (Intuitive Surgical Inc., Sunnyvale, CA, USA). This system allows for an easier setup and multiquadrant access thanks to a faster docking, simpler OR setup (boom-mounted rotating arms) and longer instruments, when compared to previous robotic systems.

Patient positioning

The patient is placed in lithotomy position with arms alongside the body and is carefully secured with dedicated patient positioning system (Pink Pad, Xodus Medical Inc., PA, USA) to prevent sliding.

First assistant stands on the patient's right side. The scrub nurse is at the lower right side of the table and the assistant's monitor is located at the patient's left shoulder. The cart is placed at the patient's left side and is docked from the left lower quadrant (*Figure 1*).

Port placement

A Veress needle is inserted in the left hypochondrium (Palmer's point) for the induction of a 12-mmHg pneumoperitoneum. A 12-mm optical port is inserted in the right flank. Four 8-mm robotic trocars are then inserted along a straight line that is parallel to and about 4 cm cranial to the costofemural line, maintaining a 6–8 cm distance between each port. Ports are also located at least 2–3 cm away from bony prominences. An additional 8-mm robotic port is placed in the left flank and will be used for the pelvic phase of the procedure (*Figure 2*).

Robot positioning and docking

A complete exploration of the abdominal cavity is performed and an intraoperative liver ultrasonography is carried out with a laparoscopic dedicated probe to complete the intraoperative staging of the disease. The patient is then placed in a 20–25° Trendelemburg position with a 20–25° right tilt: the greater omentum and the small bowel loops are retracted out of the pelvic area into the right upper quadrant laparoscopically.

The robotic cart is then approximated and deployed for docking from the patient's left side. A green laser, emitted from the overhead boom, is used to define the correct cart position. The optical port is then docked and the endoscope is inserted to complete the automated targeting process towards the left iliac fossa. The other robotic arms are then docked and robotic instruments are inserted under visual control.

Step-by-step review of critical elements of the procedure

Full-robotic TME is essentially based on 3 steps:

- ❖ Splenic flexure mobilization;
- ❖ Vascular control;
- ❖ TME.

Splenic flexure mobilization

The trasverse mesocolon is lifted up with the grasper in R1 (*Figure 3*). The lesser sac is entered through the incision of transverse mesocolic root at the level of the anterior pancreatic border. Splenic flexure mobilization is carried out with a medial-to-lateral approach along the pancreatic body. A sponge is placed underneath the transverse mesocolon and the splenic flexure is

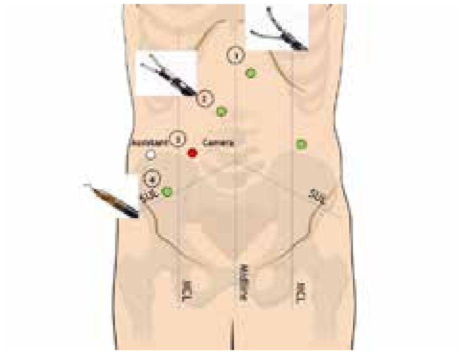

Figure 3 Splenic flexure mobilization and vascular control, instruments setup.

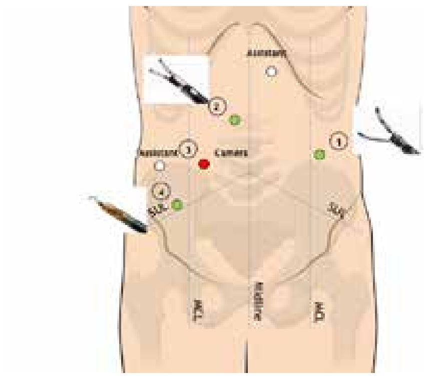

Figure 4 Total mesorectal excision, instruments setup.

retracted medially by the assistant. Splenic flexure mobilization is completed in a lateral-to-medial fashion along the white line of Toldt up to the inferior splenic pole and the plane previously developed is easily reached. Coloepiploic detachment is then carried out.

Vascular control

During this step of the procedure R2 and R4 are the operative arms, whereas R1 is used for stable retraction. A 30°-down robotic camera is mounted on robotic arm R3. The assistant trocar in the right flank is used for suction/irrigator, clip applier, swab introduction or additional retraction if needed.

The assistant grasper and the robotic grasper in R1 lift anteriorly and laterally the sigmoid colon and upper rectum to expose the root of the sigmoid mesocolon and the upper mesorectum. The peritoneum is then incised at the level of the sacral promontory to obtain the avascular presacral plane and the hypogastric nerves are identified. The robotic monopolar hook on R4 and bipolar grasper on R2 work synergically for the dissection of the IMA, which is freed by the surrounding lymphatic tissue, providing a wide locoregional lymphadenectomy and preserving the main trunks of the hypogastric plexus at the IMA origin.

Before IMA division, the Toldt's fascia is identified underneath the inferior mesenteric vein (IMV) in a medial-to-lateral fashion and left gonadal vessels and left ureter are identified and preserved. The IMA is then dissected free and a high-tie is performed by the application of Hem-o-lok® (Teleflex, Weck, USA) clips. The dissection along the Toldt's fascia, that has been previously identified cranially and caudally to the IMA origin, is completed in a medial-to-lateral fashion and the retroperitoneal structures are preserved. The IMV is isolated and dissected at its root between clips at the inferior border of the pancreas.

TME

During this step, R1 is moved and connected to the left flank 8-mm trocar to achieve optimal access to the mesorectum, whereas R2 and R4 remain in their original position (*Figure 4*). An additional 8-mm epigastric trocar is now available in order to maximize the assistance with cranial retraction on the sigmoid colon and simultaneous suction/irrigation or additional gentle pelvic sidewall retraction.

Robotic R2 and R4 are the operative arms, whereas R1 is used to expose the pelvic area with lateral traction on pelvic sidewalls or anterior/upward traction on the Douglas peritoneal reflection, vaginal wall or seminal vesicles/Denonvilliers fascia. Frequent repositioning of R1 is fundamental to maintain the adequate countertraction that will allow the dissection plane to be continued up to the level of the pelvic floor.

TME is carried out according to Heald's principles through the so-called "holy plane". This step is fundamental to avoid the transection of the hypogastric nerve plexus and sacral venous plexus located deep in the parietal layer within the presacral space. Dissection starts on the posterior aspect of the mesorectal envelope: the right lateral and the anterior plane are then subsequently dissected up to the seminal vesicles in a counterclockwise fashion. The left lateral pelvic fascia is then dissected up to its lower portion to allow for the identification of the pelvic nerve plexus and to gain access to the "bare rectum area" (*Figure 5*). Dissection is then completed anteriorly on the lower portion of the Denonvilliers fascia and circumferentially below the reflection of the mesorectal fascia to gain access

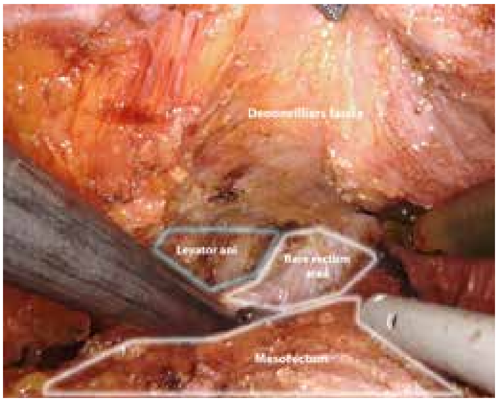

Figure 5 Intraoperative view after completion of total mesorectal excision.

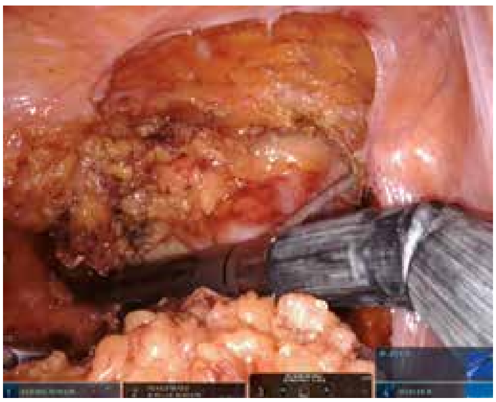

Figure 6 Ultralow rectal transection with endowristed robotic stapler.

to the levator ani plane. During the dissection of the lower mesorectum, it may be helpful to shift to a 0° camera in order to achieve better visualization.

According to tumor distance from the anal verge, rectal transection is performed with 45-mm robotic staplers (*Figure 6*) after evaluation of rectal stump perfusion with the integrated fluorescence imaging system (*Figure 7*).

Short-term postoperative outcomes

To date, few studies with low level of evidence comparing robotic versus laparoscopic rectal resection are available. No multicentre randomized controlled trial has been published yet. Nevertheless, several meta-analysis have been published as the interest in robotic surgery is growing.

Several studies reported longer operative time for the robotic approach compared to laparoscopy (13-15), the available meta-analysis showed no significant differences between the two procedures (16-19). Only one study reported a shorter operative time for robotic rectal resection (20).

Laparoscopic rectal resection is a demanding procedure with still high CRs (21); the CLASICC trial reported a CR of 34% (7), while in the COLOR II trial CR to open surgery decreased to 17% (8). Recently, two randomized trials (3,4) found a CR of 9% and 11.3% respectively. To date, the majority of the studies showed lower CRs to open surgery for robotic rectal approach when compared to laparoscopy (22-24) and, probably, this is the most frequently reported finding in favour of robotic rectal surgery in the literature. Trastulli *et al.* (18) reported a CR of 2% for robotic rectal resections, and Xiong *et al.* (17) in a recent meta-analysis comparing robotic and laparoscopic TME, found a significantly lower CR for the robotic group.

This measure of surgical outcome has also been chosen as primary endpoint of the ROLARR Trial, whose results have been recently presented. In the study design (superiority trial), it was hypothesized that the CR could be reduced by 50% (from 25% to 12.5%) in the robotic group. Though the study failed to meet the criterion for statistical superiority, an a priori defined subgroup analysis showed a possible advantage in the most challenging cases, namely male patients, low anterior resections and obese patients.

Regarding blood loss, some reports demonstrated a lower mean operative blood loss in robotic procedures compared to either open or laparoscopic ones (23,25).

Two studies (26,27) found a significant reduction in length of hospital stay in the robotic group, probably due to the lower overall surgical trauma of the robotic technique and to lower CRs. To date, however, there is no high level of evidence that robotic surgery could reduce length of stay when compared to standard laparoscopy (17,18,28).

Post-operative complications rates are similar and particularly the anastomotic leak rate is not different between the two approaches (17,18,24,28,29). Only one recent meta-analysis by Sun and coworkers (19) demonstrated a lower overall post-operative complications rate for the robotic group compared to the laparoscopic one.

Functional outcomes

Whether or not laparoscopic surgery could have an advantage over open surgery in preserving urogenital function is still controversial, later studies suggest better

Figure 7 Evaluation of bowel perfusion with integrated indocyanine green fluorescence imaging system.

outcomes with laparoscopy, but earlier reports stated the opposite (30). Undoubtedly, in this scenery the robotic system could find its place, combining the advantages of minimally invasive surgery with a more precise dissection.

Kim *et al.* (31), in their series of 69 patients, demonstrated that robotic TME is associated with earlier recovery of normal voiding (3 months versus 6 months) and erectile function (6 months versus 12 months) when compared to its laparoscopic counterpart. Recently, Panteleimonitis *et al.* (32) found that Robotic TME has better postoperative urogenital outcomes in men and urological outcomes in women. For female sexual function there was no difference between the two groups, but the sample was very small (9 laparoscopic, 4 robotic). Another series of 74 patients submitted to robotic TME, showed that robotic surgery allows for preservation of urinary and sexual function, with values at 1-year comparable to those measured before surgery (33). A similar trend for urogenital function has been observed in other studies (34,35).

Oncological outcomes

Studies comparing oncological outcomes of robotic and laparoscopic resections for rectal cancer have small number of cases, and for the most part are nonrandomized controlled trials with a short follow up (17,21).

A specimen with an adequate and complete mesorectum directly correlates with recurrence rates (36), but few studies on minimally invasive TME specify the macroscopic assessment of mesorectal excision according to the criteria initially described by Quirke (37). Baik *et al.* (38) reported statistical significance in the quality of the mesorectum in favor of the robotic group, ascribing this result to the technical advantages of the robotic platform. In a recent review that considered 11 studies assessing the quality of the mesorectum, complete excision ranged from 100% to 60% in the robotic series, and from 100% to 40% in the laparoscopic group (21).

Preliminary results of the ROLARR trial seam to show no statistical difference between laparoscopic and robotic resection in terms of CRM positivity, thus confirming the results of several others series (13,24,26,39,40).

Kang *et al.* (15) in their case matched study reported a significant decrease in CRM involvement in the robotic group compared to the open group in mid to low rectal cancer resections. 165 patients had robotic resection with a CRM positivity rate of 4.2%, while the open group (165 patients) presented with a CRM positivity rate of 10.3%. No significant difference was found between the robotic and the laparoscopic group (CRM+ 6.7%).

Ghezzi *et al.* (41) reported a significant higher number of retrieved lymph nodes in the robotic group, this finding was confirmed also by other authors (13,27,42), but the majority of the studies reports similar numbers of harvested nodes between laparoscopic and robotic rectal resection (17,21).

Survival data from the ROLARR trial are still unavailable and reports of long-term oncologic outcomes for robotic rectal surgery remain limited (*Table 1*). No significant difference has been reported in overall and disease free survival (DSF) or local recurrence rates (LR) (53). Park *et al.* (26) found no differences in the 5-year overall survival (OS), DSF and local recurrence rates. Similar results were reported by Cho et al in a case matched series of 278 patients (40), with a 5-year OS of 92.2% and a DSF of 81.8% in the robotic group. More recently, Kim *et al.* (45) showed that robotic surgery was a significant good prognostic factor for OS and cancer specific survival in multivariate analysis.

Table 1 Oncological mid- and long-term outcomes

Ref	Year	Country	Technique	Pts.	Harvested nodes (mean)	CRM + (%)	Distal margin (mm, mean)	Median FU months	LR %	DSF %	OS %
Lim *et al.* (43)	2017	Republic of Korea	ROB	74	11.6	4	17	56.1	2.7	76.8 (5 y)	90 (5 y)
			LAP	64	14.7	1.6	22		6.3	76 (5 y)	93.3 (5 y)
Tang *et al.* (44)	2017	China	ROB	392	14.6	2.5	35	24*	5.1	74.3 (3 y)	86.4 (3 y)
Kim *et al.* (45)	2017	Republic of Korea	ROB	192	20.2	4	23	40.3	–	72.6 (5 y)	90.5 (5 y)
			LAP	192	21	4.9	24		–	68 (5 y)	78 (5 y)
Law *et al.* (13)	2016	Hong Kong	ROB	220	14***	4.1	30	31.4	–	81.9** (5 y)	71.8 (5 y)
			LAP	171	12***	8.2	30		–	80** (5 y)	74.3 (5 y)
Sammour *et al.* (46)	2016	USA	ROB	276	22***	2.5	–	23.8	2.4# (5 y)	82# (5 y)	87# (5 y)
Feroci *et al.* (27)	2016	Italy	ROB	53	18	0	25	37.4	1.9	79.2 (3 y)	90.2 (3 y)
			LAP	58	11 [3–27]	1.7	15		5.2	83.4 (3 y)	90 (3 y)
Pai *et al.* (47)	2016	USA	ROB	101	15	5	35	33	4	79.2 (3 y)	90.1 (3 y)
Park *et al.* (26)	2015	Republic of Korea	ROB	133	16.34	6.8	27.5	58	2.3	81.9 (5 y)	92.8 (5 y)
			LAP	84	16.63	7.1	28.5		1.2	78.7 (5 y)	93.5 (5 y)
Cho *et al.* (40)	2015	Republic of Korea	ROB	278	15	5	20	51.8*	5.9	81.8 (5 y)	92.2 (5 y)
			LAP	278	16.2	4.7	22		3.9	79.6 (5 y)	93.1 (5 y)
Ghezzi *et al.* (41)	2014	Brazil	ROB	65	20.1	0	27	46.7*	3.2	73.2 (5 y)	85 (5 y)
			OPEN	109	14.1	1.8	22	55.1*	16.1	69.5 (5 y)	76 (5 y)
Yoo *et al.* (48)	2014	Republic of Korea	ROB	43	13.93	9.1 §	13.3	33.9	12.8	76.7 (3 y)	95.2 (3 y)
			LAP	26	21.42	19.2 §	16.7	36.5	8.3	75 (3 y)	88.5 (3 y)
Hara *et al.* (49)	2014	Republic of Korea	ROB	200	17***	2.5	18***	29.8	4.5	81.7 (5 y)	92 (5 y)
Baik *et al.* (50)	2013	Republic of Korea	ROB	370	15.6	5.7	25	24	3.6	79.2 (3 y)	93.1 (3 y)
Baek *et al.* (51)	2010	USA	ROB	64	14.5	0	34	20.2	3.1	73.7 (3 y)	96.2 (3 y)
Bianchi *et al.* (24)	2010	Italy	ROB	25	18	0	20	–	–	–	–
			LAP	25	17	4	20				
Pigazzi *et al.* (52)	2010	Multicentric (USA/Italy)	ROB	143	14.1	0.7	29	17.4	1.5	77.6 (3 y)	97 (3 y)
Patriti *et al.* (20)	2009	Italy	ROB	29	10.3	0	21	29.2*	0	100	96.6
			LAP	37	11.2	0	45	18.7*	5.4	83.7	97.2

ROB, robotic; LAP, laparoscopic; LR, local recurrence; DFS, disease free survival; OS, overall survival. *, mean; **, cancer specific survival; ***, median; #, 83 patients followed up for a minimum of 3 years; §, CRM ≤2 mm.

Learning curve

Rectal cancer surgery with TME is complex and demanding and the number of cases required to achieve the learning curve in laparoscopic rectal resection is estimated to be between 60 and 80 (9,54). The majority of the studies published so far suggest a shorter learning curve for robotic rectal cancer surgery, ranging from 15 to 30 cases (9,55,56). Yamaguchi *et al.* (57) found a learning curve of 25 cases before reaching the plateau. Robotic assistance could probably facilitate the adoption of minimally invasive rectal surgery (58), that still maintains a low penetration worldwide (10-12), by overcoming the technical constraints of standard laparoscopy and by shortening the learning curve.

The robotic technology represents a unique tool for training with the aid of the dual console and of the virtual simulator, but competence assessment is mandatory. Recently, a structured training protocol has been proposed (59), in an attempt to standardize and objectively evaluate the learning process.

The robotic system has the potential of shortening the learning curve for complex procedures not only for experienced surgeons (56), but also for novice surgeons that may learn a procedure approaching it directly with the robot. Foo *et al.* (60) evaluated the learning curve for robotic assisted rectal resection in a surgeon that had previously performed less than 5 open or laparoscopic rectal cancer resections. On a series of 39 consecutive TME they found the learning curve to be 25 cases. At our Institution, we recently introduced a structured training program in robotic colorectal surgery in order to assess its safety and efficacy for young surgeons without prior experience in both open and laparoscopic colorectal surgery. Robotic right colectomy with intracorporeal anastomosis has been chosen as a model and two junior attending surgeons were trained through sequential steps that included: virtual simulator, dry lab, wet lab hands-on courses, at least 20 procedures as table assistant and proctored clinical practice with the dual console. They were then privileged to perform right colectomy without mentoring. Preliminary results showed neither conversions nor intra- or postoperative complication. Mean operative time was 200 minutes and mean length of hospital stay was 6 days. The program will then involve novice surgeons in left-sided resections and, finally, in most complex procedures such as TME in a stepwise approach.

Costs

One of the biggest reasons for skepticism about robotic surgery is often related to high costs.

When focusing on robotic rectal cancer surgery, Kim *et al.* (61) and Park *et al.* (26) failed to prove the cost-effectiveness of robotic versus laparoscopic rectal resection based on short-term and long-term oncological outcomes, respectively. Baek *et al.* (62) in their case-matched study reported higher total hospitalization costs for the robotic group compared to the laparoscopic one, but without reaching a statistical significance. Besides, Byrn *et al.* (63) found that direct costs of robotic rectal resection decreased with time, showing that later procedures were actually less expensive. A recent Italian study (64) reported a similar finding: although overall mean costs of laparoscopic TME were significantly lower than those of robotic TME, costs gradually decreased in the robotic group as the surgeon advanced in his learning curve, thus suggesting a significant optimization of instruments and OR time use with experience.

Recently, Daskalaki *et al.* (65) reported that robotic and open liver resections were financially comparable. Though direct costs (purchase, maintainance and use of the system) were higher in the robotic group, they were balanced by shorter length of stay and better postoperative outcomes (lower rates of major complications and shorter ICU stay).

Conclusions

Robotic surgery is often considered to be associated with longer operative times because of the docking and system setup. However, these steps can be quickly performed with practice and are not among the main reasons for this finding. Robotic surgery represents a new concept of surgery, where precise dissection and careful visualization of even the smallest anatomical structure play a crucial role. This aspect could probably explain a trend towards better functional outcomes of robotic surgery versus the laparoscopic approach that should be further investigated.

The technological advantages provided by the robotic system translates into a shorter learning curve and lower CRs when compared to standard laparoscopy, and these aspects could probably facilitate the widespread adoption of minimally-invasive TME that still has a low penetration worldwide. Moreover, the educational capabilities of the platform, together with structured training programs, could allow novice surgeons to safely approach colorectal surgery directly with the robot, defining the "robotic surgeon" as a new paradigm.

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Footnote

Conflicts of Interest: Dr. Paolo Pietro Bianchi is proctor for Intuitive Surgical. The other authors have no conflicts of interest to disclose.

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A review on robotic surgery in rectal cancer

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Abstract: Robotic surgery has the upper hand when compared to the laparoscopic approach in terms of superior visualisation, flexibility in movement, steadiness and accessibility to confined anatomical spaces. Nevertheless, limitations still exist with regards to cost, reduced tactile sensation, time-consuming setup and a significant learning curve to achieve. Although studies have shown better or at least comparable outcomes between the robotic and laparoscopic approach, the limitations mentioned result in poor penetrance among centres and surgeons. Advancements in robotic surgery technology and attaining the acquired skillset will translate into better clinical outcomes for patients.

Keywords: Robotic surgery; robotic-assisted surgery; rectal dissection; total mesorectal excision (TME); minimally invasive surgery (MIS)

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Introduction

Robotic surgery in the field of colorectal has been around since 2001. The first published experience was reported in 2002, where two colonic resections were performed on benign cases. With the rapid advancement in the field of medical science, there is definite potential for robotic surgery to overcome some of the limitations of conventional laparoscopic surgery.

Rectal dissection has always been a challenge due to its confined location and various dimensions of the rectum and mesorectum. Since it was described in 1982, total mesorectal excision (TME) has been the gold standard of rectal cancer surgery (1). In order to obtain good quality TME, a precise sharp dissection must be performed along the avascular plane while encompassing the entire mesorectum, which bears potential malignant lymph nodes (2).

Worldwide, laparoscopic surgery has been acknowledged as a safe and effective modality of rectal cancer surgery (3). However, a randomised controlled multicentre trial has recently suggested that the use of laparoscopic surgery in T3/T4 tumours may result in incomplete resection, affecting the oncological outcome in this group of patients (3).

The challenges of an incomplete TME in laparoscopic surgery are often encountered when faced with anatomical difficulties i.e., a narrowed male pelvis; bulky tumours and obese patients. Robotic rectal surgery, with superior visualisation and agility of its EndoWrist® (Intuitive Surgical Inc., Sunnyvale, CA, USA), might be the answer to this predicament.

This review will shed light on the potential benefits, clinical outcomes and pitfalls of robotic rectal surgery.

Surgical techniques

The da Vinci® robotic system (Intuitive Surgical Inc., Sunnyvale, CA, USA) is widely used in robotic rectal surgery. Robotic rectal surgery can generally be performed in two ways—the hybrid technique or the totally robotic technique (4).

The hybrid technique comprises of standard laparoscopic isolation and ligation of the inferior mesenteric vessels, mobilisation of the left colon and splenic flexure take down. The robotic system is then brought in to complete the pelvic dissection for TME. Distal rectal dissection can be performed laparoscopically or via robotics.

The totally robotic technique is typically a two-stage or three-stage procedure depending on the number of times the robotic cart is repositioned. A desirable single-stage totally robotic technique in which the robotic cart remains stationary throughout the surgery, has been described (5). Only the robotic arms were repositioned from the colonic phase to the pelvic and TME phase.

Potential benefits

Superior visualization

Minimally invasive surgery (MIS) would not have been successful if not for the technology that permits indirect viewing of the operating field either on a monitor or console. The quality and steadiness of the images produced are paramount to excellent surgical dissection.

Laparoscopic surgery gives a conventional 2-dimensional (2D) view, whilst robotic surgery produces a 3-dimensional (3D) image. This confers the added advantage to the surgeon by allowing better judgement in terms of depth and spatial relationships (6). The relative anatomy between important structures will be more apparent, thus allowing meticulous dissection.

With the advent of 3D vision systems in conventional laparoscopic surgery, some parties question the necessity for a robotic system. Furthermore, the usage of conventional laparoscopy with 3D images was comparable to robotic surgery in terms of short-term operative outcomes (7). We believe, however, that a mounted 3D camera system eliminates unavoidable assistant drawbacks such as fatigue or inexperience, thus producing impeccable steady images throughout surgery.

Enhanced motion

A limited range of movement as a result of the rigid design of conventional laparoscopic instruments beckons for the need of a more versatile appliance. The answer to this was the development of the EndoWrist®, an intuitive robotic instrument which mimics the human wrist. The motion is totally regulated by the surgeon's hand and finger movement (8). The system provides improved dexterity, seven degrees of freedom and motion scaling, while eliminating physiological tremor (9). This avoids iatrogenic injuries and improves peri-operative outcomes (10).

Ergonomics

Laparoscopic surgery has been related to an increased musculoskeletal discomfort for the surgeon, with studies reporting a rate of 73–87% (11). Ergonomic stress was believed to be a compounding factor. In laparoscopic surgery, the substantial use of muscles of the upper torso is associated with more fatigue (11). In robotic surgery, the surgeon is seated within the console, with an armrest in place. This ergonomic design reduces musculoskeletal discomfort.

Achievable learning curve

In general a learning curve can be ascertained from two methods; observation of a consecutive case series and cumulative sum (CUSUM) analysis.

In the first method, a consecutive case series is split into smaller segments i.e., quartiles. A univariate analysis will be performed to compare the means of these quartiles. Most publications look into decreased operative times, complications and estimated blood loss as indicators of improvement (12-14).

In the CUSUM analysis, the learning curve is divided into three phases (15,16). Bokhari *et al.* (16) and Yamaguchi *et al.* (17) described the initial phase (phase I) as a phase comprising of 15 and 25 cases respectively. As the surgeon becomes more experienced, they reach a plateau in the learning curve (phase II). Subsequent cases will be represented in phase III of the curve.

Interestingly, a study has reported that novice rectal surgeons—with limited experience of less than five cases in open/laparoscopic low rectal cancer resection—were able to achieve a similar learning curve in robotic-assisted low rectal resection (18). This faster learning curve may be compensated by their experience in other forms of minimally invasive colonic resection.

It should be reiterated that robotic surgery is technically demanding. We therefore propose a formal form of training in rectal dissection before undertaking robotic rectal surgery. This is best achieved through the proctorship of cases within a robotic rectal cancer surgery setting.

Clinical outcomes

The use of robotics for the treatment of rectal cancer has recently shown to be feasible, and numerous studies have looked into the short- and long-term clinical outcomes of robotic rectal surgery. The short-term outcomes that have been studied include the conversion rate, estimated blood loss, length of hospital stay, functional outcomes and post-operative complications. In the long-term, the oncological outcomes in robotic rectal surgery are discussed.

Conversion rate

Conversion to open surgery is an important predictor of the feasibility of minimally invasive approaches (19). Most studies report rates of conversion of 10–20% in laparoscopic low anterior resection (19). In robotic rectal surgery however, data with regards to conversion rate remains inconsistent.

A recent nationwide analysis showed a significant reduction of conversion for robotic versus laparoscopic rectal resections (5.38% *vs*. 13.38%). Similar findings were presented in other studies, where robotic surgery was shown to have lower or even a zero conversion rate (20-22). Despite this, other studies found no difference in conversion rates between robotic and laparoscopic surgery (23-26).

The on-going ROLARR (Robotic versus Laparoscopic Resection for Rectal Cancer) trial, that has now completed the phase of patient recruitment, aims to compare multiple outcomes between robotic and laparoscopic surgery. Conversion rate to open surgery is the primary endpoint of this study. Early reports have criticised the study design of this trial with regards to this primary endpoint, as a high assumption of 25% was hypothesised in the laparoscopic group. Due to this postulation, this study has failed to detect a clinically relevant difference in terms of conversion rate between robotic and laparoscopic surgery (robotic 8.1% *vs*. laparoscopic 12.2%; odds ratio 0.61, 95% CI: 0.31–1.21, P=0.158) (27).

Causes of conversion are multifactorial, but can be simply classified into patient factors and tumour characteristics. The most common cause for conversion was the inability to perform pelvic dissection satisfactorily; attributed to obesity or a narrow pelvis (28). Other reasons for conversion included presence of adhesions, excessive bleeding and bowel dilatation.

Estimated blood loss

A systemic review of 21 studies showed the amount of blood loss was only ranging from 16 to 400 mL for colorectal robotic surgery (29). A recent case-controlled analysis comparing TME between robotic and laparoscopic methods did not show any significant difference in the amount of blood loss (30). A separate meta-analysis review reaffirmed these findings (31).

Length of stay (LOS)

The LOS for robotic surgery was either similar (7) or shorter compared to laparoscopic surgery. The mean LOS differed between studies, with some reporting a mean LOS of approximately 5–7 days, while others quoting a post-operative LOS of 9–12 days (22,32,33). These findings are not unexpected, as both modalities are minimally invasive.

Postoperative complications

With regards to postoperative complications, again, many studies have shown similar or lower rates compared with laparoscopic surgery. Among the complications reported were anastomotic leakage, surgical site infection and ileus. Anastomotic leakage is a common postoperative complication after MIS, at a rate of 5–11% (5,8,34-36). In a meta-analysis review, Trastulli *et al*. (26) showed a lower leak rate with robotic resection.

The advantages of robotic surgery that were discussed earlier, including superior visualisation systems and enhanced motion allow for more precise dissection, thus resulting in favourable postoperative outcomes.

Preservation of function

When performing rectal cancer surgery, preservation of sexual function and urinary continence are essential, particularly as indicators of postoperative quality of life. The main cause of genitourinary dysfunction is injury to the hypogastric and/or sacral splanchnic nerves during surgery. These essential nerves are preserved when there is good visualisation and precise dissection that to our knowledge can best be achieved by robotic TME.

Most studies use the International Index of Erectile Function (IIEF) and International Prostate Symptoms Score (IPSS) to determine sexual and urinary function respectively. An IIEF score of less than 10 is defined as having sexual dysfunction whereas an IPSS score of more than 8 as urinary dysfunction.

In a recent prospective study, it was concluded that there was no difference in sexual dysfunction in open *vs*. robotic TME (37). In terms of urinary function, it was noted that patients who underwent open surgery suffered from urinary dysfunction in the first 3 months following surgery, but were able to regain their baseline function within a 3 to 12 months follow-up period (37). Another paper that discussed genitourinary outcomes in laparoscopic *vs*. robotic TME found that robotic TME for rectal cancer was associated with earlier recovery of normal voiding and sexual function compared to patients who underwent laparoscopic TME (38).

Survival rate

With regards to short-term oncologic outcomes, Baek *et al*. (39) reported that the 3-year overall survival (OS) rate after robotic surgery was 96.2% with a 3-year disease free survival (DFS) rate of 73.7%. This was found over a mean 20.2-month follow-up period. Pigazzi *et al*. (28) reported similar figures in his multicentric study, with a 3-year OS of 97% and a 3-year DFS of 77.6%. The mean follow-up rate in this study was 17.4 months. Both studies did not report any isolated loco-regional recurrence, but there were patients who developed distant metastasis, with or without local recurrence.

Long term OS rate was comparable between laparoscopic and robotic rectal surgery. At least two publications (25,33), have reported similar 5-year OS rates; 93.1% and 93.5% respectively in the laparoscopic arm, and 92.2% and 92.8% respectively in the robotic arm. A 5-year DFS rate was higher in the robotic group for both studies, at about 81%; 78% in the laparoscopic group. These values, however, did not translate into any significant difference between the OS and DFS rates between the two arms. Park *et al*. (33) showed a cumulative local recurrence of only 2.3% in the robotic group with no involvement of port and wound site.

It was initially hypothesised that robotic surgery, with its precise TME would improve survival rate. However, as evidenced by various studies looking into the short- and long-term OS and DFS rates, it appears that robotic surgery does not produce superior results compared to conventional laparoscopic technique.

Pitfalls

Technical limitations

Tissue handling is an important aspect in surgery. In laparoscopic surgery, there is presence of tactile feedback. In robotic surgery however, the surgeon has to rely more on visual cues to know how much force to exert in handling delicate tissue. As the tactile feedback is not apparent, sensation of pressure, vibration and sheer force are being masked. This leads to tissue injuries in inexperienced hands. In addition, robotic arm collisions can occur as a result of unplanned placement of working ports and the inability of the surgeon to visualise the movements of robotic arms during surgery.

Cost

Cost is a major issue and becomes a hindrance for new technology to flourish. In robotic surgery the cost comprises the robotic appliance, annual maintenance and changing of ancillary equipment.

The robotic systems typically costs anywhere between $1–$2.3 million. As a result of the steep price of equipment, patients who opt for MIS have to pay more when robotic surgery is performed. The charges range from $7,150 to $10,700 for robotic surgery, a 7- to 10-fold increase compared to laparoscopic surgery ($1,240) (40). Inevitably, total hospital charges were noted to be 1.5 times higher in the robotic group ($14,647 *vs*. $9,978). Furthermore, authors also reported a significantly lowered hospital profit (40).

Whether the high cost associated with robotic surgery translates into better clinical outcomes is yet to be proven in a cost-effectiveness study. To date, there are limited publications on this issue. A recent study by Kim *et al*. concluded that there was no evidence of cost-effectiveness of robotic surgery compared with laparoscopic surgery in 30 days. However, the functional i.e., sexual and bladder functions, and long-term outcomes were not analysed to give a more comprehensive understanding on the economical worth of robotic surgery (41).

With the increased awareness of the advantages that robotic colorectal surgery has to offer, coupled with competitive industry players, we are optimistic that there will be reductions in cost in the new future, making this modality more appealing for the masses.

What the future holds

Advancement in robotic systems will be apparent in years to come. Currently the fourth generation da Vinci® surgical system, the Xi® has revolutionised robotic surgery with its multiple enhancements and upgrades. Simpler docking, laser guided port placement and mounted robotic arms on a rotated-boom are among the key features in this new system. This is claimed to ease a single-stage fully robotic rectal dissection i.e., splenic flexure and pelvic dissection.

In the reported early experience performing rectal dissection with the da Vinci Xi®, there were no apparent intraoperative and postoperative complications. In addition, no conversion to open surgery has been reported (42).

Already, there are several novel technologies that have been incorporated to complement the existing robotic system. One such example is the da Vinci EndoWrist® Stapler 45 with its SmartClamp® feedback. This application allows for full range of motion while providing adequate tissue compression based on tissue thickness during stapling. Whether this advancement translates into better clinical outcomes, particularly in terms of anastomotic leak, is yet to be studied (43).

Another fascinating addition is the FireFly® Fluorescence Imaging application. The integration of this equipment, which utilises near-infrared technology, provides real-time, image-guided identification of key anatomical landmarks. This assists in better oncological resection, i.e., identification and preservation of anatomical structures, lymph node dissection, differentiating malignancy from normal tissue, and assessing organ and tissue perfusion (44,45).

Numerous research and technology groups are working towards transforming the robotic system that we use today. Concurrent with the growth in the fields of artificial intelligence, nanotechnology and communication systems, it is promising that our current robotic surgical systems will undergo revolutionary changes over the next few decades (46-48).

Conclusions

Patient safety is central to modern surgical treatment. With MIS making headway, it is promising that robotic surgery will provide the next major breakthrough in the treatment of rectal cancer. As of today, robotic systems have already revolutionised the surgical field, proving its advantage over laparoscopic techniques in terms of superior visualisation, enhanced motion, ergonomics and comparable clinical outcomes.

Before robotic rectal surgery is widely adopted however, the long-term prospects need to be better established. At present, the Robotic versus Laparoscopic Resection for Rectal cancer (ROLARR) trial is underway. Believed to be a robust study comprising of about 20 centres and involving eight countries, this study that is estimated to be completed by mid-2018 will address not just the short- and long-term clinical outcomes, but also the economical feasibility of robotic rectal surgery. It will be interesting to see if this trial changes the standard of care for rectal cancer surgery in the future. As an old saying goes—little do we know what the future holds.

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Footnote

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Single stage robotic total mesorectal excision—a stepwise approach

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Contributions: (I) Conception and design: SH Kim; (II) Administrative support: None; (III) Provision of study materials or patients: E Priatno; (IV) Collection and assembly of data: E Priatno; (V) Data analysis and interpretation: All authors; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

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Background: The totally robotic procedure was traditionally described as a two-stage technique or a three-stage technique. The number of stages corresponds to the number of movements of the robotic cart. In this video article, we develop a stepwise approach video of robotic total mesorectal excision (TME) for mid rectal cancer (the surgery was performed by SHK) using a da Vinci® Si HD Surgical System (Intuitive Surgical, Sunnyvale, CA, USA) at Korea University Anam Hospital, Seoul.

Methods: After the induction of general anesthesia, the patient is placed in a modified lithotomy position. Six ports are used, including one 12-mm camera port, four 8-mm robotic working ports, and one 5-mm port for the assistant. The patient is tilted to the right side and placed in the Trendelenburg position. The small-bowel loops retracted out from the pelvic cavity to the right upper quadrant (RUQ) to expose the inferior mesenteric artery (IMA). The surgery is divided into three phases: (I) abdominal phase: vascular ligation, and sigmoid colon to splenic flexure mobilization; (II) pelvic dissection phase; and (III) rectal reconstruction phase. Mesorectal clearing was done at the level of rectal transection line (1–2 cm from distal tumor margin), then the rectum was transected with robotic stapler. Once this step is finished, the robotic arms are undocked and the cart is moved away from the patient. The remaining steps are performed in a conventional laparoscopic method.

Results: Robotic TME was performed in a 56-year-old man with an endoscopically define rectal mass. The lesion was moderately differentiated adenocarcinoma, 8 cm from the anal verge (AV). The rectal mass was managed with single stage robotic TME. The operative time was 160 minutes and the patient was discharge on post operative day 10. Final pathology revealed moderately differentiated adenocarcinoma.

Conclusions: Single stage robotic TME was efficient and feasible technique for mid rectal cancer resection.

Keywords: Robotics; total mesorectal excision (TME); robotic TME

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Introduction

Development of laparoscopic surgery over the past two decades has given a new paradigm in management of colorectal cancers. Various randomized controlled trials have demonstrated its short-term and long-term benefits over conventional open surgery in the treatment of colon cancer such as faster recovery, decreased morbidity and reduced hospital length of stay with comparable oncological result and survival outcome (1,2). However, laparoscopic surgery has some limitations such as 2-dimension view, unstable assistant controlled camera, poor ergonomics, straight tip instruments, fulcrum effect and enhanced tremor effect.

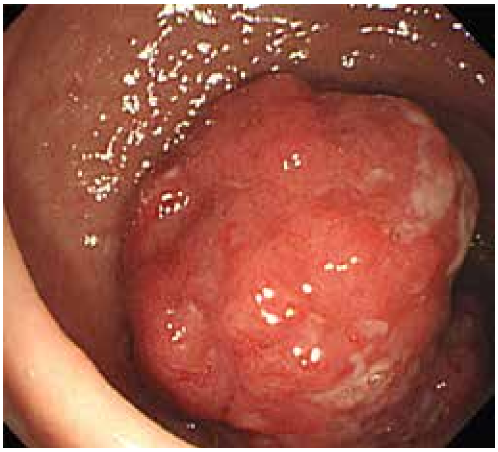

Figure 1 Colonoscopy finding shows mid rectal mass.

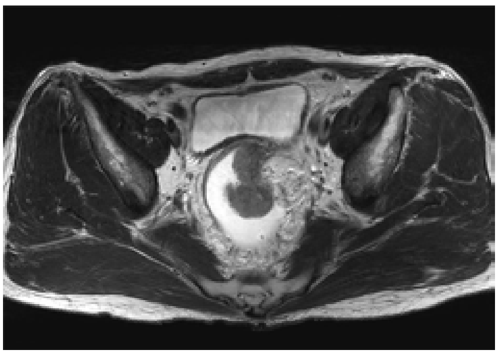

Figure 2 Coronal view pelvic MRI shows mid rectal tumor with several lymph node, no CRM involvement. MRI, magnetic resonance imaging; CRM, circumferential resection margin.

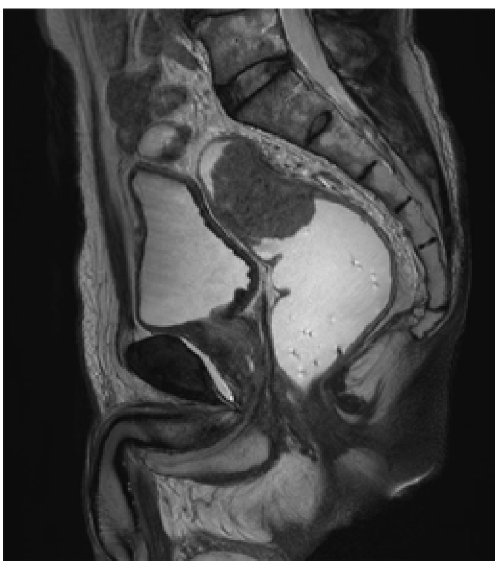

Figure 3 Sagittal view pelvic MRI shows mid-rectal tumor, no peritoneal reflection involvement. MRI, magnetic resonance imaging.

To overcome these limitations, robotic surgery is a new technique with the benefits of a three-dimensional view, the ability to use multi-degree-of-freedom forceps, the elimination of physiological tremors, and a stable camera view. Performing surgery in a narrow pelvic cavity with conventional laparoscopy is a challenging procedure, especially in patients undergoing rectal cancer surgery. Robotic surgery is a new modality to overcome these difficulties (3-6). Several studies have demonstrated the safety and feasibility, as well as acceptable short-term outcomes, of robotic colorectal surgery (7-10).

This video article will describe a stepwise approach of single stage robotic total mesorectal excision (TME).

Clinical summary

A 56-year-old man presented with a bowel habit change. Digital rectal examination (DRE) shows rectal mass located 8 cm from anal verge (AV). Colonoscopy revealed a malignant looking mid rectal mass, no others synchronous lesion was found (*Figure 1*). The biopsy shows moderately differentiated adenocarcinoma. Clinical staging with magnetic resonance imaging (MRI) show mid-rectal tumor with clear circumferential margin with several lymph nodes (*Figures 2,3*). Chest and abdominal computed tomography (CT) show no distance metastasis. Patient was staged as cT3N2M0.

Patient selection and workup

Robotic TME was selected for unfavorable tumor characteristic patients such as mid and low rectal cancer, male and obese patients. Colonoscopy was routinely performed to confirm histological diagnosis on biopsy and to role out other synchronous lesions. The distance between the tumor and AV was assessed via DRE and/or rigid sigmoidoscopy. Patients were staged according to the American Joint Committee on Cancer staging manual (7^{th} edition). Clinical staging was performed via pelvic MRI, and a whole abdominal and chest CT.

Pre-operative preparation

Preoperative preparation begins with a full history and physical examination. Blood tests should be including a full blood count, electrolytes, liver function tests, carcinoembryonic antigen (CEA) level. An electrocardiogram is requested, where appropriate, cardiopulmonary exercise

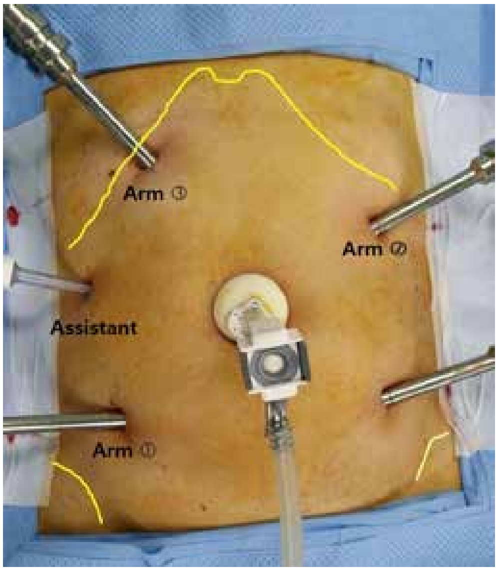

Figure 4 Robot ports placement.

Figure 5 Robotic TME: a stepwise approach (11). TME, total mesorectal excision.
Available online: http://www.asvide.com/articles/734

testing is done to stratify operative risk and optimize perioperative management. In our institution, a mechanical bowel preparation is not routinely given, otherwise, patient has only one time rectal enema a day before surgery. Fasting is maintained for at least 6 hours before surgery. Prophylaxis antibiotic was given 30 minutes before surgery.

Operating room setup, patient positioning, and ports placement

After the induction of general anesthesia, patient is placed in a modified lithotomy position with the legs apart on a bean's bag mattress to prevent any sliding. Six ports are used (*Figure 4*), including one 12-mm camera port, four 8-mm robotic working ports, and one 5-mm port for assistant. A 12-mm trocar is placed through a peri-umbilical incision for the robotic camera. The intraabdominal pressure is maintained at 8–10 mmHg. The first daVinci® 8-mm port on right lower quadrant (RLQ) is placed at the Mc Burney point. The second port on right upper quadrant (RUQ) is inserted in the right subcostal area on the midclavicular line (MCL). The third port is placed in the left upper quadrant (LUQ) approximately 1–2 cm above the camera port at the crossing of MCL. The fourth port is inserted in the left lower quadrant (LLQ) approximately 1–2 cm lateral to the MCL. These four ports are used for the robotic arms and are separated from each other by at least 8 cm. To allow the assistant access, a 5-mm trocar is placed in the right flank area, near the anterior axillary line, at the umbilical level. This is used for suction/irrigation, clipping of vessel, and retracting of tissues. During pelvic dissection stage, the assistant uses the RUQ port as well, therefore maximizing assistance by use of both hands.

Procedure

Our technique is called a single-stage procedure because the surgery is performed without changing the position of the robotic cart. The surgical procedure (*Figure 5*) was divided into three phases (12-14).

Abdominal phase: vascular ligation, and sigmoid colon to splenic flexure mobilization

The patient is tilt to the right side and placed in the Trendelenburg position. The small bowel loops retracted away from the pelvic cavity to the RUQ to expose the inferior mesenteric artery (IMA). Before docking of the robot, the whole abdominal cavity is explored by conventional laparoscopic instruments. The robot cart is positioned obliquely at the LLQ along the imaginary line from the camera port to the anterior superior iliac spine (*Figure 6*). Then, the robotic arms are docked to the trocars. A zero degree robotic camera is used. A monopolar curved scissors is used by the RLQ arm as the surgeon's right hand. A Maryland bipolar grasper forceps is taken by the RUQ arm as the surgeon's left hand, and a Cardiere grasper are used by the LUQ arm as the surgeon's second left hand. In this phase, the LLQ port is not used (*Figure 7*). Initially, the mesocolon over the IMA is retracted upwardly with a

Figure 6 The angle for docking of robot. The robot cart is docked obliquely along the imaginary line from the camera port to the anterior superior iliac spine.

Figure 7 Docking of robot in abdominal phase. The LLQ port is not used. LLQ, left lower quadrant.

Figure 8 Docking of robot in Pelvic dissection phase. The assistant uses the RUQ port for cephalad traction of sigmoid colon and 5 mm port for suction. RUQ, right upper quadrant.

Cardiere forceps. The peritoneum around the base of IMA is incised and dissected with a monopolar scissors. The periaortic hypogastric nerve plexus is carefully preserved. The IMA is divided near the root (high ligation) with Hem-o-lok® clip. The inferior mesenteric vein (IMV) is identified by dissecting superiorly toward the ligament of Treitz, and is divided near the inferior border of pancreas. The medial dissection continues laterally until the left colon is separated from the retroperitoneum, and superiorly over the pancreas until the lesser sack is entered. The left gonadal vessels and ureter are identified and preserved. Lateral detachment is initiated along the white line while the sigmoid colon retracted medially by the assistant. The lateral counter traction by the LUQ arm will facilitate a safe dissection. Lateral dissection contininues cephalad from the proximal part of the decending colon to splenic flexure.

Pelvic dissection phase

The robotic instrument of the RUQ and LUQ ports are dedocked to the LUQ and LLQ ports, respectively (LUQ for Maryland forceps and LLQ for Cardiere forceps). Now assistant uses the RUQ port for cephalad traction of sigmoid colon and 5 mm port for suction. Therefore, five instruments are used (*Figure 8*) in the operative field (three robotic and two handheld), maximizing assistance for TME. An avascular plane between the mesorectal fascia and the presacral fascia is shaply dissected with a monopolar scissors. The inferior hypogastric nerves and distally, the pelvic nerve plexus are identified and preserved. Because the small bowel would obscure the right lateral plane, further posterior dissection down to the levator ani muscle is approached from the left lateral plane, while the rectum lifted up by the Cardiere graspers. The left lateral dissection was performed while the rectum was drawing to the right side by assistant. The right lateral dissection is completed in a reverse fashion of rectal retraction. Finally, the anterior dissection was performed by incising the peritoneal reflection. Shap dissection continues to develop the correct plane between the rectum and the seminal vesicle-prostate/vaginal. Pelvic dissection was performed to the level of pelvic floor muscles.

Rectal reconstruction with or without ileostomy

The rectum and sigmoid colon are delivered via RLQ port site for further ileostomy site. Sometimes if the tumor is too big or the mesentery is too bulky, the specimen is delivered via a mini-laparotomy incision on the LLQ port. After transection of the specimen, reconstruction of bowel continuity was performed using end to end anastomosis with CDH 29. After anastomosis was done, air leak test was performed. Finally a closed suction drain was inserted in pelvic cavity.

Post-operative management

(I) Begin clear fluid intake as soon as possible;
(II) Start soft diet on post-operative day 3;
(III) Remove Foley catheter on post-operative day 4;
(IV) Drainage catheter removal on post-operative day 5;
(V) Discharge on post-operative day 10.

Tips, tricks and pitfalls

(I) To prevent hypogastric nerves injury, IMA should be clipped at 1 cm distal to the IMA-aorta junction;
(II) The high ligation of IMA and IMV, complete splenic flexure mobilization, and medial peritoneal detachment from pancreas are the keys to provide adequate colon length for tension free anastomosis;
(III) Complete pancreas separation from mesocolon is an important step to prevent pancreatic tail injury during splenic flexure mobilization;
(IV) During medial to lateral dissection of the sigmoid colon, preservation of left ureter and gonadal vessel must be the first priority;
(V) Injury of marginal artery may occur during detachment gastrocolic ligament from transverse colon;
(VI) Use a nylon tape for cephalad traction of upper rectum to facilitate good exposure and to get a proper TME plane;
(VII) Distal resection margin 2–3 cm from tumor is the goal;
(VIII) Before apply stapler for rectal transection, clearing the mesorectal fat at the level of transection line should be done;

Conclusions

Single stage robotic TME is feasible with acceptable outcome.

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None.

Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

Ethical Statement: The study was approved by the ethnical committee. Written informed consent was obtained from the patient. A copy of the written consent is available for review by the Editor-in-Chief of this journal.

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Robot-assisted approach to a retrorectal lesion in an obese female

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Background: Often detected incidentally, retrorectal tumors frequently require resection secondary to possibility of malignancy, development of infection, and localized growth with compression. The surgical approach is summarized to abdominal, posterior or a combination, depending on the location of the retrorectal mass and its relationship to the pelvic sidewall. Laparoscopic transabdominal resection of retrorectal tumors has shown safety and efficacy. Robot technology offers a stable platform with superb optics, and endo-wristed instruments that can facilitate dissection in the narrow pelvis. We present the emerging new technique of robot-assisted minimally invasive approach to a retrorectal mass in an obese female.

Methods: An obese 35-year-old female, body mass index (BMI) 41 kg/m^2, with an incidental 2 cm cystic retrorectal lesion involving the pelvic sidewall was taken to the operating room for a robot-assisted minimally invasive resection of the mass.

Results: Total operative time was 2 hours and 30 minutes, and total robotic dissection at 70 minutes. The patient was discharged on postoperative day 2. Final pathology revealed a benign Mullerian type cyst, 2.2 cm in greatest dimension.

Conclusions: Robot-assisted minimally invasive resection of a retrorectal mass is safe and feasible. This method can be particularly useful in the narrow pelvis and with obese patients.

Keywords: Robotics; presacral; retrorectal tumors; minimally invasive

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Introduction

Presacral or retrorectal tumors are rare, corresponding to an incidence of 1 in 40,000 admissions in major metropolitan medical centers per year (1). Often times found incidentally, retrorectal masses, such as cystic lesions, can be asymptomatic in up to 50% of cases (2). Categorized broadly into congenital, neurogenic, inflammatory, osseous and miscellaneous, 45–50% are malignant or contain malignant degeneration (*Figure 1*). Once diagnosed, surgery is often required for the treatment of a retrorectal lesion secondary to the possibility of a false negative benign lesion, malignant degeneration, and risk of symptom or disease progression (3). Resection of presacral tumors can be done via an abdominal, posterior, or combined approach depending on the size, location of the tumor relative to S3, and relationship to the pelvic sidewall. Generally, an anterior abdominal approach for resection is undertaken for tumors above the mid level of S3 or with involvement of the pelvic sidewall; and a posterior approach for resection of tumors below the mid-level of S3 (1). The laparoscopic approach to retrorectal tumors has shown safety, efficacy, shorter length of hospital stay, and no increase in intraoperative complications (4-6). However, laparoscopy in the pelvis has lower threshold

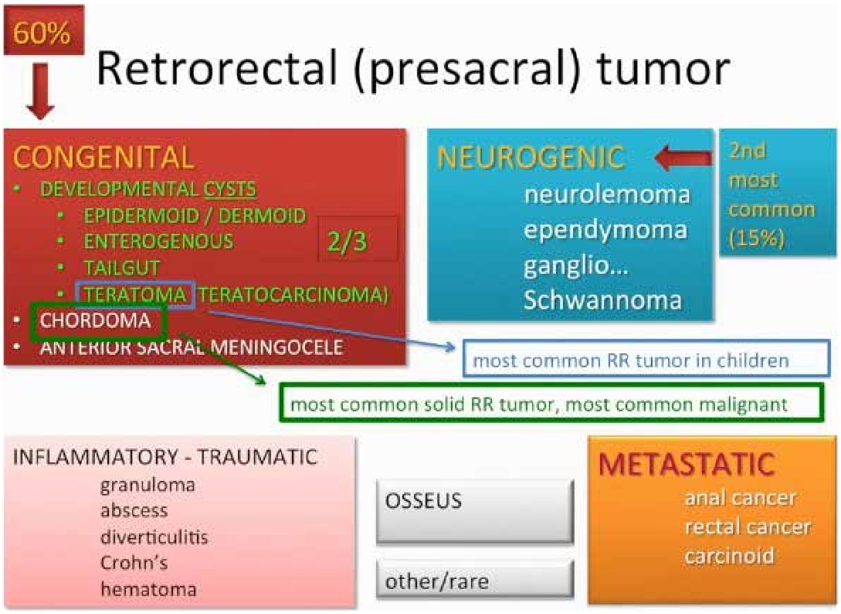

Figure 1 Representative chart on the type and incidence of retrorectal or presacral lesions.

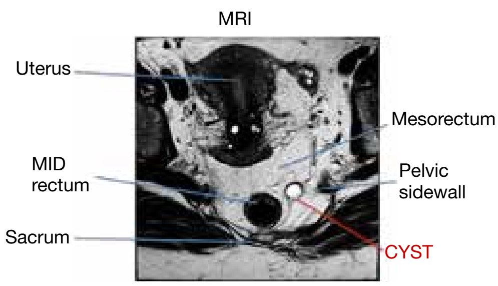

Figure 2 Pre-operative MRI showing 2 cm cystic lesion originating from the left pelvic sidewall at mid-rectal level below the piriformis muscle, indenting the mesorectal fascia posteriorly and to the left.

for conversion to open procedures compared to robotic approach as seen in the total mesorectal excision (TME) literature (7-9). Risk factors for conversion to an open procedure with laparoscopic approach to retrorectal tumors include large tumor size, obesity and high American Society of Anesthesiologist Physical Status (ASA) (1,10). Limited ergonomics of laparoscopic equipment, augmented by a narrow pelvis and obesity could exacerbate technical difficulty and lead to conversion. The stability of the robotic platform, enhanced optics, and improved dexterity with wristed instrumentation has led to the application of the robot to retrorectal mass excision. A recent case series of five patients indicated that a robotic approach to presacral tumors has decreased intraoperative blood loss and length of hospitalization as compared to an open approach (11). In that series patients' body mass index (BMI) was not known. We present an emerging technique of a minimally invasive robotic approach to a retrorectal cystic lesion in an obese 35-year-old female.

Methods

Patient selection and workup

A 35-year-old obese female (BMI 41 kg/m^2) was found to have a retrorectal mass identified incidentally on CT of the abdomen/pelvis for abdominal pain. The etiology of the abdominal pain was calculous cholecystitis which was subsequently treated with a laparoscopic cholecystectomy. The mass was barely palpable on digital rectal examination. An MRI revealed a 2-cm cystic lesion originating from the left pelvic sidewall at mid-rectal level below the piriformis muscle, indenting the mesorectal fascia posteriorly and to the left (*Figure 2*). At an outside institution, after a normal colonoscopy, she underwent a CT guided biopsy of the mass. Pathology revealed fragments of a cyst wall with atypical glandular cells. Immuno-histo-chemistry was non-diagnostic; cytomorphology was suggestive of a metastatic well differentiated neuroendocrine tumor or a malignant degeneration of a tail-gut cyst. PET scan was negative.

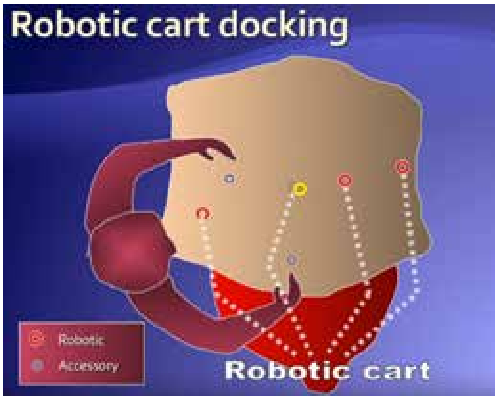

Figure 3 Robotic cart docking position with laparoscopic and robotic port placement positions.

Figure 4 The robot assisted technique for the resection of the retrorectal or presacral lesion (12).
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Secondary to possible malignant degeneration and its involvement with the pelvic sidewall, the patient was offered a resection of the mass via a minimally invasive trans-abdominal approach. A robotic platform was ideally suited for mobilization of the lateral posterior mesorectum and excision of the presacral cyst.

Preoperative preparation

Preoperative preparation included a complete blood count, electrolytes, renal, and liver function tests. Mechanical bowel preparation was administered one day before the operation and the patient was fasting at least 6 hours pre-operatively. Antibiotic prophylaxis was administered within 30 minutes of incision. Appropriate consent has been obtained from the patient per our institutional protocol.

Equipment preference card

- DaVinci Surgical System (Intuitive Surgical Inc., Sunnyvale, CA);
- Laparoscopic setup;
- Exploratory laparotomy tray (on standby);
- 8 mm robotic trocars ×3;
- Cadiere forceps (bipolar attachment);
- Monopolar electrocautery hook;
- Atraumatic bowel grasper;
- 0° 12 mm laparoscopic camera;
- 12 mm trocar.

Procedure

After induction of anesthesia, an oro-gastric tube and Foley catheter were placed. Digital rectal examination revealed a left lateral rectal wall mass approximately 3 cm in size located 7 cm from the anal verge. The patient was placed in a modified lithotomy (Lloyd-Davies) position. The abdomen and perineum were prepped and draped in a sterile fashion. A total of six ports were placed in the following positions. A camera port (12 mm) was placed supra-umbilically. Three 8-mm robotic ports included: (I) arm 1, right iliac fossa above and medial to anterior superior iliac fossa; (II) arm 2, along the left mid-clavicular line, slightly more cephalad than the camera port; (III) arm 3, in the left upper quadrant. Two 5-mm laparoscopic assistant ports were placed in the following manner: (I) right upper quadrant, mid-clavicular line; (II) supra-pubic, right of mid-line. Beginning laparoscopically, the small bowel was cleared out of the pelvis using atraumatic graspers and held in place by the assistant. The uterus was suspended out of the pelvic field. The robotic cart was then docked between the patient's legs (*Figure 3*). The sigmoid colon was pulled out of the pelvis and held taut against the pelvic sidewall by one of the robotic arms. The robotic posterior mesorectal dissection began with the incision of the peritoneum overlying the right leaf of the mesocolon above the promontory allowing access to the presacral plane (*Figure 4*). At this point we identified the hypogastric nerves taking care to avoid injuring them. The mesorectal plane was progressively developed in the standard fashion for rectal dissection. Excessive fat was encountered within the Toldt's fascia as well as the presacral fascia making the dissection more challenging than usual. Prehypogastric nerve fascia was incised allowing entrance into the areolar holy plane with dissection continuing to the level of the

Figure 5 Mass after excision. Final pathology revealed Mullerian type cyst, 2.2 cm in greatest dimension.

lower sacrum. At this point the dissection was eccentric and directed towards the left hemi-pelvis where an abnormal presacral vessel was identified leading to the mass originating from the left posterior endopelvic fascia. The endopelvic fascia was incised carefully around the mass with meticulous dissection and slowly became more evident in the inferior aspect of the pelvic sidewall fat pad. The ability of retraction, superb optics, and un-paralleled precision of dissection facilitated the dissection, justifying the chosen robotic approach. The lateral location of the lesion to the sacrum along with an anterior extension from the mass resembling a nerve structure initially suggested a neurogenic origin of the tumor. Once the anterior aspect of the lesion was released, it was used for retraction and the mass was dissected off the pelvic sidewall with ease. The mass was retrieved with an endo-catch bag. After ensuring careful hemostasis and lavage, the 12-mm port site was closed with figure of eight stitch of 0-vicryl. The abdomen was de-sufflated and the remaining port sites closed. No drain was left in place. Total operative time was 150 minutes; robotic docking was 5 minutes; robotic dissection 70 minutes. The final pathology revealed a benign Mullerian type cyst, 2.2 cm in greatest dimension (*Figure 5*).

Postoperative management

The patient was managed with standard protocols for minimally invasive surgery. Clear liquid diet was started on post-operative day 1 along with the removal of the Foley catheter. On post-operative day 2, once general diet was tolerated and pain controlled with oral analgesics, the patient was discharged. She had returned to normal activity within 72 hours.

Results

Tips, tricks and pitfalls

- Diagnosis, investigation, and approach to retrorectal (presacral) tumors are complex.
- Although good concordance of biopsy results and final pathology has been shown for a solid presacral lesion, caution must be exercised with biopsy result with cystic presacral lesions as they are inaccurate.
- Benign presacral lesions should be resected secondary to complications such as infection, local growth and compression, possibility of containing malignancy, and malignant degeneration.
- Definitive diagnosis of primary malignancy of retrorectal tumor warrants an *en-bloc* resection.
- Anterior abdominal approach is reserved for tumors above mid-level of S3, or if involving the pelvic sidewall. There is also growing evidence that anterior approach using minimally invasive techniques can often be used successfully for most lesions, including those located below S3 level.
- Only when the small bowel, uterus, and sigmoid colon are effectively retracted can robotic dissection commence.
- Access to the retrorectal space begins with incision of the peritoneal leaf at the sacral promontory.
- Care must be taken when moving laterally in the retrorectal space to avoid injury of the ureter, iliac vessels (mainly veins), hypogastric nerves and the pelvic plexus.
- Incision of prehypogastric nerve fascia allows entrance into the areolar holy plane facilitating dissection into the lower level of the sacrum.

Conclusions

Robot-assisted minimally invasive resection of a retrorectal mass is safe and feasible. This method can be particularly useful in the narrow pelvis and with obese patients.

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Selective lateral pelvic lymph node dissection through a robotic approach for rectal cancer treated with preoperative chemoradiotherapy: a long way for generalization

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Lateral pelvic lymph node dissection (LPND) in addition to total mesorectal excision (TME) without radiotherapy has been considered a standard of treatment in Japan, even though LPN metastasis is not suspected on preoperative radiologic examination (1,2). This is so called "prophylactic" LPND, and basically prophylactic LPND is performed bilaterally. Recently, the long-term results of a randomized controlled trial (JCOG0212) to confirm whether TME alone is not inferior to TME plus prophylactic LPND in clinical stage II/III low rectal cancer have been published (3). In the JCOG0212 trial, only patients without LPN enlargement with a short-axis diameter of <10 mm were included, and all patients did not undergo preoperative chemoradiotherapy (CRT). Despite an almost similar 5-year relapse-free survival between TME alone and TME with LPND groups (73.4% *vs.* 73.3%), the non-inferiority of TME alone could not be demonstrated, because the upper limit of the confidence interval (1.36) was above the non-inferiority margin of 1.34. Considering the higher percentage of local recurrence in the TME alone group than in the TME with LPND group (7.4% *vs.* 12.6%, P=0.024), the JCOG group concluded that changing the TME with prophylactic LPND is insufficient as the standard of treatment in Japan.

The JCOG 0212 trial has highlighted the importance of LPN metastasis as the source of local recurrences when it is treated by TME alone. However, the results of the JCOG 0212 trial have little impact on countries other than Japan, where preoperative CRT is the standard of care for advanced low rectal cancer. The local recurrence rate in TME with prophylactic LPND without radiotherapy in JCOG0212 was not superior to that reported in TME alone with preoperative CRT from western countries (4,5), and therefore, it is unlikely that prophylactic LPND will be recognized as a necessary procedure in patients with rectal cancer treated with preoperative CRT.

Then, is there no role of LPND in the treatment of advanced rectal cancer? Recent evidence has shown that LPN metastasis can be a source of local recurrence even after preoperative CRT. Kim *et al.* analyzed 900 patients with rectal cancer treated with preoperative or postoperative CRT without LPND, and showed that LPN short-axis diameter on pre-treatment imaging was significantly associated with LPN recurrence-free survival, and the 5-year LPN recurrence-free survival in patients with a LPN short-axis diameter of <5, 5–<10, and ≥10 mm was 98.2%, 91.7%, and 40.1%, respectively (6). An extremely high rate of LPN recurrence in patients with a LPN short-axis diameter of ≥10 mm strongly suggests that preoperative CRT alone is insufficient in these patients. Kusters *et al.* also reported that the 4-year lateral local recurrence was significantly higher in patients with a LPN short-axis diameter of >10 mm than in patients with LPNs of ≤10 mm (33.3% *vs.* 10.1%, P=0.03) (7). Therefore, it seems reasonable to add LPND selectively in patients with suspected LPN metastasis, even after CRT.

Some papers from western countries have insisted that LPN metastasis is a systemic disease, and there is no benefit to adding LPND after CRT (8,9). However, LPND was not performed in these studies and LPN metastasis was diagnosed only clinically by radiologic examination. Most papers reporting the outcomes of TME with selective LPND after CRT have been published in Asian countries (10-14). Our group previously reported that 66% of the patients who were treated by CRT and selective LPND had pathological LPN metastasis; importantly, there was only one local recurrence in patients with pathological LPN metastasis, and relapse-free survival was not significantly different from that in patients without LPN metastasis (10). Ishihara *et al.* also reported that 52% of the patients treated by CRT and selective LPND had pathological LPN metastasis, and there were no local recurrences in patients with pathological LPN metastasis (11). Taken together with worse local recurrence rate in patients with suspected LPN metastasis treated by CRT and TME alone (6,7), these data suggest that LPND has an oncological benefit when CRT could not eradicate LPN metastasis.

However, there are some hurdles in adopting LPND worldwide. First, LPND is a complex procedure resulting in more operating time, more blood loss, and more postoperative complications (15,16). Especially for surgeons without experience in LPND, it might not be easy to perform LPND safely before the learning curve reaches a plateau; nevertheless, the candidate of patients needing LPND is limited because of selective use of LPND after CRT. Potentially worse short- and long-term outcomes after LPND performed by surgeons who may still be in their learning phase might mitigate the benefit of adding LPND. Second, western patients are more obese compared with Asian patients, and LPND would be more difficult in such obese patients.

In this setting, Kim *et al.* (17) needs to be commended for conducting the first comparative study between laparoscopic and robotic LPND for advanced rectal cancer. In this study, the authors compared 50 and 35 consecutive patients undergoing robotic and laparoscopic LPND performed by a single specialized surgeon. They performed LPND when there was suspected metastatic LPNs based on a pretreatment radiologic examination. The percentage of preoperative CRT was not significantly different between groups (82% in the robotic and 69% in the laparoscopic group). For unilateral LPND, the mean operative time was not significantly different, but the estimated blood loss (EBL) was significantly lower in the robotic group than in the laparoscopic group (34.6 *vs.* 50.6 mL, P=0.002). It might be difficult to say that this small difference (15 mL) of EBL is clinically relevant, but the EBL in this study was much lower than that reported in the JCOG 0212 trial (15). The percentage of pathological LPN metastasis (28% in robotic *vs.* 41% in laparoscopic group) was adequately high. Importantly, the incidence of urinary retention was significantly lower in the robotic than in the laparoscopic approach (4% *vs.* 20%). Although the follow-up period is still short (median follow-up of 26.3 months), the local recurrence rate was excellent considering the high rate of pathological LPL metastasis (6.0% and 11.4% in the robotic and laparoscopic groups, respectively). This study suggests that the robotic approach might enable more meticulous dissection, resulting in less blood loss and less urinary dysfunction compared with the laparoscopic approach in LPND when performed by expert robotic surgeons.

Recently, the results of the ROLARR randomized clinical trial comparing robotic versus laparoscopic surgery for rectal cancer have been published (18). In this study, the conversion rate to open surgery as the primary endpoint was not significantly different between the robotic and laparoscopic groups (8.1% *vs.* 12.2%), and all the other secondary endpoints, including circumferential resection margin, postoperative complications, and urinary and sexual dysfunction, were also not significantly different. These findings suggest that generalized use of the robotic approach for rectal cancer cannot be justified. However, a subgroup analysis showed that the conversion rate was lower in the robotic approach than in the laparoscopic approach (8.7% *vs.* 16.0%), suggesting that the robotic approach might offer a benefit in the narrower male pelvis. In this sense, robotic surgery might still potentially offer a benefit in a technically challenging procedure such as LPND.

The results of the Kim's study cannot be generalized at present because their study is a retrospective, single-institutional study and LPND was performed by a single surgeon who is an expert both in laparoscopic and robotic surgery. Apart from the technical issues, before LPND is accepted as the standard procedure for patients with suspected LPN metastasis worldwide, the issue of an optimal indication of LPND considering the balance between the positive rate of pathological LPN metastasis and potentially increased postoperative complications must be solved. To shed light on this problem, multi-institutional large data will be necessary because of the limited number of rectal cancer patients with pathological LPN metastasis after CRT in a single institution. Regarding the best approach for LPND, multi-institutional data might be useful, but we have to carefully analyze such data because the prior experiences and proficiencies of laparoscopic or robotic LPND might be considerably different among surgeons. Further studies are warranted about the best indication and best approach for LPND in rectal cancer treated with preoperative CRT.

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Modular approach for single docking robotic colorectal surgery

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We have read the article by Priatno and Kim with great interest (1). The article and attached video describe the single docking technique for rectal resection using the da Vinci® Si system. Robotic rectal surgery has shown steady increase during recent times. With challenging ergonomics of heavy mechanical arm of the robotic Si system, arm collision was often quoted as the main reason for limited adoption. With this in mind, surgeons have tried various other techniques such as hybrid, laparoscopic assisted or double docking as possible solution to this problem (2-4). We concur with authors regarding the stepwise approach for single docking robotic rectal surgery. This technique is now well established for robotic rectal cancer surgery (5,6).

Single docking approach is slightly demanding especially during learning curve. In addition, while performing the splenic flexure mobilization, collision of robotic arms during dissection in left upper compartment of abdominal cavity may pose further challenges. Hence, splenic flexure mobilization is probably the most challenging part during single docking approach, while using Si robotic system, as patient remains in the maximum Trendelenburg and right tilt position during the entire procedure. Applying similar principles of stepwise technique, we have published our three steps standardized approach for complete mobilization of splenic flexure during single docking colorectal surgery (7).

We agree with authors that this technique is safe, feasible and may reduce some operative time due to single docking. Perhaps now, the single docking technique has become easier and hassle free with the use of next generation of robot da Vinci® Xi surgical system. It has different port configuration and has ability to change patient's position, during various steps of operation, through an integrated cart and table motion system, without undocking.

In our practice, we have developed and described the modular stepwise approach for the laparoscopic colorectal surgery and later on the same standardized approach was applied for the robotic colorectal surgery (5,8,9).

We believe a standardized and stepwise technique is the key aspect of minimally invasive surgery. It is an effective method for learning complex surgical procedures. The stepwise approach is also useful for trainee surgeons to learn and master the operation. Furthermore, it helps to develop a sense of pattern recognition of surgical planes, which is vital for dissection in the correct operative field. The dissection between the true embryological layers i.e., correct planes enables to operate in bloodless field. We have published the largest case series from the UK that has demonstrated robotic surgery involves minimal blood loss (5).

In conclusion, authors have made an excellent effort to demonstrate the stepwise approach in this video article, and we believe this approach has significant inherent benefits for patients as well as training and learning robotic surgery.

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Are the clinical risk scores of survival after colorectal liver metastases still valuable in the era of laparoscopic liver surgery?

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We read with interest the article by Barkhatov *et al.* reporting on laparoscopic liver resection for colorectal liver metastases with the aim to validate different clinical risk scores (1). This elegant study shows that excellent long-term results (e.g., up to 32% 10-year survival) can be achieved with adequate surgical resection in selected patients with laparoscopic approach. Interestingly, the Fong score, pre- and postoperative BPI and the Nordlinger score systems can be used to predict survival for laparoscopically operated patients in the era of multimodal-treatment.

A prediction of the risk of recurrence after resection that is as precise as possible is essential for maximizing the benefit from such an invasive strategy. A lot of clinical scores have been proposed by different surgical institutions over the years and all were based on easily available parameters associated with the extent of the primary tumor and colorectal liver metastases or grossly defining the aggressiveness of the disease course. Probably one of the most relevant attempt to define prognosis after surgery on colorectal liver metastases was conducted by Fong *et al.* at the Memorial Sloan-Kettering Cancer Center (MSKCC); the authors analyzed a large database of all patients admitted to their institution for liver surgery from 1985 to 1998. Among the 1,001 patients identified resected for colorectal liver metastases, the authors investigated characteristics of the primary tumor and related colorectal liver metastases or extrahepatic disease, identifying seven parameters that independently predicted outcome after resection: (I) positive surgical margin; (II) presence of extrahepatic disease; (III) number of lesions; (IV) preoperative carcinoembryonic antigen level >200 ng/mL; (V) size of the largest lesion; (VI) nodal status of the primary tumor; (VI) disease-free interval from the primary to diagnosis of colorectal liver metastases and (VII) bilateral tumors as variables.

Limiting to the five factors that can be accessible before resection and not considering the variables that represented absolute contraindication to resection at the time (i.e., positive margin and the presence of metastases outside the liver, which are both associated with a 1.7-times higher risk of death), a clinical risk score was developed assigning each criterion one point; the MSKCC score proved to be highly predictive of long-term outcome after surgery for colorectal liver metastases, with the risk of death increasing when the number of concomitant risk factors increased. In fact, prognosis varied from patients with no risk factors, who achieved a 5-year actuarial survival rate of 60%, to patients with all the five points, who had a 5-year actuarial survival rate of 14%. The clinical risk score proposed by Fong *et al.* has been subsequently validated by independent data sets and should therefore guide patient selection and treatment allocation but should not be interpreted as absolute contraindication to surgery.

These results are in line with the study from our group published last year in Annals of Surgery concerning long-term outcomes following second and third laparoscopic hepatectomies for patients with recurrent CRLM (2). While tumor recurrence is frequent after either a first or second resection, the benefit provided by second and third LLRs was suggested by the excellent 5-year survival rates, which were both better than those obtained after a first LLR and comparable to those observed by open approach. Likewise, Allard *et al.* showed that laparoscopy yields better operative outcomes without impairing long-term survival in a cohort including more than 2,500 patients (3).

Potential benefits of laparoscopic approach compared with open in liver resection have been largely investigated. The different results suggest the superiority of the laparoscopy in terms of length of hospital stay, transfusion rate, and morbidity. Indeed, the role of the pneumoperitoneum and the magnification achieved by 2D or 3D cameras enable excellent control of small intrahepatic vascular structures and this contributes to limit bleeding during the parenchymal transection. Of course, the laparoscopic approach may be impaired by tumor location, adequate resection margins, and complete intraoperative exploration of the liver. This may lead to worse oncological results in patients operated by laparoscopy for CLM and prefer open hepatectomy.

Overall, these data strongly suggest that in both laparoscopic and open approaches bring equivalent long-term outcomes. In their study the Norvegian teams show that the actual survival exceeded the predicted value by the scoring systems. The reason is more probably due to the multimodal treatments than the mini invasive approach itself. In this setting, the Fong score, even with an underestimation of 16.8% for 5 years survival and 20 months for median survival is the closest of the currents results and can be used to predict survival in all patients with CRLM.

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Synchronous resection of colorectal primary and hepatic metastasis

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Abstract: Up to 50% of the over 140,000 new colorectal cancer patients will present with synchronous colorectal cancer and liver metastasis. Surgical management of patients with resectable synchronous colorectal hepatic metastasis is complex and must consider multiple factors, including the presence of symptoms, location of primary tumor and liver metastases, extent of tumor (both primary and metastatic), patient performance status, and underlying comorbidities. Possible approaches to this select group of patients have included a synchronous resection of the colorectal primary and the hepatic metastases or a staged resection approach. The available literature regarding the safety of synchronous versus staged approaches confirms that a simultaneous resection may be performed in selected patients with acceptable morbidity and mortality. Perioperative mortality when minor hepatectomies are combined with colorectal resection is consistently ≤5%. Perioperative morbidity varies considerably following both synchronous and staged resections. However, the bulk of the existing literature confirms that simultaneous resections are both feasible and safe when hepatic resections are limited to <3 segments. Data regarding the oncologic outcomes following synchronous versus staged resections for Stage IV colorectal cancer are more limited than those available regarding postoperative morbidity and mortality. The available data suggest equivalent overall and disease-free survival regardless of timing of resection. Experience with minimally invasive combined colorectal and hepatic resections is extremely limited to date and consists exclusively of small single center series. The potential benefits of a minimally invasive approach will await the results of larger studies.

Keywords: Colorectal cancer; colorectal liver metastases; synchronous resection

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Introduction

Approximately 23% to 51% of the 157,000 new colorectal cancer patients will present with synchronous colorectal cancer and liver metastasis (1). Surgical resection of all tumor sites is the only treatment that offers prolonged survival (2-4). However, optimal management of patients with synchronous colorectal hepatic metastasis is complex and must consider multiple factors, including the presence of symptoms, location of primary tumor and liver metastases, extent of tumor (both primary and metastatic), patient performance status, and underlying comorbidities.

When faced with a patient with an asymptomatic primary colorectal cancer, isolated hepatic metastases, and reasonable performance status, a primary consideration when formulating a possible surgical treatment plan involves assessment of resectability of the hepatic metastases. This select group of patients with asymptomatic primary tumors and isolated liver-only metastases can be classified into three groups: (I) diffuse, bilobar, unresectable liver metastases, (II) marginally resectable liver metastases and (III) clearly resectable hepatic metastases. In the first group, most oncologists favor palliative systemic chemotherapy as the primary treatment modality and would reserve surgical management for complications of the primary (e.g. bleeding, obstruction, perforation) or cases where the

Table 1 Potential risks and benefits of synchronous versus staged resection

Synchronous		Staged	
Benefit	Risk	Benefit	Risk
Reduced complications due to single operation	Increased infectious liver complications due to bacterial contamination from intestinal resection		Increased morbidity associated with multiple procedures
Reduced length of hospital stay	Risk of complications from unresected primary	Reduced complications from unresected primary	Risk of hepatotoxicity from chemotherapy given between colorectal and hepatic resections
	Increased anastomotic complications due to impaired liver function		
	Extent of hepatic resection limited due to concomitant intestinal resection	Larger hepatic resections may be performed without increased morbidity	
No delay in initiating systemic treatment	Chemotherapy-associated hepatotoxicity may limit extent of liver resection		Risk of complications following colorectal resection may delay chemotherapy prior to liver resection
Opportunity to observe tumor response to neoadjuvant chemotherapy	No opportunity to assess tumor response if resection precedes systemic therapy		

hepatic metastases may be rendered resectable. In the latter two groups, the following treatment strategies have been employed: (I) resection of the primary followed by systemic chemotherapy followed by liver resection ± additional systemic chemotherapy (Staged approach), (II) systemic chemotherapy followed by simultaneous resection of the primary and hepatic metastases (Synchronous approach) and (III) systemic chemotherapy followed by resection of hepatic metastases followed by resection of the primary (so-called "Reverse Strategy") (5).

The potential risks and benefits of synchronous compared to staged resections are summarized in *Table 1*. Advocates of a staged approach endorse this strategy due to concerns about increased morbidity and mortality associated with simultaneous resection of the colorectal primary and hepatic metastases. Concerns about the potential safety and technical feasibility of rectal resections and major hepatic resections have been raised as concerns regarding simultaneous resections (6). In addition, some surgeons and oncologists have pointed to complications associated with the unresected primary tumor as another reason for not adopting synchronous resections (7,8). In contrast, proponents of synchronous resections point to the morbidity associated with multiple procedures as a major advantage of a simultaneous resection approach. From an oncologic standpoint, synchronous resection following neoadjuvant chemotherapy provides insight into the patient's tumor biology and prevents a delay in administering systemic therapy which may occur due to complications following resection of the colorectal primary.

The current discussion will review the existing literature on staged versus synchronous resection of colorectal cancer and isolated hepatic metastases. Two key issues will be considered: the safety of each resection strategy and oncologic outcomes followed a synchronous versus staged resection. Lastly, we will examine the emerging data available regarding a minimally invasive approach to synchronous colorectal disease with hepatic metastases.

Safety of simultaneous versus staged resections

The first question to be addressed when considering a synchronous versus staged resection for colorectal tumors with hepatic metastases is the safety of each approach. A study by Vogt *et al.* was among the first to examine the safety of synchronous resection for colorectal cancer (9).

The authors compared operative mortality between 19 patients who underwent a synchronous resection to 17 patients who had a staged resection (median 2 months between resections). There were no perioperative deaths in either group. One patient in the synchronous group developed a bile leak (overall complication rate 5%) while three patients in the staged group developed complications (overall complication rate 17.6%). The authors concluded that synchronous resection was associated with a low rate of complication and no operative mortality provided that colorectal resections are not combined with extended liver resections. Five years following the study by Vogt *et al.* (9), Nordlinger and colleagues (6) compared operative outcomes between 115 patients who underwent a synchronous resection to 893 patients who underwent a staged resection. The operative mortality among the synchronous resections was 7% compared to 2% in the staged resection group. Perioperative morbidity for simultaneous versus staged resections were not reported. Given the increased mortality associated with colorectal resections combined with major liver resections, the authors subsequently adopted a policy of performing synchronous resections only if they can be done with a minor liver resection and through the same abdominal incision. Conversely, when a major liver resection is required to resect synchronous metastases from a rectal carcinoma, for example, they perform the rectal excision first and the liver resection 2 or 3 months later if the liver tumors have remained stable.

Advances in anesthesia and critical care, improved understanding of hepatic anatomy, and better preoperative radiological imaging have led to significant advancements in hepatobiliary surgery in general, and the management of patients with colorectal hepatic metastases specifically. Mortality following major liver resections in current series ranges from 0-5.8% (10-12). Morbidity from these same reports ranges from 22-48% (10-12). As a result, perioperative outcomes following simultaneous resections may also be expected to improve compared to those of the earlier series reported above. Martin and colleagues from Memorial Sloan-Kettering Cancer Center published their experience comparing 134 simultaneous versus 106 staged resections for metastatic colorectal cancer (13). Perioperative mortality was similar in both groups. Using their standard classification scale for complications, they reported a significantly lower complication rate of 48% among simultaneous resection patients compared to a 68% rate among staged resection patients. Importantly, they included the complications sustained during both hospitalizations in the staged resection group. They noted that the difference in the overall complication rate between the simultaneous and the staged group occurred primarily from the need for a second laparotomy in the staged group. An examination of hepatectomy versus colectomy-related complications revealed no difference in procedure-specific complications between the two groups. In 2004, Tanaka *et al.* (14) published their series of 39 simultaneous and 37 staged resection patients. The perioperative mortality rate was zero in both groups. The morbidity rate was 28% in the simultaneous group compared to 16% in the staged group. The authors noted that although the rate of hepatectomy-related complications (e.g. hyperbilirubinemia, biliary fistula) were slightly higher in the simultaneous resection group the compared to the staged resection group, the results were comparable to those seen in their conventional colorectal hepatic metastasectomy patients. Three years following the report by Tanaka *et al.* (14), Reddy *et al.* (15) published a retrospective study of simultaneous or staged colorectal and hepatic resections at three hepatobiliary centers. One hundred and thirty five patients underwent simultaneous and 475 patients underwent staged resection. Mortality and severe morbidity were similar after simultaneous colorectal resection and minor hepatectomy compared with isolated minor hepatectomy. However, increased mortality and severe morbidity was seen following simultaneous colorectal resection and major hepatectomy. Based upon these findings, the authors recommended caution when considering simultaneous colorectal and major hepatic resection but felt simultaneous colorectal and minor hepatic resections were safe and could be recommended for most patients. A smaller study of synchronous versus staged resections for colorectal cancer with hepatic metastases was published by Capussotti in 2007 (16). A major advantage of this study over those described above, however, is that only patients with major liver resections were included. The authors reported their experience in 31 patients who underwent synchronous resection to 48 patients who underwent staged resection. Perioperative mortality occurred in 3.2% of synchronous resection patients and in none of the staged resection patients. Perioperative morbidity occurred in 33% of synchronous resection patients compared to 56% of staged resection patients. Based upon their findings, Capussotti *et al.* (16) concluded that major hepatectomies can be safely performed at the same time as colorectal surgery in selected patients with synchronous metastases. Furthermore, they did not feel that rectal cancer requiring an anterior resection was a contraindication to synchronous major hepatectomy since 9/31 (29%) of the patients in their synchronous resection group underwent a rectal resection. Thelen *et al.* (17) sought to clarify the safety of simultaneous liver resections compared to staged hepatectomies and identify criteria of patient selection for simultaneous liver resection. They compared the perioperative outcomes between 40 patients who underwent simultaneous resection to 179 patients who underwent staged resections. The 90-day mortality rate was 10% in the synchronous group compared to 1.1% in the staged group. Morbidity was similar between the two groups: 18% in the simultaneous resection group versus 25% in the staged group. When independent predictors of postoperative mortality were analyzed, only extent liver resection was found to be a significant influence on mortality after simultaneous liver resections. In contrast, none of the demographic or clinical factors investigated had a significant influence on postoperative mortality in the staged resection group.

Martin *et al.* (18) recently published their experience comparing 70 simultaneous resections of colon primary and liver metastases to 160 patients who underwent staged operations. In contrast to some of the earlier series cited above, the frequency of major liver resections (≥3 Couinaud segments) was similar in the two groups at 33%. The type of primary resection was also similar in the two groups. The postoperative mortality was rate was 2% in both groups. Complication rates were similar in the staged and simultaneous groups: 56% in the simultaneous groups versus 55% in the staged group. The authors concluded that simultaneous resections are safe and acceptable and result in shorter overall length of hospital stay.

In contrast to the above retrospective studies which compared outcomes following synchronous and staged resections for colorectal cancer and hepatic metastases, Moug *et al.* (19) performed a small case-matched comparison of 32 patients who underwent simultaneous versus staged resections. The patients were matched for age, gender, American Society of Anesthesiologists grade, type of hepatic and colon resection. Major hepatic resections performed were 22% of patients in both groups. There were no postoperative deaths in either group. No significant differences in postoperative morbidity were found between the two groups: the overall morbidity in the synchronous group was 34% compared to 59% in the staged group. The investigators concluded that synchronous resections can be safely performed and noted the absence of any colonic anastomotic leaks, even considering that slightly over one third of the patients underwent a rectal resection with anastomosis. A limitation of this study, however, is the small percentage of patients who underwent a major hepatectomy (resection of ≥3 segments).

A variation on the classic staged approach (colon then liver) has recently been proposed by Brouquet *et al.* and the group from M.D. Anderson Cancer Center (5). In their "Reverse Strategy" preoperative chemotherapy is followed by resection of the hepatic metastases and then by resection of the colorectal primary at a second operation. The rationale for this approach is based upon the following observations: complications related to the primary colorectal tumor are rare and treatment of metastatic disease is not delayed by local therapy for the primary tumor or complications associated with treatment of the primary tumor. In their study, they examined the perioperative outcomes between 72 patients who underwent a classic staged approach to 43 patients who had a synchronous resection of their primary and metastatic lesions to 27 patients who were treated according to the "Reverse Strategy". Postoperative mortality rates in the simultaneous, classic, and reverse strategies were 5%, 3%, and 0%, respectively. Postoperative cumulative morbidity rates for the three groups were similar at 47%, 51%, and 31%, respectively. Based upon their findings, the authors concluded that the "Reverse Strategy" can be considered as an alternative option in patients with advanced hepatic metastases and an asymptomatic primary.

In summary, the literature to date supports the safety of a synchronous approach to the resection of colorectal cancer and hepatic metastases (*Table 2*). Perioperative mortality in most series is ≤5% for either simultaneous or a staged approach. In contrast to the consistently low mortality associated with either a synchronous or staged colorectal and hepatic resection, morbidity rates following these approaches are more variable. One theme does emerge from the available literature, however; morbidity rates are generally increased when colorectal resections are combined with major hepatectomy defined as resection of ≥3 segments. Despite the technical and postoperative improvements associated with hepatic resections over the past decade, most authors recommend caution when considering combining major hepatectomy with colorectal resections. Another risk for increased morbidity among synchronous resection patients is the location of the colorectal primary - specifically the potential for increased morbidity associated with combining rectal and hepatic resections. There appears to be a general trend away from

Table 2 Perioperative outcomes following synchronous and staged resections

Study (Year)	N	Primary Location (%)	Extent of Hepatectomy (%)	Morbidity(%)	Mortality(%)
Vogt (1991)	Synch: 19 Staged: 17	NR	< Lobe: Synch: 68 Staged: 47 ≥ Lobe: Synch: 32 Staged: 53	Synch: 5.2 Staged: 17.6	Synch: 0 Staged: 0
Nordlinger (1996)	Synch: 115 Staged: 893	Colon: 63 Rectum: 36 Other: 1	Major: 64% Minor: 36%	NR	Synch: 7* Staged: 2
Martin (2003)	Synch: 134 Staged: 106	Right colon: Synch: 40 Staged: 14 Left colon: Synch: 22 Staged: 29 Rectum: Synch: 37 Staged: 56 Other: Synch: 1 Staged: 1	< Lobe: Synch: 67 Staged: 28 ≥ Lobe: Synch: 33 Staged: 72	Synch: 49 Staged: 67*	Synch: 2 Staged: 2.8
Tanaka (2004)	Synch: 39 Staged: 37	Synch: Colon: 61.5 Rectum: 38.5 Staged: NR	Minor resection: Synch: 87 Staged: 41 Major resection: Synch: 13 Staged: 59	Synch: 28 Staged: 16	Synch: 0 Staged: 0
Capussotti (2007)	Synch: 31 Staged: 48	Right Colon: Synch: 39 Staged: 19 Left colon / sigmoid: Synch: 26 Staged: 41 Rectum Synch: 29 Staged: 33 Other: Synch: 6 Staged: 7	All ≥ 3 segments	Synch: 33 Staged: 56*	Synch: 3.2 Staged: 0
Thelen (2007)	Synch: 40 Staged: 179	Right colon: Synch: 47.5 Staged: 19 Left colon: Synch: 37.5 Staged: 41 Rectum: Synch: 15 Staged: 40	Minor Resection: Synch: 62.5 Staged: 21 Major Resection: Synch: 37.5 Staged: 79	Synch: 18 Staged: 25	Synch: 10* Staged: 1.1

Table 2 (*continued*)

Table 2 (*continued*)

Study (Year)	N	Primary Location (%)	Extent of Hepatectomy (%)	Morbidity(%)	Mortality(%)
Reddy (2007)	Synch: 135 Staged: 475	Right colon: Synch: 33 Staged: 16 Left colon: Synch: 16 Staged: 27 Rectum: Synch: 44 Staged: 54 Other: Synch: 6 Staged: 3	Minor Resection: Synch: 73 Staged: 39 Major Resection: Synch: 27 Staged: 61	Minor Hepatic Resection: Synch: 33* Staged: 20 Major Hepatic Resection: Synch: 44* Staged: 27	Minor Hepatic Resection: Synch:1.0 Staged: 0.5 Major Hepatic Resection: Synch: 8.3* Staged: 1.4
Martin (2009)	Synch: 70 Staged: 160	Right colon: Synch: 45 Staged: 33 Left colon: Synch: 23 Staged: 34 Rectum: Synch: 30 Staged: 23 Other: Synch: 2 Staged: 10	< Lobe: Synch: 53 Staged: 60 ≥ Lobe: Synch: 47 Staged: 40	Synch: 55 Staged: 56	Synch: 2 Staged: 2
Moug (2010)	Synch: 32 Staged: 32	Right colon: Synch: 22 Staged: 22 Left colon / sigmoid: Synch: 31 Staged: 31 Rectum: Synch: 37.5 Staged: 37.5 Other: Synch: 9.5 Staged: 9.5	≤ 2 segments: Synch: 78 Staged: 78 ≥ 3 segments: Synch: 22 Staged: 22	Synch: 34 Staged: 56	Synch: 0 Staged: 0
Brouquet (2010)	Synch: 43 Staged: Colon-Liver: 72 Liver-Colon: 27	Colon: Synch: 58 Staged: Colon-Liver: 51 Liver-Colon: 30 Rectum: Synch: 42 Staged: Colon-Liver: 49 Liver-Colon: 70	<3 segments: Synch: 65 Staged: Colon-Liver: 37 Liver-Colon: 19 ≥3 segments: Synch: 35 Staged: Colon-Liver: 66 Liver-Colon: 89	Synch: 47 Staged: Colon-Liver: 51 Liver-Colon: 37	Synch: 5 Staged: Colon-Liver: 3 Liver-Colon: 0

NR: not reported; Synch: synchronous resection of colorectal primary and hepatic metastasis; *indicates statistically significant difference between resection groups.

combining rectal resection with hepatic resection although at least one small case-matched study (19) which controlled for this variable failed to show an increase in postoperative morbidity when rectal resections were combined with mostly minor hepatectomy.

Oncologic outcomes following simultaneous versus staged resections

Having established the safety of synchronous resection of colorectal and hepatic metastases in select patients, the next key consideration is oncologic outcomes. Do patients who undergo synchronous resections have equivalent (or improved) oncologic outcomes compared to patients who undergo staged resections? In the following section, we will consider overall and disease-free survival rates following simultaneous and staged resections for synchronous metastatic colorectal cancer.

Prior to examining the outcomes following these two resection approaches, it is instructive to review the oncologic outcomes among Stage IV colorectal cancer patients with isolated hepatic metastases treated by standard chemotherapy. A study by Emmanouilides *et al.* (20) examined outcomes following upfront therapy with bevacizumab, oxaliplatin, leucovorin, and 5-Fluorouracil in chemotherapy-naïve patients with metastatic colorectal cancer. Approximately two-thirds of the patients in their study had liver only as their site of metastasis. A complete response rate of 15% was found following this regimen while partial response was seen in 53%. Time to tumor progression was 11 months. One, two, and three-year survival probabilities were 80%, 64%, and 58%, respectively. Median overall survival had not yet been reached after a median follow-up of 20 months. Despite the significant improvement in time to progression and overall survival associated with modern chemotherapy regimens for metastatic colorectal cancer, the superiority of complete resection, when possible, has been clearly established. In a study of 151 patients with synchronous colon cancer and isolated hepatic metastases, Fahy *et al.* (4) reported a 5-year disease-specific survival of 54% among resected patients. In contrast, the median survival amongst patients who were not able to undergo hepatic resection was 27 months. This proven superiority of complete surgical resection of colorectal cancer and hepatic metastases over best systemic therapy notwithstanding, in order to evaluate the risks and benefits of a simultaneous versus staged resection, the inherent morbidity and mortality of resectional therapy must compare favorably with best current systemic therapy.

The early study comparing synchronous (N=19) versus staged (N=17) resection of colorectal hepatic metastases by Vogt *et al.* (9) previously discussed reported an overall median survival in all 36 patients of 28 months. The median overall survival in the synchronous resection group was 18 months with a median disease-free interval of 7 months. Among patients undergoing staged liver resection, median survival was 31 months and disease-free interval was 19 months. Despite this trend toward improved oncologic outcomes following staged resections, the authors concluded that their data do not show an effect of surgical approach on survival. Specifically, an improvement in survival was not seen among simultaneous resection patients.

The advances in surgical technique and perioperative assessment associated with liver resection over the past decade previously discussed have been paralleled by improved systemic therapies for advanced colorectal cancer. Therefore, improved oncologic outcomes may be expected with more current studies since the early report by Vogt *et al.* (9). In 2004, Tanaka *et al.* (14) reported their experience with 39 patients who underwent a synchronous colorectal and hepatic resection to 37 patients who underwent staged resections. The overall cumulative 5-year survival rates were similar between the two resection groups at 86% for the simultaneous resection group and 83% for the staged resection group. Disease-free survival was also equivalent between the groups with 5-year rates of 64% and 51% for simultaneous and staged resection groups, respectively. Thelen (17) compared oncologic outcomes between 40 patients who underwent a synchronous resection for colorectal metastases to 179 patients whose disease was resected in a staged fashion. Similar to the findings of Vogt *et al.* (9) and Tanaka *et al.* (14), no difference in overall survival was found between the two groups. A multivariate analysis performed to determine predictors of overall mortality identified nodal status of the primary, number of metastases and completeness of hepatic resection (R0 versus R1/R2) as the only independent predictors of mortality. After a mean follow-up of 70 months for all patients, 135/219 patients developed recurrent disease. Recurrent liver-only disease developed in 49 patients, and 12 patients developed both intra- and extrahepatic recurrence. The site(s) of recurrence did not differ between the resection groups. Given the impact of the entire extent of disease burden on oncologic outcomes, the case-matched study by Moug et al. (19) of 32 patients who underwent simultaneous versus staged resections is particularly informative regarding oncologic outcomes following these two resection approaches. As noted above, the patients in this study were matched for age, gender, American Society of Anesthesiologists grade, type of hepatic and colon resection. The overall median survival in the synchronous resection group was 39 months and compared favorably with the median survival of 42 months observed in the staged resection group. Similarly, the median time to cancer recurrence in the synchronous resection group was 10 months, similar to the 14 month disease-free survival seen among the staged resection patients. Although the small sample size is a limitation of this study, these findings provide some provisional evidence that timing of resection does not appear to impact oncologic outcomes adversely.

As discussed previously, the group from M.D. Anderson Cancer Center has recently published their experience with the "Reverse Strategy" toward staged resection of synchronous colorectal hepatic metastases (5). In their study, they reported an overall median survival for the entire population who underwent complete resection of all disease of 64 months. Median survival rates were 95 months in the simultaneous resection group, 55 months in the classic resection group, and 50 months in the "Reverse Strategy" resection group. Overall, 65% of all patients developed recurrent disease: 53% in the combined resection group, 71% in the classic resection group, and 70% in the "Reverse Strategy" group. These recurrence rates were not significantly different. Additionally, median disease-free survivals were the same in the three groups. The authors noted that the outcomes for patients treated with the "Reverse Strategy" who had more extensive disease were similar to outcomes of patients treated with the classic or simultaneous resection groups who had a smaller overall disease burden.

In summary, oncologic outcomes are superior following complete resection of all disease when compared to best available systemic therapies. Additionally, the result of the studies reviewed above indicate that oncologic outcomes, including both overall and disease-free survival, are not different following a synchronous compared to a staged approach to colorectal cancer metastatic to the liver (*Table 3*). A major limitation to the majority of available studies, however, is the variable extent of disease present among patients subjected to a simultaneous compared to a staged resection approach. Only the study by Moug *et al.* (19) attempted to address this issue. Based upon their limited case-matched study, the oncologic equivalence seen among the larger studies available appears to be sustained. The "Reverse Strategy" approach (5) is interesting insofar as it provides an approach which allows for extensive hepatectomies to be performed safely in a select group of patients with asymptomatic primary colorectal tumors. The authors have found that this approach helps increase resectability in patients not initially considered candidates for resection and avoids the delay off chemotherapy following initial colorectal resection which may allow for hepatic progression. It is noteworthy that the authors routinely give chemotherapy to all patients with synchronous resection colorectal liver metastases as this is not the routine practice amongst some surgeons who advocate a simultaneous resection for resectable colorectal hepatic metastases.

Role of minimally invasive approaches to synchronous colorectal cancer with hepatic metastases

The safety and efficacy of minimally invasive approaches to colorectal disease, including cancer, was established following the report of the Clinical Outcomes of Surgical Therapy (COST) trial (21) which showed equivalent recurrence and overall survival rates between patients who underwent laparoscopically-assisted compared to open resection for colon cancer. An increase in minimally invasive hepatic resections has paralleled and followed the increased use of minimally invasive approaches to colorectal malignancies. A recent report by Nguyen *et al.* (22) retrospectively reviewed all cases of minimally invasive hepatectomy for colorectal liver metastases performed in the United States and Europe between 2/2000 - 9/2008. A total of 109 cases were included in the review. Synchronous hepatic lesions were present in 11%. The median interval between resection of the colorectal primary and hepatic resection was 12 months among metachronous patients. Minor hepatectomies (≤3 segments) were performed in 61.5% of patients. The overall complication rate was 12% with no perioperative deaths. Negative margin resections were achieved in 94%. Actuarial overall survival was 88% at one year, 69% at three years, and 50% at 5 years. Disease-free survival for 1-, 3- and 5-years were 65%, 43%, and 43%, respectively. Based upon their review, Nguyen *et al.* (22) concluded that minimally invasive liver resections for colorectal metastases were feasible and could be performed safely with acceptable safety and oncologic outcomes. Currently,

Table 3 Oncologic outcomes following synchronous and staged resections

Study (Year)	N	Overall Survival (median months)	Disease-free Survival (median months)
Vogt (1991)	Synch: 19 Staged: 17	Synch: 18 Staged: 31	Synch: 7 Staged: 19
Tanaka (2004)	Synch: 39 Staged: 37	Synch: 1 year: 86% 3 year: 68% 5 year: 53% Staged: 1 year: 83% 3 year: 47% 5 year: 47%	Synch: 1 year: 64% 3 year: 20% 5 year: 16% Staged: 1 year: 51% 3 year: 34.5% 5 year: 28%
Thelen (2007)	Synch: 40 Staged: 179	Synch: 1 year: 86% 5 year: 53% 10 year: 32% Staged: 1 year: 90% 5 year: 39% 10 year: 26%	Site(s) of recurrence did not differ between Synch and Staged
Moug (2010)	Synch: 32 Staged: 32	Synch: 39 Staged: 42	Synch: 10 Staged: 14
Brouquet (2010)	Synch: 43 Staged: Colon-Liver: 72 Liver-Colon: 27	Synch: 95 5 year: 55% Staged: Colon-Liver: 55 5 year: 48% Liver-Colon: 50 5 year: 39%	Synch: 11 5 year: 55% Staged: Colon-Liver: 11 5 year: 48% Liver-Colon: 11 5 year: 39%

Synch: synchronous resection of colorectal primary and hepatic metastasis.

only small single institution series of minimally invasive surgical approaches to synchronous colorectal cancer and hepatic metastases have been published. Kim *et al.* (23) reported on their initial experience with 10 patients with colorectal cancer and synchronous liver metastases in order to assess the feasibility of a minimally invasive approach to synchronous disease. The primary tumors were resected via anterior or low anterior resection in eight patients, right hemicolectomy in one patient, and subtotal colectomy in one patient. Major hepatectomies were performed in six patients. There were no perioperative deaths. One patient developed postoperative bleeding requiring open re-exploration. The authors concluded that a synchronous minimally invasive approach was feasible in selected patients with colorectal cancer and hepatic metastases. Akiyoshi (24) also published their results following synchronous laparoscopic resection in 10 patients. All primary tumors were located in the sigmoid or rectum. Seven of their patients had an open hepatic resection following their laparoscopic colorectal resection and three patients underwent a minimally invasive resection for an isolated hepatic metastasis. There was no postoperative mortality and one patient developed a complication unrelated to the colorectal or hepatic resection. The open technique required for the hepatic resections limits the significance of this study but provides some insight into the safety of hybrid laparoscopic resections for synchronous colorectal cancer. Lee *et al.* (25) recently published their 10 patient series of laparoscopic simultaneous colorectal and hepatic resection. Primary tumors were right-sided in four patients, left-sided in three cases, and rectal in three cases. Six patients had single hepatic metastases while the other four patients had ≥2 hepatic metastases. One patient underwent a right hemihepatectomy while others underwent minor hepatic resections. One case required conversion to an open approach due to bleeding from a hepatic vein and this patient also developed an anastomotic leak. There were no postoperative mortalities. This study provides additional limited support for a simultaneous minimally invasive approach for colorectal cancer with limited hepatic metastases. The largest study to date on simultaneous minimally invasive resection of colorectal cancer with hepatic metastases was published by Huh *et al.* (26). In their study, they compared 20 patients who underwent laparoscopic colorectal resection with 20 patients who had an open approach. In all cases, after the colorectal was completed (either laparoscopically or open), hepatic resection was performed, either laparoscopically or via laparotomy. There were no differences between the laparoscopic and open colectomy groups with regard to the extent of hepatic disease. Minor hepatectomies were performed in 95% of the laparoscopic group and 75% of the open colectomy group. Approximately one third of patients in the laparoscopic colectomy group also had their hepatic resections performed laparoscopically; in all cases minor hepatectomies were performed. No postoperative mortality occurred in either group. Colorectal-related complications were similar between the two groups. One intrahepatic abscess occurred in both the laparoscopic and open group. One patient in the laparoscopic group developed a bile leak. Overall morbidity was similar in the two groups. Despite the small sample size and limited number of patients who underwent a purely minimally invasive approach to both their primary tumor and hepatic metastases, the study by Huh *et al.* (26) does confirm the general feasibility and safety of a combined minimally invasive approach to colorectal cancer with limited hepatic metastases.

The very limited experience utilizing a completely minimally invasive approach to both a colorectal primary and hepatic metastases prevents us from drawing any major conclusions at this point. However, surgeons who care for patients with synchronous colorectal cancer and hepatic metastases will benefit from the lessons already learned from open synchronous and staged resections. Specifically, surgeons performing each portion of these resections must be able to ensure equivalent safety to that which is associated with open techniques. Furthermore, the literature points to major hepatectomy as the most consistent predictor of postoperative morbidity. Coincident with concerns regarding the safety of a synchronous minimally invasive approach are concerns related to oncologic outcomes. For those few institutions with surgeons with expertise in both minimally invasive colorectal cancer surgery as well as minimally invasive hepatic resection techniques, a minimally invasive simultaneous resection may be considered in patients with limited hepatic disease requiring less than hemihepatectomy.

Conclusion

The current discussion has reviewed the safety and oncologic outcomes associated with simultaneous and staged resections of synchronous metastatic colorectal cancer to the liver. In modern series of simultaneous resections, perioperative mortality is consistently ≤5% but can be expected to be higher when colorectal resections are combined with major hepatectomies involving resection of ≥3 segments. The frequency of complications following synchronous resections involving minor hepatectomies ranges from 5-48% while rates of 33-55% have been reported following major hepatectomies performed simultaneously with colorectal resections. Postoperative morbidity following staged procedures ranges from 16-67% and reflects the fact that major hepatectomies are performed more often in a staged fashion in patients with synchronous colorectal hepatic metastases.

Although complete surgical resection is superior to best systemic therapy in patients with synchronous Stage IV colorectal cancer, no clear benefit has been shown between a simultaneous resection compared to a staged resection. Future studies designed to address this question will have to control for extent of disease, timing and duration of chemotherapy, and chemotherapy-associated hepatotoxicity which may limit the extent of hepatic resection that can be safely performed.

Finally, results following minimally invasive approaches to both the colorectal primary and synchronous hepatic metastases are as yet too preliminary to draw any conclusions regarding the possible advantages of a simultaneous versus staged resection. The same rigorous evaluation of both the safety and oncologic outcomes must be performed before a minimally invasive approach can be adopted.

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Footnote

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Prevention and management of hemorrhage during a laparoscopic colorectal surgery

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Abstract: Laparoscopy is believed to play an important role in the treatment for colorectal cancer and is now extensively applied across the world. Although the safety and feasibility of laparoscopic colorectal surgery has been verified by several randomized controlled trials, intraoperative hemorrhage is still a challenge for clinicians, which could lead to conversion to laparotomy or increased mortality. In this article we discuss the strategy for prevention and management of hemorrhage in laparoscopic colorectal surgery in terms of anatomy and surgical skills.

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Introduction

Laparoscopic techniques have been widely used in the surgical treatment of gastrointestinal tumors. In particular, the feasibility of laparoscopic surgery for colorectal cancer has been well documented in a number of prospective, randomized, and controlled clinical studies. Among them, the laparoscopic radical resection of colorectal cancer has been recognized by the US National Comprehensive Cancer Network (NCCN) as an optional therapy. In fact, the laparoscopic radical operation for rectal cancer has an obvious advantage of being minimally invasive. While achieving minimal invasive and radical resection are the main targets of surgeries for tumors, safety is the foundation and prerequisite of a successful surgery. For beginners, performing a laparoscopic colorectal surgery in a safe and reliable way is the only way to success.

One of the most important and notable surgical complications is intraoperative hemorrhage. In particular, severe bleeding is one of the major complications of some laparoscopic colorectal surgeries and also one of the major causes of conversion to laparotomy.

Severe intraoperative bleeding is often caused by the injury of major blood vessels. The main causes of intraoperative hemorrhage include: (I) inadequate knowledge of the anatomical courses of the vessels under laparoscope; (II) poor identification of anatomic layers; (III) lack of correct and effective traction and effective exposure of visual field; and (IV) lack of cooperation among skillful team members. During the surgery, the operator must be able to identify the anatomic courses of vessels under the laparoscopic view and carry out correct and effective traction, so as to effectively expose the surgical field, obtain good surgical view, and thus prevent any possible injury of any vessel. This proposes higher requirements on the operator, the first assistant, and the camera holder,

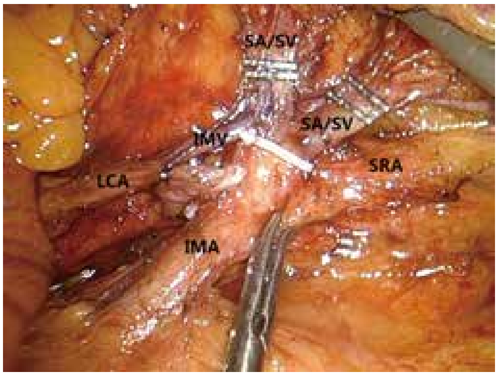

Figure 1 Blood vessels in rectum and left colon. IMA, inferior mesenteric artery; IMV, inferior mesenteric vein; LCA, left colic artery; SRA, superior rectal artery; SA, sigmoid artery; SV, sigmoid vein.

especially close cooperation and good teamwork. The operator must perform separation and dissection in correct anatomic layers to avoid vascular injury and bleeding.

As a young surgeon who is now able to independently carry out laparoscopic radical surgery for colorectal cancer, I had some experience in encountering intraoperative hemorrhage and also have seen or heard much from my mentors and peers, which I would like to share in this article.

Prevention of hemorrhage in a laparoscopic colorectal surgery

Identifying the appropriate anatomical landmarks

Surgeries in rectum or left colon: during the laparoscopic radical treatment of rectal cancer, left colon cancer, and sigmoid colon cancer, the vessels (mainly inferior mesenteric vessels and their branches) to be handled during the surgery are relatively simple. The inferior mesenteric artery (IMA) originates at the midway between the abdominal aorta at the level of the duodenum and the aortic bifurcation and then courses towards the left lower side, showing slight bulge and beating. The inferior mesenteric vein (IMV) is purple in color under laparoscope; it leaves the IMA and arises alone, with its medial landmark being the ascending part of the duodenum and the peritoneal folds of the duodenum and jejunum and the head-side landmark being the lower edge of the pancreas. A key skill for laparoscopic exposure of IMA and IMV is as follows: the assistant pulls the inferior mesenteric vascular pedicles towards the left upper side vertically, so as to form a triangle operating window with the abdominal aorta. By doing so, the unnecessary vascular injury and intra-abdominal hemorrhage can be avoided. During the dissection of the inferior mesenteric vessels, the operator uses a HIFU to complete technical actions such as picking, pulling, isolating, and separating, so as to skeletonize the vessels. This enables both lymph node dissection and prevention of bleeding. Meanwhile, the direction of HIFU energy surface should be carefully adjusted to avoid any vascular injury or bleeding. Meanwhile, during the division of the IMA root, the relationship between IMA and IMV and that between IMA and its branches [including left colic artery (LCA) and sigmoid colon artery] should be taken into consideration. In general, when IMA is closer to the root, it has a longer distance away from IMV. Therefore, when IMA is transected at its root, it will be less likely to injure IMV, left colon vessels, or sigmoid vessels. During the left colon vessel-preserving D3 radical treatment for rectal cancer or the superior rectal artery (SRA)-preserving D3 radical treatment for left colon cancer, a good knowledge of this anatomic feature will be particularly useful for the protection of vessels (*Figure 1*).

Right colon surgeries: the anatomic layers encountered during a right colon surgery are far more complex than those for left colon, rectum, and sigmoid colon; meanwhile, there are more anatomic variations in the arteries of the right colon. In fact, surgeries involving right colon are featured by a large number of variations. The right colon vessels, in particular the vein, have relatively more anatomic variations. While the ileocolic vein has a relatively fixed position and course, the right colic vein, middle colic vein, and gastrocolic common trunk often have variations. It has been reported that the frequencies of occurrence of the gastrocolic trunk and middle colic vein were 69% and 85%, respectively, whereas the frequency of the absence of right colon vein could be up to 57%; furthermore, the frequency of the right colon artery ranges only 20–30%. The branches of gastrocolic trunk also have many variations (*Figure 2*), which include the typical three-branch type (i.e., right colic vein, right gastroepiploic vein, and anterior superior pancreaticoduodenal vein), two-branch type (right colic vein and right gastroepiploic vein), and even variation that the right colic vein directly connects the superior mesenteric vein (SMV). The presence of these variations dramatically increases the risk of bleeding during a laparoscopic surgery for right colon lesions. In particular, during the handling of the common trunk, since this vessel has short and thick

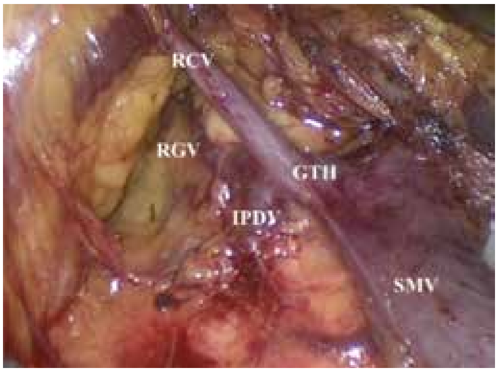

Figure 2 The classic three-branched anatomic appearance of gastrocolic common trunk.

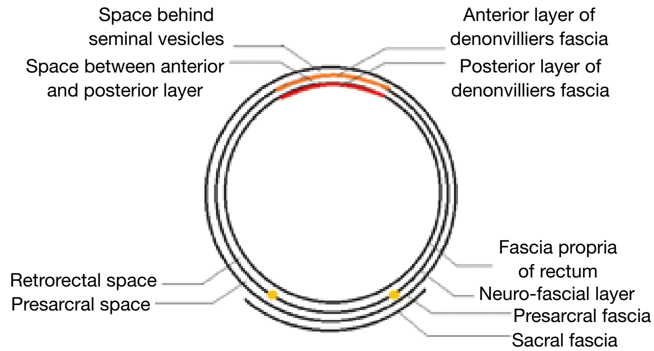

Figure 3 Schematic diagram of the anatomic layers during a rectal surgery.

anatomic structures and crispy texture, excessive traction may tear the common trunk and thus lead to bleeding; even worse, improper management can cause fatal bleeding of SMV; in contrast, inadequate traction can also result in poor exposure of anatomic layers, thus leading to bleeding. Therefore, at the beginning of the surgery, it's better to use ileocolic vascular pedicles as the anatomic landmarks; then, divide the colonic mesentery at its lower edge to open a window, which enables the operator to further search for the right retrocolic space (RRCS) and then trace and dissect the SMV along the ileocolic vessels. SMV is the main line during the surgical anatomy of the whole right colon. Dissect mesenteric adipose tissue on its surfcace to completely expose SMV; along the SMV, the dissection moves upwards to expose the branches of the arteries and veins at its right side. The ligation and transection of these branches not only are less likely to cause bleeding and meanwhile ensure the thorough D3 lymph node dissection. The same skill can be applied during searching for the common trunk and its branches, so as to adequately dissect and expose these vessels. The common trunk is often located within the range from the lower edge of pancreatic head to the line 2 cm upper from the lower edge of pancreatic head. Thus, the lower edge of the pancreatic head can also be used as one of the landmarks during searching for common trunk in a laparoscopic right colon surgery.

Entering the correct anatomical layers

Along with research advances in the local anatomy of the colorectal regional under laparoscope, it has been well documented that the Toldt's space is a vessel-free space located between mesorectum/mesocolon and prerenal fascia (PRF). Due to the continuity of PRF, it is a mutually intersecting anatomic layer that can be used as a surgical plane during the colorectal surgery. There are only two substantive obstacles: the inferior mesenteric vessels and the lateral ligaments of rectum (may include middle rectal artery). For the rectum, this plane is initially seen as the retrorectal space, which extends towards its tail side till the S4 level, at which the mesorectum and the neuro-fascial layer merge into the rectosacral fascia (Waldeyer fascia). During the operation this fascia must be divided before entering the presacral space behind it (*Figure 3*). For the left colon, this plane extends upwards to form the left retrocolic space and the transverse retrocolic space (TRCS), till the lower edge of the body and tail of the pancreas; in the right colon, it is seen as the RRCS and the TRCS. In addition, the intermembrane space (IMS) between the posterior layer of the great omentum and the top of the transverse mesocolon can communicate with the RRCS via the posterior side of the root of transverse mesocolon; therefore, IMS must be entered during the dissociation of transverse mesocolon in a left/right colon surgery. In addition, IMS can be entered by extending towards the head side in the RRCS/left retrocolic space, so as to completely resect the transverse mesocolon (*Figure 4*).

In the clinical settings, a medial approach is recommended during the entering of the proper anatomic layers. During a rectal surgery, the assistant lifts the inferior mesenteric vascular pedicle and the mesenteries of rectum and sigmoid colon towards the abdominal side and meanwhile expand and tighten the mesenteries, thus producing adequate tension. Thus, with the sacral promontory as the starting landmark, the operator cut open the mesenteries towards

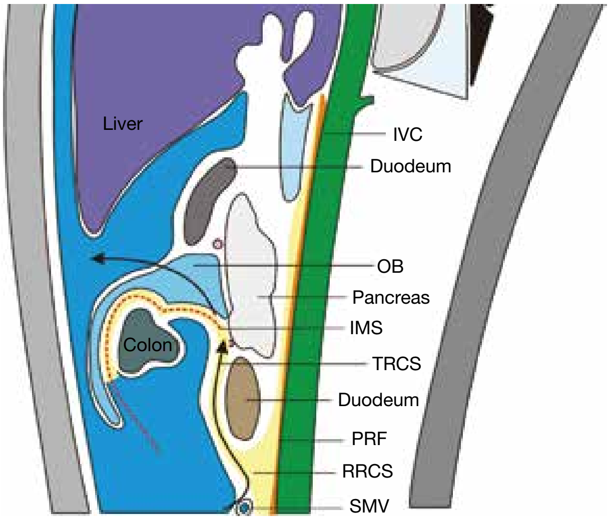

Figure 4 Schematic diagram of the anatomic layers during a colon surgery. RRCS, right retrocolic space; TRCS, transverse retrocolic space; IMS, intermensentric space; PRF, prerenal fascia; RPS, retroperitoneal space; EPS, extraperitoneal space.

the head side. Due to the atomization effect of HIFU, the space behind the rectum and the sigmoid colon naturally appears. Then, toward the tail side the retrorectal space can be gradually extended, and then the rectal fascia can be broken through to reach the presacral space; towards the head side the root of the IMA can be reached for further lymph node dissection. In this correct layer, it can be found that the proper rectal fascia wraps the fat inside the mesorectum and gently hangs down, which is smooth and thin under the endoscopic light source. After the inferior mesenteric vessels are handled, the dissection continues towards the head side till the space behind the left colon. Thus, during the left colon surgery, the same strategy can be applied to find the proper space behind left colon, so as to avoid that the application of lateral approach may lead to the entering of the excessively deep layer or even the posterior side of left kidney. Similarly, the medial approach can also be applied during a right colon surgery. As described above, the mesenterium can be cut open at the lower edge of the ileocolic vascular pedicles; then, the RRCS is entered and extended towards the head side. The duodenum and pancreatic head can be used as landmarks successively to make sure that the right space has been extended. Similarly, it can be found that the posterior lobe of the right mesocolon also holds the fat inside the mesentery and gently hangs down, which is smooth and thin. The dissection continues towards the head side to reach the TRCS and the IMS, so as to finalize the dissociation of transverse mesocolon. Towards the lateral side it can reach the peritoneum.

In summary, both sharp and blunt separation can be carried out in such a proper vessel-free surgical plance, which is a key strategy for preventing severe bleeding in abdominal or presacral cavity during a surgery.

Management of hemorrhage in a laparoscopic colorectal surgery

If severe bleeding occurs during operation, the bleeding site should be controlled as soon as possible. In this process, the operator must keep calm; meanwhile, it is equally important that the assistant and camera holder provides calm response and cooperation. Severe bleeding often has a serious impact on the laparoscopic vision, including brightness and sharpness. The "eyes" of the operator depends on the actions of the camera holder. Often a camera holder is a doctor with lowest qualification; when bleeding occurs, his performance has important impact on the operator's operations in stop bleeding. Thus, teamwork is particularly important. The camera holder must be trained to know how to avoid the impact of pulsatile bleeding on the camera, how to keep the vision clear, and how to put the main surgical field at the center of the camera. The assistant shall thoroughly expose the surgical field by adequate traction and/or effective suctioning, so that the operator can use the left hand to cooperate with the right hand to stop bleeding. For bleeding caused by vascular injury, under the active cooperation of the assistant, the operator can use the instrument in left hand to oppress or clamp the vessel firstly; then, based on the diameter of damaged blood vessel, electro-coagulation, titanium clamps, HIFU, Ligasure, absorbable clips, or large plastic clips may be applied for hemostasis; if necessary, suture ligation may be applied for hemostasis. Same as hemostasis in conventional surgeries, clamping without clear visual field should be avoided; instead, it should be performed after the bleeding has been controlled. If condition allows, the bleeding vessel can be adequately dissociated and exposed before clamping, so as to leave sufficient space for operation and thus achieve proper hemostasis. Remember: once bleeding occurs during surgery, there are limited chances for successful hemostasis. Thus, bleeding should be effectively stopped during each operation. For oozing blood (e.g., presacral hemorrhage), the bleeding may be controlled by compression firstly, followed by sunctioning of the remained blood and clearing of the visual field; finally, hemostatic gauze or bone screw may be applied for hemostasis. In most cases, hemostasis can be completed under laparoscope. Injury of a large blood vessel may lead to massive bleeding in the abdominal cavity; in such cases, conversion to celiotomy should be arranged immediately. Blind pursuit of laparoscopic surgery may miss the chances of hemostasis and therefore should be avoided.

Prevention and treatment of anastomotic bleeding

Anastomotic bleeding during a colorectal surgery (especially the surgeries for rectal cancer) is one of the severe compliations early after surgery. In most cases it occurs after surgeries for low rectal cancer. In fact, the anastomotic bleeding often occurs immediately after intraoperative anastomotic operation; however, since the bleeding is obscure, the condition will not be found until the patient is transfered to the ward. According to our experience, for patients with low rectal cancer, the intestinal canal at the distal end of the tumor shall be skeletonized as thoroughly as possible before it is transected. When a cutter & stapler or a circular stapler is applied, the stapling shall be maintained for about 15–20 s to ensure the sufficient compression and closure of the vessels inside the tissue before the transection of the intestinal canal, which can minimize the potential risk of bleeding.

Furthermore, after the anastomotic operation is completed, the intraoperative endoscopic examination is clinically meaningful for the assessment of anastomosis: it enables the early detection and timely management of anastomotic bleeding and proactively eliminates any potential bleeding, thus minimizing the risk of postoperative anastomotic bleeding. According to our experience, after the anastomotic operation is completed, the condition around the anastomosis should be carefully observed during the intraoperative endoscopic examination. If anastomotic bleeding is found, the accumulated blood should be suctioned off firstly; then, appropriate management is provided, which includes intraoperative endoscopic hemostasis using titanium clips or electrocautery unit; alternatively, suturing under direct vision may be performed to stop bleeding in the ultra-low anastomosis, so as to reduce the occurrence of postoperative anastomotic bleeding. Any active bleeding must be handled immediately; delayed treatment may lead to postoperative bleeding, which might require a second hemostasis treatment.

The management strategy of postoperative anastomotic bleeding is as follows: for minor hemorrhage, conservative treatment is preferred, along with the close observation of the bleeding volume and the patient's general condition; for major hemorrhage or in patients with unstable hemodynamics or in patients who are unresponsive to conservative treatment, non-conservative treatment should be applied. There are three specific endoscopic hemostatic therapies: spraying a haemostatic agent; electrocoagulation; and use of hemostatic clips. The endoscopic hemostatic approaches have many advantages: direct vision of the bleeding site; assessment of bleeding volume; small trauma; fewer complications; and avoiding prolonged hospital stay and saving treatment costs due to a second surgery. Many surgeons also believed that endoscopic techniques are safe and effective in treating anastomotic bleeding after a surgery for rectal carcinoma and proposed that an endoscopic hemostatic approach is preferred before a second hemostatic surgery.

When endoscopic hemostasis is applied, the patient's general condition should be carefully observed to ensure that the operation can be performed as quickly as possible when the vein is cut open and fluid replacement is performed for volume maintenance. During the operation, the accumulated blood and blood clots in the intestinal cavity should be suctioned off to improve the visual field inside the intestinal cavity; then, the bleeding site should be carefully searched for to allow appropriate hemostatic treatment. A small amount of oozing blood may exist at the anastomosis; in such cases, endoscopic spraying of epinephrine may be performed to stop bleeding; alternatively, an electro-coagulation hemostasis method may be applied, during which thermal coagulation may contribute to tissue edema and compress the blood vessels, thus achieving the hemostatic effect. For a larger amount of oozing blood or pulsatile bleeding, spraying of adrenaline should be followed by clamping with titanium clip, particularly for bleeding from a naked blood vessel or a small artery.

For surgeons, while surgical complications can not be completely avoided, there are still chances for reducing the incidence. Intraoperative hemorrhage can be caused by a variety of factors, among which anatomy, operations, and teamwork are most important. Laparoscopic colorectal surgeons must have solid knowledge on the key laparoscopic anatomic landmarks of colon and rectum and the natural anatomic layers under laparoscope and meanwhile grasp the basic operational skills required in a laparoscopic colorectal surgery. Furthermore, the surgeons should also be familiar with the prevention and management of various complications, including hemorrhage. During this process, the operator should never forget that teamwork is equally important in performing a successful laparoscopic colorectal surgery. It is for sure that the quality of laparoscopic colorectal surgeries will be constantly improved and the complications will be reduced if we strictly follow the surgical specifications, introduce new techniques in a balanced way, and continue to strengthen the technical training and learning.

Conclusions

Intraoperative hemorrhage is a common complication in colorectal surgery that needed to be identified and managed as soon as possible. It requires the surgeon to have a sound comprehension of the anatomy of colon and rectum, qualified laparoscopic operation skills, a calm mind and good teamwork.

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Footnote

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Small bowel obstruction after colon cancer surgery: does the laparoscopic approach mitigate risk?

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Provenance: This is an invited Editorial commissioned by Section Editor Wanglin Li (Department of Gastrointestinal Surgery, Guangzhou First People's Hospital, Guangzhou Medical University, Guangzhou Digestive DiseaseCenter, Guangzhou, China).

Comment on: Jensen KK, Andersen P, Erichsen R, *et al.* Decreased risk of surgery for small bowel obstruction after laparoscopic colon cancer surgery compared with open surgery: a nationwide cohort study. Surg Endosc 2016;30:5572-82.

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Jensen *et al.* present a thoughtful study exploring the incidence and outcomes of laparoscopic surgery for colon cancer. A national database, the Danish Colorectal Cancer Group database, was utilized over a 7-year period, to compare outcomes of open and laparoscopic colon cancer surgery in 8,601 patients, with a median follow up of 9.6 and 7.0 years, respectively. The primary endpoint of this study was operations for small bowel obstruction at any time after the first 30 days postoperatively and the secondary endpoint was mortality. Multivariate analysis was used to compare laparoscopic and open procedures and to identify risk factors for surgery for small bowel obstruction. The authors report a 2.9% incidence of surgery for small bowel obstruction over the study period, with a 3-year cumulative incidence of 1.5% (1.2% for laparoscopic surgery and 1.6% for open surgery) with a median time to surgery of 19.1 months. Multivariate analysis identified significant risk factors for surgery for small bowel obstruction to be: perioperative blood transfusion, higher mean blood loss during the operation, lower BMI, anastomotic leak, left/sigmoid colectomy, and open surgery. In regards to the secondary outcome of mortality, there was a 36-month median mortality of 8.6%, and 55.1% of patients who underwent surgery for small bowel obstruction died during the follow up period. The authors report that there was no significant difference in mortality between patients who underwent laparoscopic and open surgery.

The utility of laparoscopic surgery has been studied in several randomized control trials, which have paved the way for the widespread adoption of laparoscopy for colon cancer surgery by colorectal surgeons. The COST trial, a randomized multicenter prospective trial, was the first trial to confirm the non-inferiority of laparoscopy for colon cancer, with no significant differences in oncologic outcome and improved postoperative outcomes for patients undergoing laparoscopic resection (1-3). Soon after, the MRC CLASSIC trial from the UK and the COLOR trial from multiple centers in Europe also demonstrated non-inferiority of the laparoscopic approach (4-6). Since that time, several other trials have confirmed these findings (7-10). The incidence of mechanical bowel obstruction following abdominal surgery has been reported to be 9% and one of the purported benefits of laparoscopy is the lesser development of postoperative adhesions (11,12). Laparoscopic colon resection is associated with shorter intensive care unit stays, fewer complications, lower mortality, fewer readmissions and less utilization of skilled nursing facilities post discharge (13). Recently, it has been suggested that the combination of laparoscopy and enhanced recovery protocols may confer an overall survival benefit in patients with colorectal cancer (14). Similarly, a large national database study including over 45,000 patients utilized propensity score matching to demonstrate that laparoscopic colectomy is associated with lower 30-day mortality, shorter length of stay, and greater likelihood of adjuvant chemotherapy initiation among stage III colon cancer patients when compared with open colectomy (15).

Given the suspected benefits of laparoscopy, it is hypothesized that utilizing the laparoscopic approach theoretically should decrease the development of postoperative adhesions and therefore decrease the development of postoperative bowel obstruction that present and that require surgery. The article by Jensen *et al.* demonstrated that patients who underwent laparoscopic surgery had decreased risk of requiring surgery for small bowel obstruction and had decrease mortality. Surprisingly, the mortality rates reported for all patients in this study seem remarkably high. The three year overall survival rate from the index operation reported by Jensen *et al.* was 51.4%, which was not reported stage for stage. Stage for stage survival, which is a major factor in overall survival, would be helpful in interpretation of the mortality statistics provided. In the Jensen study, there was a significant difference in stage between the laparoscopic and open group, but on univariate and multivariate analysis of those undergoing surgery for small bowel obstruction, there was no difference in stage. The mortality rate amongst those patients who underwent surgery for small bowel obstruction was also considerably high at 55.1%. Stage for stage data was again not provided, which would be helpful in the interpretation of the data. Also, the methodology of identifying small bowel obstruction was "any operation for small bowel obstruction from 30 days after the index operation" utilizing procedure codes in the Danish National Patient Registry. Though we are not familiar with the Danish coding system, without review of operative notes, it is hard to assess the true incidence of adhesions as the cause of obstruction, and differentiate between adhesions and malignant obstruction. It would be informative to know more details about the patients that died after surgery for small bowel obstruction. Factors that could potentially play a significant role in mortality rates, but were not reported in this study, include: presence of carcinomatosis, age, functional status, frailty, presence of preoperative sepsis, and code status. Additionally, it would be informative to know the threshold for operative intervention in the patients who underwent surgery for small bowel obstruction as well as the severity of adhesions identify upon exploration. How long was non-operative therapy attempted prior to operative intervention? Also, did any patients undergo laparoscopic exploration for adhesive small bowel obstruction, and was this a protective factor? Another question that comes to mind is to examine similar outcomes in patients who underwent laparoscopic or open resection for diverticular disease. Though this would not necessarily compare apples to apples, it may help explore the influence of malignancy on the development of small bowel obstruction and specifically could help shed light on the reported mortality rates. If, even in benign disease, there was an increased mortality in patients who undergo open resection, this would greatly support a laparoscopic approach for all colorectal resections especially in the setting of patients with malignancy who may require adjuvant therapy.

There is also little mention of the need for, and delivery of, adjuvant therapy, nor the relationship of timing of adjuvant therapy to the development of small bowel obstructions and the potential role it may play in mortality. It is possible that patients with advanced stage disease develop and undergo surgery for small bowel obstruction while undergoing adjuvant therapy would naturally carry a higher mortality risk given their immunosuppression and possibly increase in frailty.

A similar study was recently published examining only patients undergoing rectal cancer resection (16). They reported that laparoscopic rectal cancer resection carried a decreased risk of the future need for surgery for adhesive small bowel obstruction, and reported a higher rate than following colon cancer resection (4.4%). Aquina *et al.* utilized propensity score matching to evaluate over 69,000 patients who underwent laparoscopic versus open resection (17). They reported a 2% incidence of surgery for small bowel obstruction, with open surgery and laparoscopic converted to open surgery carrying an increased risk of not only developing small bowel obstruction but requiring surgery.

There are several reports that suggest there is no difference in the risk of development of adhesive small bowel obstruction between open and laparoscopic colon cancer surgery. Alvarez−Downing *et al.* reported the frequency of small bowel obstruction to be 1.8% in the open surgery group and 1.1% in the laparoscopic surgery group within the first postoperative year (18). However, this report only followed patients for 1 year postoperatively; given that the risk of adhesive small bowel obstruction is lifelong, this study period is most likely not long enough to draw firm conclusions. Another study by Smolarek *et al.* showed no difference between laparoscopic and open, but unplanned conversion from laparoscopic to open and stoma formation carried higher risks of future development of small bowel obstruction (19). These conflicting reports of outcomes for laparoscopic resection and subsequent small bowel obstruction mandate further exploration to further elucidate the true incidence of this clinical phenomenon.

The question of whether laparoscopy improves long term outcomes for colorectal cancer is an important one but has yet to be firmly established. Laparoscopy is currently utilized in only 32.5% of colon cancer resections and a majority of operations are still performed in an open fashion (20). A survey of recent graduates of accredited colon and rectal surgery fellowship training programs in the United States demonstrated that the comfort level with laparoscopic resections has grown steadily over the last 5 years (21). As laparoscopy continues to grow, it is necessary to ask questions regarding outcomes, both short and long term. Patients undergoing any abdominal operation remain at lifelong risk for adhesive bowel obstruction, which can have a significant impact on their quality of life. While overall survival is typically the outcome of interest, the prevalence of small bowel obstruction is also important.

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Footnote

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Prolonged postoperative ileus after colorectal surgery: still an unresolved problem

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Prolonged postoperative ileus (PPOI) is often an unavoidable event after surgery, and is associated with important financial consequences such as increased complications and mortality, resource utilization and healthcare costs (1,2). An estimated 2.7 million procedures are performed annually in the US that develops PPOI leading to a readmission rate of 10% in abdominal surgeries (3). PPOI is estimated to add $8,000–9,000 to hospital costs per patient (3). Total PPOI costs to the US healthcare system were estimated to be $1.46 billion annually (1).

Data from the literature (3-13) reveal that the incidence of PPOI after colorectal surgery ranges from 2% to 54% (*Table 1*). Pooled data from a wide variety of settings show that the median incidence of PPOI is 10.3% (*Table 1*).

According to some recent studies, length of stay doubles in patients with PPOI when compared to that of patients without (3,4,8). In our previous study, the mean hospital stay was 11 days in patients without PPOI and 20 days for patients with PPOI (P<0.001) (10).

There is considerable heterogeneity with respect the definition of PPOI and there remains a need for uniformity (14). To some (7,15), postoperative ileus is the occurrence of three episodes of vomiting over 24 h, the need for re-insertion of a nasogastric tube, or the cessation of progression of oral diet. Moreover, it can be further stratified into primary (e.g., within 5 days), or PPOI (e.g., after 5 days or requiring readmission). Indeed, PPOI lasts longer, and the symptoms are uniformly recognized: abdominal pain and distention, nausea, vomiting, lack of flatus and intolerance to diet.

In our previous study (10), patients with a postoperative anastomotic leak, pelvic abscess, peritonitis, or evidence of dehiscence at relaparotomy were excluded from analysis. We defined PPOI as no flatus by postoperative day (POD) 6, with or without intolerance to oral intake by POD 6. This definition held, regardless of whether there was intolerance to oral intake by POD 6 due to abdominal distension, nausea, and emesis after starting a liquid diet and in the absence of mechanical obstruction. Finally, in some studies PPOI was defined as no return of bowel function within 7 days of operation (8).

Many surgeons have suggested that postoperative ileus after a bowel resection should last 3 days following a laparoscopic surgery and 5 days in an open approach (16). In some studies, however, the duration of PPOI is still reported to be as long as 4 days in the laparoscopic approach, which is just about 1 day earlier than that in the open approach (17).

The cause of PPOI is thought to be multifactorial and impaired contractility, dysmotility, and gut wall oedema constitute a common final pathway. Physical (e.g., manipulation of the bowel or peritoneal irritation), neural (e.g., postoperative sympathetic hypersensitivity), inflammatory (e.g., inflammatory cell activation), and

Table 1 Incidence of PPOI after colorectal surgery

Author	Year	Laparotomy	Laparoscopy	Elective	Organ	Type of study	Patients (n)	PPOI (%)	
								Overall	Laparoscopy
Hain *et al.* (4)	2018	–	x	x	Rectum	Single Institution	428	15	15
Lee *et al.* (5)	2016	–	x	x	Colorectal	Single Institution	3,188	5.5 (previous surgery) *vs.* 2.0	5.5
Wolthuis *et al.* (6)	2016	x	x	x	Colorectal	Meta-analysis	18,983	10.3	6.4
Gan *et al.* (3)	2015	x	x	x	Colon, gallbladder	Premier research database	138,068	10.3	–
Vather *et al.* (7)	2015	–	–	x	Colorectal	Single institution	327	26.9	–
Moghadamyeghane *et al.* (8)	2016	–	–	–	Colorectal	NSQIP database	27,560	12.7	–
Boelens *et al*. (9)	2014	–	–	–	Rectum	Single institution	123	54 (enteral) *vs.* 68 (parenteral)	–
Millán *et al.* (10)	2012	x	x	x	Colorectal	Single institution	773	15.9 (patients without anastomotic leak)	–
Poon *et al.* (11)	2011	–	x	–	Colorectal	Single institution	180	6	–
Kronberg *et al.* (12)	2011	–	x	–	Colorectal	Single institution	413	10.2	10.2
Delaney *et al.* (13)	2010	–	x	–	Colorectal	Multicenter	148	10.1	10.1

x, indicates type of surgery where available. PPOI, prolonged postoperative ileus.

humoral factors (e.g., increased circulating catecholamines, changes in gastrointestinal hormones released to the circulation or acting locally at the intestinal wall) or electrolyte disturbances seem to be involved in the mechanism (2,10,14,18,19).

Several studies have identified numerous risk factors that are associated with the occurrence of PPOI after colorectal surgery (*Table 2*).

Chronic preoperative use of narcotics is independently associated with PPOI in patients undergoing laparoscopic colectomy (3,12). Administration of opioids to patients who develop ileus following abdominal surgeries is associated with prolonged hospitalization, greater costs, and increased readmission rate. Furthermore, higher doses of opioids are associated with higher incidence of PPOI (3).

Open or converted operative technique is an independent predictor for the development of PPOI after colorectal surgery (4,7). In some studies, the incidence of PPOI is higher after open colorectal resection when compared to the laparoscopic approach (6). Moreover, male gender has been observed to be associated with a higher risk for the development of PPOI (4,7,10). Age (>70 years old in one study) is an independent predictor of PPOI (4,12).

A history of chronic obstructive pulmonary disease (8,10), or finding of disseminated cancer at laparotomy (8) are disease predictors of PPOI. It is of interest to note that oral antibiotic bowel preparation seems to act as a protector against the development of PPOI (8).

Finally, delayed first mobilization (8), parenteral nutrition (9), ileostomy (10), and emergency surgery (2) are associated with an increased risk for the development of PPOI.

In a recent issue of the *Journal of Gastrointestinal Surgery*, Sugawara *et al.* (20) published the results of the analysis of 841 patients operated on for major abdominal surgery that were managed following an enhanced recovery after surgery (ERAS) program. Patients who underwent less-invasive surgery (such as laparoscopic cholecystectomy, appendectomy, stoma construction or closure, and gastrointestinal bypass), ileus-related surgery, and emergency surgery were excluded from the analysis. A total of 73 patients (8.8%) developed prolonged PPOI. The authors identified smoking history, colorectal surgery, and an open approach as independent predictive factors for

Table 2 Risk factors associated with PPOI after colorectal surgery

Variables	Hain *et al.*, 2018 (4)	Vather *et al.*, 2015 (7)	Moghadamyeghaneh *et al.*, 2016§ (8)	Gan *et al.*, 2015 (3)	Millán *et al.*, 2012 (10)	Kronberg *et al.*, 2011 (12)	Other
Opioid use	–	–	–	1.99	–	3.17	–
Open surgery	–	6.37$^{\Phi}$	–	–	–	–	x
Male gender	2.3	3.01	–	–	1.61	–	–
Age	2.0*	–	–	–	–	1.89	–
Conversion to open approach	4.9	–	–	–	–	–	–
Intraabdominal surgical infection	3.8	–	2.56	–	–	–	–
Duration of surgery	–	–	–	–	–	–	x
Previous major abdominal surgery	–	–	–	–	–	2.41	x
Anastomotic leakage	–	–	2.5	–	–	–	–
Preoperative sepsis	–	–	1.63	–	–	–	–
Disseminated cancer	–	–	1.24	–	–	–	–
Chronic obstructive pulmonary disease	–	–	1.27	–	1.99	–	–
Ileo-colonic anastomosis	–	–	1.25	–	–	–	–
Oral antibiotic preparation	–	–	0.77	–	–	–	–
Laparoscopic surgery	–	–	0.51	–	–	–	–
Decreasing preoperative albumin	–	1.11	–	–	–	–	–
Increasing wound size	–	1.09	–	–	–	–	–
Operative severity	–	1.28	–	–	–	–	–
Operative bowel handling	–	1.38	–	–	–	–	–
Red cell transfusion	–	1.84	–	–	–	–	–
Intravenous crystalloid administration	–	1.55	–	–	–	–	–
Delayed first mobilization	–	1.39	–	–	–	–	–
Parenteral nutrition	–	–	–	–	–	–	x
Ileostomy	–	–	–	–	1.95	–	–
Emergency surgery	–	–	–	–	–	–	x

Data are expressed as odds ratio (OR). x, indicates association where no OR data is available; *, >70 years old; $^{\Phi}$, *vs.* laparoscopic approach; §, adjusted OR. PPOI, prolonged postoperative ileus.

PPOI. Further, they elegantly devised a nomogram based on these three predictive factors that aided in identifying patients with a high probability of developing PPOI.

According to their findings, the authors (20) suggest that patients with a high probability of PPOI should have a different perioperative management compared to those with a low probability of PPOI. The recommendations of the ERAS protocols, namely preoperative counseling, a non-fasting period, optimal fluid management, decreased use of tubes, enforced early mobilization, gum chewing, and opioid-sparing analgesia, should be enforced in these patients.

It is believed that multimodal postoperative rehabilitation (fast-track care, ERAS), and minimally invasive surgery can reduce PPOI without shortening its duration (11,21).

Minimalization of surgical manipulation may help in this regard (22).

Sugawara *et al.* (20) further explain that numerous studies have shown a lower incidence of PPOI in laparoscopic colorectal surgery compared with the open approach. However, a brief review of several studies shows that the median incidence of PPOI using the laparoscopic approach for colorectal surgery is 10% (*Table 1*), a figure similar to the overall data obtained from patients in different settings.

In terms of treatment, it has been suggested that medications such as alvimopan, ghrelin agonists, and intravenous lidocaine can prevent PPOI (16). Alvimopan is an oral, peripheral μ-opioid receptor antagonist, and currently the only US FDA-approved medication to accelerate the return of gastrointestinal function postoperatively (1). The beneficial effect of alvimopan has been validated, although it augments risk of myocardial infarction and its costs are high (22).

Recently, Gastrografin® has been examined in two randomized clinical studies comparing patients with PPOI after colorectal surgery treated with gastrografin *vs.* patients treated by placebo (23,24). Both studies did not observe benefit in shortening length of stay. However, in one trial (23), Gastrografin accelerated significantly time to flatus or stool, and time to resolution, or improved abdominal distension. Further studies are needed with larger series including a wider range of colorectal procedures to determine which groups of patients could benefit from its use.

In conclusion, PPOI still represents a clinical problem that increases postoperative length of stay with an important impact on the economic burden. To study and demonstrate the mechanisms responsible of PPOI, to develop a clinical risk stratification tool, as well as to analyze the response to specific treatments on a larger series, will provide benefit to patients and health systems.

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Footnote

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