William C.S. Meng · Hester Y.S. Cheung
David T.Y. Lam · Simon S.M. Ng *Editors*

Minimally Invasive Coloproctology

Advances in Techniques and Technology

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Preface

Starting from the conception throughout the making and final delivery of this volume, we have all along borne in mind the purpose of it all, not to replicate just another operative manual in colorectal surgery, but something handy, succinct, and evidence based. As far as it is practicable, we adopt a one-surgery, one-chapter layout with state-of-the-art technology and knowledge. We absent the book with academically loaded discourses not because they are irrelevant, rather in the contrary, we believe the speed of academic development will inevitably make any textbook dwelled in academic discussion obsolete by the time it is published. Seasoned surgeons will certainly turn to conferences and web-based medical literature to locate such discussions.

We gathered together writers who are practicing surgeons in colorectal surgery, drawing from whose experience tips, tricks, and cautionary notes scattered throughout the text will hopefully turnout helpful to the surgeon in training, and interesting in the eyes of the experienced surgeons.

This volume is the fruit of friendship between surgeons and the common aspiration of the Hong Kong Society for Coloproctology. It is our aspiration to contribute to the maturing field of colorectal surgery in Hong Kong, in China, in Asia Pacific Region, and also internationally.

We hope our readers will see our concept embodied in the text. Finally we wish to acknowledge our families without whose support and tolerance, we could not have completed this volume.

Hong Kong, China

William Meng
Hester Cheung
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Contents

Robotic Endolaparoscopic Operating Theatre

1

Michael Li

The set-up of the operating theatre (OT) has evolved and diversified from its humble beginnings to as simple as a kitchen table [1] centuries ago to a theatre today with high-definition technology and all the equipment and tools at the surgeons' fingertips.

Previously the OT was designed to accommodate the patient. The surgeon and the operating room staff adapted to the environment. With the coincident development and refinement in anaesthesia, undergoing surgery became safer, and more operations were being performed. Designs for renovation of the OT to accommodate the growing needs for equipment and tools of both the surgeon and the anaesthesiologist started to unfold.

Through the twentieth and twenty-first century, we have seen the transition of operation from open surgery to minimally invasive surgery (MIS). With the merging of endoluminal therapy and MIS [2], the needs of both fields in the same OT became a concern. We have witnessed the development initially of an MIS theatre, which transitioned to an endolaparoscopic theatre [3, 4]. With the introduction of the robot in the late 1990s [5–10], we integrated the robot in our theatre. We present our robotic endolaparoscopic theatre, hopefully making it a framework for future OT design.

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1.1 Robotic Endolaparoscopic Operating Theatre

The vision is to incorporate all the tools of MIS and endoluminal therapy into the OT. The new OT has the space and capabilities as the previous endolaparoscopic OT but integrates the special needs of the new tool in MIS, the robot.

The OT is equipped with the following:

1. Two 3-dimensional screens, a 45-in. screen, beside the robotic console and a 19-in. screen, for the surgical assistant and operating room team (Fig. 1.1).
2. The robot and the robotic console.
3. Ceiling mounted architecture holding both laparoscopic and endoscopic equipments (Fig. 1.2).
4. Two 63-in. LCD monitor screens and multiple 19-in. LCD screens covering the area 360° around the OT table (Figs. 1.3 and 1.4).
5. Cameras located on the ceiling and on the overhead lights.
6. Blue light installed to make the figures in the LCD screen sharper.
7. Centralized display and control with an easy touch screen for operating room personnel

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Fig. 1.1 Professor Li at the robotic console. The 45-in. 3D plasma screen on the upper right and special 3D glasses below the screen are provided for observers who want to appreciate the same 3D image as the console surgeon the (*white arrow*) pointing to the monitor that mentioned on the citations

Fig. 1.2 The 3D monitor for the assistants mounted on the ceiling on the far right (*white arrow*)

for table control, audio and video control of various MIS and endoscopic equipment (Fig. 1.5).

8. Centralized endoalpha, audio and video system to enhance communication between the endolaparoscopic OT and the training centre for training and teleconference.
9. Centralized patient data system inside the OT.

1.2 Rationale for a Robotic Endolaparoscopic Operating Theatre

The rapid advancement in technology allows surgeons to conduct more advanced operations through minimally invasive incisions with improved clinical outcomes. With the

Fig. 1.3 One of the 63 in. 2D plasma screens at the back of the operating team the (*white arrow*) pointing to the monitor that mentioned on the citations

Fig. 1.4 LCD monitors surrounding 360° axis around the operating table

Fig. 1.5 Centralized video and audio display with touch screen

introduction of the robot in the late 1990s [5, 6], it has paved its way to becoming an integral part of the armamentarium of MIS. The robot was integrated into the current robotic endolaparoscopic OT because it serves as one of the tools of MIS. Further, MIS tools are concurrently used in applying the best technique to the patient when it is needed. The robot is viewed as no different from the other tools in MIS.

1.2.1 Benefit for the Surgeon

The robot was designed specifically to compensate for the technical limitations of laparoscopic instruments [11]. Its capability to reproduce complete hand and wrist-like movements at the instrument tip overcomes the limited degrees of freedom and fixed trocar axis points found in standard laparoscopic instruments [5–8].

The current display system in laparoscopic surgery has two types of visual problems: impaired depth perception and difficulty in varying the perspective of point of view of the operative field [9]. The 3D depth cues that naturally provide humans with the sense of depth perception (parallax, stereopsis and disparity) are missing in endoscopic surgery [9].

With the addition of a 3-dimensional view in robotic surgery, depth perception is almost as good as in open surgery. The robot is used in instances where precision is paramount, enabling

Fig. 1.6 The blue light on the right provides a clearer and definite image on the monitors in the operating theatre

more accurate and precise surgery [12] and predictably should result in fewer complications and improved patient outcomes. However, this view in robotic operating theatres around the world is limited to the surgeon operating at the robotic console, while the assistants and the observers see the image only in its 2-dimensional view.

A unique, clear, high-definition 3-dimensional software technology was specifically designed by our medical physicist for Pamela Youde Nethersole Eastern Hospital. This design is called the 'stereotactic visualization system for robotic and laparoscopic surgery'.

The innovation of this robotic endolaparoscopic Operating Theatre is the presence of two 3D monitors, a 19-in. screen for the assistant surgeons and scrub nurses, and a 45-in. plasma screen for teaching purposes. With these, the 3D view appreciated by the surgeon working at the robotic console is translated and shared not only to the assistants, but also to the operating room staff and observers. This results in the assistants working in synchrony and harmoniously with the surgeon. The big plasma 3D screen aids in teaching and sharing of skills wherein trainees and observers are provided with special glasses to appreciate the 3D view during robotic surgery, a view which was previously limited only to the surgeon.

The theatre is also equipped with two 63-in. 2-dimensional plasma screens and six 19-in. 2-dimensional flat screens. The lighting in the new operating theatre makes use of blue light; this important feature results in improved clarity and resolution of the images in the screens around the operating theatre. With the current OT set-up, it makes the OT easier for the surgeon as a variety of minimally invasive and endoscopic equipment are available anytime the surgeon needs it (Fig. 1.6).

Communication capabilities are available within this new theatre. Routing of images from the endoscope, laparoscopic or robotic camera, cameras mounted on operating room lights and overhead cameras to strategically placed flat panel monitors around the operating theatre can be performed using a central control unit. The integrated audio and video system of the new robotic endolaparoscopic theatre allows communication and telesurgery [13] from the operating theatre to the conference room down the hall, across the street, to teaching and training centres and hospitals not only in Hong Kong but also to other countries around the world.

1.2.2 Benefit for the Operating Room Staff

The ceiling mounted beams hold both laparoscopic and endoscopic equipment. This design saves space and rids the operating theatre of bulky equipment [13–17]. It also facilitates theatre set-up by the operating room staff, in that the equipment and cords are off the floor, and there is no need to do equipment connection or reconnection all the time [13–17]. The clean-up after operation is also made easier, with improved theatre turnover overall. Occupational safety is better as electric cables are not on the floor, and thus hazard is minimized [14].

There is no question that suspending the major equipment and the screens greatly increases the amount of floor space available, thereby improving the OR staff's traffic patterns, and making it easier for the surgeon to keep track of the procedure. In our endolaparoscopic theatre there was a 38% reduction in OR set-up time (6.7 vs. 10.8 min), 46% reduction in turnover time (6.3 vs. 11.6 min) and a 60 % reduction in time required to set up an additional scope (4.6 vs. 11.6 min) [3].

1.2.3 Benefit for the Patient

The benefit of MIS for patients includes both short- and long-term benefits. Short-term outcomes include faster perioperative recovery, less pain, shorter hospital stay and cosmesis. Long-term outcomes include equivalent oncologic outcomes, equivalent recurrence rates and equivalent quality of life outcomes as compared to the traditional open surgery [18–22].

However, the benefit of the robot to patients has not been established as of yet. However, using the robot in specific parts of the operation, using it when it is needed most, allows the surgeon to see better, perform better and hopefully results in optimal clinical outcomes.

1.3 Operating Theatre of the Future

The goal is to provide the best environment for the surgeon and the operating team [13, 14]. An optimal work environment that prevents errors and discomfort is also dependent on factors such as the environment, equipment, and medical staff. Working conditions are improved without sacrificing safety, efficiency, and comfort [14].

By providing the best environment, hospitals need to invest in hospital equipment; however, a major deterrent in setting up is the cost. However, investing in hospital equipment may result in better delivery of patient services and shorter hospital stay [15].

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2 Evidence-Based Minimally Invasive Surgery for Colorectal Cancer

Dennis Chung Kei Ng and Ka Lau Leung

2.1 Introduction

Colorectal cancer is a major health problem worldwide. It accounts for 9 % of cancer incidence. It is also the third most common cancer and the fourth most common cause of death in the world [1, 2]. The incidence of colorectal cancer in Hong Kong raised from 3,210 per 100,000 persons in 2,000 to 4,450 per 100,000 persons in 2011, and it also become the commonest cancer in Hong Kong [3]. Traditionally, cancer surgery consisted of laparotomy and resection of the involved colon or rectum, together with its blood supply and lymphatic drainage. With the advancement of technology, there are many varieties of minimally invasive approach in managing this condition. Enormous data, ranging from case reports to well-organized randomized control trials (RCT) and meta-analyses are available in the literature. We review the local data as well as the international data of different minimally invasive approach in this chapter.

Generally speaking, minimally invasive surgery for colorectal cancer can be classified into local excisions, i.e., endoscopic submucosal dissection (ESD) and transanal endoscopic microsurgery (TEM), colorectal resection with laparoscopic approach, derivatives of laparoscopic surgery such as hand-assisted laparoscopic surgery (HALS), single incision laparoscopic surgery (SILS), and natural orifice transluminal endoscopic surgery (NOTES), to the newest robotic surgery. Each approach has its own advantage and limitation.

2.2 Endoscopic Submucosal Dissection (ESD)

Endoscopic submucosal dissection is a novel endoscopic technique which consisted of submucosal injection and elevation, mucosal incision, submucosal dissection, and on-bloc removal of the lesion. It is most commonly performed in Japan. The current recommendation by the Colorectal ESD Standardization Implementation Working Group included those lesions difficult to be removed en bloc with a snare endoscopic mucosal resection (EMR); those lesions with fibrosis due to biopsy or peristalsis; sporadic localized lesions in chronic inflammation such as

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ulcerative colitis; and local residual early carcinoma after endoscopic resection [4–6].

The role of ESD in colorectal cancer is less well defined. In view of the technical limitation, it can only remove those lesions without submucosal invasion. Therefore, besides being a diagnostic tool, it can only be used as a curative treatment for those early cancers without submucosal invasion or lymph node metastasis. Hon et al. compared the technique of ESD versus local excision in the treatment of early rectal neoplasm. They showed that ESD offered better short-term clinical outcomes in terms of faster recovery and possibly lower morbidity than local excision [7].

In conclusion, ESD is an option in managing early colorectal cancers, providing that expertise is available (Table 2.1).

2.3 Transanal Endoscopic Microsurgery (TEM)

Transanal endoscopic microsurgery was first described by Professor Gerhard Buess from Tubingen, Germany, in the early 1980s [9]. This minimally invasive technique revolutionizes the local resection of rectal lesions. By making use of an operating microscope, it permits resection of rectal lesions with adequate margin, which may require a major proctectomy or even an abdominoperineal resection in some patients. It has the advantage of scarless operation, faster recovery, shorter hospital stay, reduced morbidity and mortality, and decreased long-term dysfunction [10–13].

How about its role in colorectal cancer? TEM was proposed as standard treatment for lower rectal T1 tumor in the past two decades. Wu et al. performed a meta-analysis on TEM versus conventional rectal surgery (CRS) in the treatment of T1 rectal cancer [14]. Five studies and 397 patients were enrolled in the meta-analysis. Only one of them was RCT [15]. The complications were observed in 16/196 in the TEM group and 77/163 in the CRS group ($p=0.01$). Mortality was 3.68 % in CRS group and 0 in TEM group ($p=0.01$). There was more recurrence in the TEM group (12.0 % vs. 0.5 %), but this difference did not transfer to the 5-year survival rates [14].

On the contrary, the evidence of TEM alone in the management of T2 tumor is less favorable. The main reason is the higher chance of lymph node metastasis in more advanced tumor. Borschitz et al. performed a review on the effect of local excision in more advanced rectal tumors [16]. They identified 8 studies and 124 patients in the literature in whom their T2 carcinoma was locally excised as the sole procedure. The local recurrence rate was 19 % after R0 resection by local excision alone, and rose to 52 % if high risk factors also present. By immediate radical reoperation, the recurrence rate decreased to 7 %. The recurrence rate for local excision after adjuvant therapy and neoadjuvant chemoradiotherapy was 16 % and 9 %, respectively. Eleven percent of patients developed metastasis after adjuvant therapy [16].

In a recent RCT in 2012, Lezoche et al. compared the endoluminal locoregional resection versus laparoscopic total mesorectal excision for T2 rectal cancer after neoadjuvant therapy [17]. They demonstrated significantly shorter operative time, lesser blood loss, lesser analgesic requirement, shorter hospital stay, and less stoma (temporary and definitive) in the TEM group. At long-term follow-up, local recurrence had developed in four patients (8 %) after TEM and three (6 %) after TME. Distant metastases were observed in two patients (4 %) in each group. There was no statistically significant difference in disease-free survival ($P=0.686$) [17].

In summary, TEM is a recognized option in the treatment of T1 rectal cancer. For more advanced tumor, TEM alone is not recommended. Combination with adjuvant or neoadjuvant therapy may be considered in selected patients and on research basis (Table 2.1).

2.4 Laparoscopic Colorectal Resection

After the first successfully laparoscopic colectomy in 1991 [18], the treatment of colorectal cancer was completely revolutionized in the past

Table 2.1 Evidence of different minimally invasive approach in colorectal cancer surgery

	Applications	Short-term benefits	Long-term outcomes
Endoscopic submucosal dissection (ESD)	Early colonic or rectal cancer without submucosal invasion	Faster recovery and possibly lower morbidity when compared with local excision (Level 3[a])	Data insufficient
Transanal endoscopic microsurgery (TEM)	T1 rectal cancer, or selected T2 rectal cancer when combined with adjuvant or neoadjuvant therapy	Scarless operation, faster recovery, shorter hospital stay, and reduced morbidity and mortality when compared with open surgery (Level 3[a])	T1: More recurrence but no survival difference when compared with open rectal surgery (Level 3[a]) T2: More recurrence when used alone (Level 3[a]) Insufficient data when combined with adjuvant or neoadjuvant therapy
Laparoscopic colectomy	Colonic cancer	Less blood loss, less pain, shorter hospital stay, less ileus, better pulmonary function, better quality of life, and less morbidity when compared with open surgery (Level 1[a])	Long-term survival and disease-free survival are comparable to open surgery (Level 1[a])
Laparoscopic proctectomy	Rectal cancer	Less blood loss, less pain, faster first defecation, shorter hospital stay, fewer wound complications, and less morbidity when compared with open surgery (Level 1[a])	Long-term survival, disease-free survival, and sexual and bladder function are comparable to open surgery (Level 1–2[a])
Hand-assisted laparoscopic surgery (HALS)	Colonic or rectal cancer	Less blood loss, less wound infection, less ileus, shorter wound length, faster recovery of gastrointestinal function, and shorter hospitalization stay when compared with open surgery (Level 1[a]) No significant advantage over conventional laparoscopic surgery (Level 2[a])	Data insufficient
Single incision laparoscopic surgery (SILS)	Selected small colonic cancer	Shorter wound length and shorter hospital stay when compared to laparoscopic surgery (Level 3[a])	Data insufficient
Nature orifice transluminal endoscopic surgery (NOTES)	Selected colonic or rectal cancer under research condition	Better pain score and lesser wound infection when compared to laparoscopic surgery (Level 2[a])	Data insufficient
Robotic surgery	Rectal cancer	Lower conversion rate, longer operative time and higher costs when compared with laparoscopic surgery (Level 3[a])	No difference in lymph node harvested and circumferential margin when compared with laparoscopic approach (Level 3[a]) Data insufficient in survival

[a]The Oxford 2011 Levels of Evidence [8]

two decades. Many RCTs and meta-analyses were performed and published in the literature. More and more colorectal surgeons changed their practice from the conventional open to the laparoscopic approach. Many technical obstacles were gradually resolved with the advancement of technology. Nowadays, laparoscopic resection is the "gold" standard in many of the world leading colorectal centers.

The short-term benefit of laparoscopic colorectal cancer resection was well addressed in the literature. The first RCT was published by Lacy et al. in 2002, 219 patients were randomized into laparoscopic and open groups. They showed that laparoscopic approach was more effective in terms of morbidity, hospital stay, tumor recurrence, and cancer-related survival [19]. However, this study was being challenged for the high recurrence rate in the open group (14 %) and inadequate lymph node harvest from both groups. In 2004, Leung et al. [20] from Hong Kong published another RCT on the laparoscopic resection of rectosigmoid cancer. Four hundred and three patients were randomized into open and laparoscopic group. They showed that laparoscopic approach was no different from open group in terms of distal margin, number of lymph node harvested, morbidity, and mortality. The only difference was longer operative time but the hospital stay was shorter. There was no difference in both the 5-year survival (laparoscopic 76.1 % vs. open 72.9 %) and disease-free survival (laparoscopic 75.3 % vs. open 78.3 %) between two groups [20].

When compared to single center RCTs, multicenter RCTs can recruit more patients in a shorter period of time. There were multiple landmark large-scale multicenter RCTs carried out in the subsequent years – COST [21], CLASICC [22], and COLOR [23] trials. In the COST trial, 48 institutions and 872 patients were involved. Twenty-one percent conversion rate was seen in the laparoscopic group. Short-term benefits including shorter hospital stay (5 days vs. 6 days, $p<0.001$), briefer use of parenteral narcotics (3 days vs. 4 days, $p<0.001$), and oral analgesics (1 day vs. 2 days, $p=0.02$) were observed. The rates of intraoperative complications, 30-day postoperative mortality, complications at discharge and 60 days, hospital readmission, and reoperation were very similar between groups. The overall survival rate at 3 years was also very similar between the two groups (86 % in the laparoscopic-surgery group and 85 % in the open-colectomy group; $p=0.51$; hazard ratio for death in the laparoscopic-surgery group, 0.91; 95% CI: 0.68–1.21) [21].

While in the CLASICC trial, 794 patients with colorectal cancer were recruited from 27 UK centers. The conversion rate was 29 %. No differences were recorded between open surgery and laparoscopic-assisted surgery for colorectal cancer with respect to tumor and nodal status, short-term endpoints, and quality of life. Eighty-one (10 %) patients had intraoperative complications, with no difference between treatments (difference 0.2 %, 95 % CI −4.2 % to 4.6 %, χ^2 test, $p=0.93$). Complication rates were higher for rectal procedures, (51 (13 %) of 381 vs 30 (7 %) of 413, respectively). The complication rate was also higher in converted patients than in nonconverted patients and in those who underwent open surgery, even after adjustment for stratification factors ($p=0.002$) [22].

In the COLOR trial, 1,248 patients with right, left, or sigmoid colon cancer were recruited from 29 hospitals. Laparoscopic group had less blood loss compared with those assigned to open resection (median 100 mL [range 0–2,700] vs. 175 mL [0–2,000], $p<0.0001$), although laparoscopic surgery lasted 30 min longer than did open surgery ($p<0.0001$). Conversion to open surgery was needed in 91 (17 %) patients. Number of removed lymph nodes and length of resected bowel did not differ between groups. Laparoscopic colectomy was associated with earlier recovery of bowel function ($p<0.0001$), fewer analgesics requirement, and a shorter hospital stay ($p<0.0001$) when compared with open colectomy. There was no difference in morbidity and mortality [23].

We can see that the short-term benefits were very obvious in these RCTs, and it was further summarized in a meta-analysis in 2005 [24]. Twenty-five RCTs with 3,526 patients were included in this meta-analysis. It demonstrated that laparoscopic technique was associated with the following advantages: blood loss was reduced (−72 cc), pain was less intense (−8 to −12 mm on a 100 mm VAS for pain), pulmonary function was improved (0.38–0.56 l on postoperative day 1 and 3), duration of postoperative ileus was shorter (−1.0 day), postoperative duration of hospital stay was less (−1.4 days), and quality of life might be improved in the early postoperative course (10 points on a 0–100 scale on day 7, 14 points on day 30, not any more at day 60). Furthermore, the risk of postoperative morbidity was decreased by the laparoscopic approach (RR 0.72 [95 % CI 0.55–0.95]), namely because of reduced surgical morbidity (wound infection [RR 0.56; 95% CI 0.39–0.82] and postoperative mechanical ileus [RR 0.42; 95 % CI 0.24–0.75]). However, the incidence of general postoperative complications was not decreased by the laparoscopic approach (RR 0.85 [95 % CI 0.61–1.18]) [24].

How about the long-term outcomes? Survival is the most important outcome indicator in any cancer surgery. In 2008, the same group of researcher performed a meta-analysis on the long-term results of laparoscopic colorectal cancer resection for the Cochrane Database of Systematic Reviews [25]. Thirty-three RCTs were identified while 12 of these trials, involving 3,346 patients, reported long-term outcome and were included. No significant differences in the occurrence of incisional hernia, reoperations for incisional hernia, or reoperations for adhesions were found between laparoscopically assisted and open surgery. Rates of recurrence at the site of the primary tumor were similar. No differences in the occurrence of port-site or wound recurrences were observed. Similar cancer-related mortality was found after laparoscopic surgery compared to open surgery (colon cancer: 5 RCTs, 1,575 patients, 14.6 % vs 16.4 %; OR (fixed) 0.80 (95 % CI 0.61–1.06) ($p=0.15$); rectal cancer: 3 RCTs, 578 patients, 9.2 % vs 10.0 %; OR (fixed) 0.66 (95 % CI 0.37–1.19) ($p=0.16$)). Four studies were included on hazard ratios for tumor recurrence in laparoscopic colorectal cancer surgery. No significant difference in recurrence rate was observed between laparoscopic and open surgery (hazard ratio for tumor recurrence in the laparoscopic group 0.92; 95 % CI 0.76–1.13). No significant difference in tumor recurrence between laparoscopic and open surgery for colon cancer was observed (hazard ratio for tumor recurrence in the laparoscopic group 0.86; 95 % CI 0.70–1.08). However, the long-term results on rectal cancer were not sufficient in the literature [25].

In view of insufficient data on the long-term outcomes to justify the recommendation of laparoscopic rectal cancer excision, many researchers try to retrieve the long-term survival data from their existing RCTs. One of which was from the group of the Chinese University of Hong Kong [26]. Two hundred and seventy eight patients with rectal cancer were recruited from three RCTs previously performed. The median follow-up time of living patients was 124.5 months in the laparoscopic group and 136.6 months in the open group. At 10 years, there were no significant differences in locoregional recurrence (5.5 % vs. 9.3 %; $p=0.296$), cancer-specific survival (82.5 % vs. 77.6 %; $p=0.443$), and overall survival (63.0 % vs 61.1 %; $p=0.505$) between the laparoscopic and open groups. There was a trend toward lower recurrence rate at 10 years in the laparoscopic group than in the open group among patients with stage III cancer ($p=0.078$). The Cox regression analysis showed that stage III cancer, lymphovascular permeation, and blood transfusion, but not the operative approach, were independent predictors of poorer cancer-specific survival.

Until recently, the first meta-analysis compared on the RCTs of laparoscopic versus open resection for rectal cancer was published in 2012 [27]. It demonstrated that laparoscopic surgery for rectal cancer had a statistically significant advantage over open surgery in terms of intraoperative blood loss, number of blood transfusions, hospital stay, postoperative ileus, postoperative abdominal bleeding, long-term complications, and long-term morbidity including obstruction by adhesions [27]. However, another meta-analysis by Huang et al. [28] focused on the oncologic adequacy of resection and long-term oncologic outcomes. Their meta-analysis suggested that there were no differences between laparoscopic-assisted and open surgery in terms of number of lymph nodes harvested, involvement of circumferential margin (CRM), local recurrence, 3-year overall survival, and disease-free survival for rectal cancer from six RCTs [28].

Finally, comparison between open and laparoscopic total mesorectal excision (TME) of rectal cancer is always a hot discussion among colorectal surgeons. A latest meta-analysis in 2014 addressed this issue. Fourteen RCTs met the inclusion criteria. The mean conversion rate was 14.5 % (range 0–35 %). There was moderate quality evidence that laparoscopic and open TME had similar effects on 5-year disease-free survival (OR 1.02; 95 % CI 0.76–1.38, 4 studies, $N=943$). The estimated effects of laparoscopic and open TME on local recurrence and overall survival were similar, although confidence intervals were wide, both with moderate quality evidence (local recurrence: OR 0.89; 95 % CI 0.57–1.39 and overall survival rate: OR 1.15; 95 % CI 0.87–1.52). There was moderate to high quality evidence that the number of resected lymph nodes and surgical margins were similar between the two groups. For the short-term results, length of hospital stay was reduced by 2 days ((95 % CI −3.22 to −1.10), moderate quality evidence), and the time to first defecation was shorter in the laparoscopic group (−0.86 days; 95 % CI −1.17 to −0.54). There was moderate quality evidence that 30 days morbidity were similar in both groups (OR 0.94; 95 % CI 0.8–1.1). There were fewer wound infections (OR 0.68; 95 % CI 0.50–0.93) and fewer bleeding complications (OR 0.30; 95 % CI 0.10–0.93) in the laparoscopic group. There was no clear evidence of any differences in quality of life between laparoscopic and open groups regarding functional recovery, bladder, and sexual function [29].

In conclusion, laparoscopic approach for colonic cancer has a better short-term outcome while comparable long-term oncological survivals to its open counterpart on multiple large-scale RCTs and meta-analyses. The short-term benefit for laparoscopic approach over open approach for rectal cancer has also been proven by multiple RCTs and meta-analyses, and the long-term oncological outcomes are comparable in the latest meta-analysis, although the quality of evidence is moderate (Table 2.1).

2.5 Hand-Assisted Laparoscopic Surgery (HALS)

Laparoscopic surgery for colorectal cancer is technically difficult with steep and long learning curve. In the early 1990s, hand-assisted laparoscopic colectomy was introduced to facilitate the transition from open to laparoscopic approach [30]. HALS allows the surgeon to insert his or her hand into the abdominal cavity through a relatively small incision while preserving the ability to work under pneumoperitoneum. However, this technique is getting out of favor as the advancement and mature of the laparoscopic technique.

As HALS acts as a bridge between open surgery and laparoscopic surgery, comparison can be made with both approaches. A recent meta-analysis in 2014 compared the hand-assisted laparoscopic surgery versus open surgery in colorectal disease [31]. There were twelve studies that included 1,362 patients were studied. Five of them were RCTs, while 7 are retrospective studies. The conversion rate was 2.66 %. Compared with the open surgery group, blood loss, wound infection, and ileus were significantly less in the HALS group; and length of incision, recovery of gastrointestinal function, and hospitalization stay were shorter. There were no significant differences in operating time, hospitalization costs, mortality, and complications between the groups [31]. However, long-term oncological outcomes were lacking.

Another meta-analysis compared the HALS with the conventional laparoscopic colorectal surgery [32]. Only three RCTs with 189 patients met the criteria. One study focused on the malignant lesions, one on benign lesions, while the remaining one had 1/3 malignant lesions. Conversion rates (odds ratio 0.32 [95% CI: 0.11, 0.90]) were significantly decreased in patients undergoing hand-assisted surgery but there was no statistically significant difference in operative time or complication rates. There were no significant differences in both the minor and major complications, pain score, bowel function, quality of life, and length of stay. No mortality was reported and long-term oncological outcomes were lacking. All studies were associated with methodological limitations [32].

In summary, hand-assisted laparoscopic colectomy has better short-term outcomes than open approach, and comparable short-term outcomes to laparoscopic approach, however, the evidence was not strong (Table 2.1). Long-term oncological data was lacking.

2.6 Single Incision Laparoscopic Surgery (SILC)

Single incision laparoscopic colectomy was first reported by Remzi and colleagues [33] and Bucher and coworkers [34]. Its potential benefits include less patient trauma, better cosmetic result, and patient satisfaction, less postoperative pain, and faster recovery; however, the manipulation of the instrument and the limitation of the movement on the single port may have resulted in more complications and inferior oncological outcomes.

In 2012, Maggiori et al. published the first meta-analysis on this topic [35]. Fifteen comparative studies with total 1,075 procedures (494 single incision and 581 multiport laparoscopies) were included. There were no differences in conversion rate, morbidity, and operation time, but a significantly shorter total skin incision (Weight Mean Difference (WMD) 0.52 (0.79, 0.25); $p<0.001$) and a significantly shorter postoperative length of stay (WMD 0.75 (1.30, 0.20); $p=0.008$) after single incision laparoscopic surgery compared with multiport laparoscopic approach. However, the data on the lymph node harvested and long-term oncological outcomes were lacking [35].

Several RCTs published after this meta-analysis, one of the larger studies was from the Hong Kong University [36]. Twenty-five patients with small colonic cancer (<4 cm) were randomized in each arm. There were no significant differences in patient's demographics, tumor characteristics, operating time, blood loss, complication rate, number of lymph nodes harvested, and resection margin between the two groups. The SILS group had consistently lower median pain score in the whole postoperative course and shorter length of hospital stay, and the difference was statistically significant [36].

In conclusion, based on the nonrandomized comparative trials and small RCTs, single incision laparoscopic colectomy has better pain control and length of hospital stay when compared to conventional laparoscopic colectomy. The long-term oncological outcomes were lacking (Table 2.1). It should only be applied in selected patients with colorectal cancer.

2.7 Natural Orifice Transluminal Endoscopic Surgery (NOTES)

Natural orifice transluminal endoscopic surgery was first described in 2004 [37]. The technique was initially tested in animal model and later it was mainly used in specimen retraction in colorectal surgery [38]. When it is combined with the traditional laparoscopic colectomy, it becomes a hybrid NOTES approach which was described by Cheung and her team in 1999 from Hong Kong [39].

Further, an RCT was performed by the same group to compare this innovative approach with the conventional laparoscopic surgery. Thirty-five patients with left-sided colonic cancer were randomized into each group in a 3-year interval. There were no significant differences observed between the two groups with respect to operating time, blood loss, or length of hospital stay. The pain score (1 vs. 2, $p=0.017$) and wound infection (0 vs. 4, $p=0.005$) were significantly lower in the hybrid NOTES group [40].

The latest development in this approach is the transition from the hybrid NOTES to pure NOTES. Leroy and colleagues reported the first case in 2003 [41]. A middle-aged woman with mid-rectal cancer underwent a pure transanal total mesorectal excision with a coloanal anastomosis without a diverting stoma successfully.

In summary, NOTES and hybrid NOTES are still at the experimental stage. It may have potential short-term benefit in terms of pain and wound complications when compared to the conventional laparoscopic surgery in selected patients (Table 2.1). It should not be used routinely in daily practice.

2.8 Robotic Colorectal Surgery

The advantages of laparoscopic surgery in colorectal cancer are well demonstrated previously. However, the long and steep learning curve, limited two-dimensional vision, and reduced dexterity of movement are major challenges. Bulky low rectal tumor in obese male patient is always a nightmare for laparoscopic