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Evolution of laparoscopy in colorectal surgery: An evidence-based review

Alexander Emmanuel Blackmore, Mark Te Ching Wong, Choong Leong Tang

Alexander Emmanuel Blackmore, Mark Te Ching Wong, Choong Leong Tang, Department of Colorectal Surgery, Singapore General Hospital, Singapore 169856, Singapore

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Correspondence to: Mark Te Ching Wong, MBBS, FRCS, Consultant Surgeon, Department of Colorectal Surgery, Singapore General Hospital, 20 College Road, Academia, Outram Road, Singapore 169856, Singapore. mark.wong@sgh.com.sg

Telephone: +65-6-3214677 Fax: +65-6-2273787

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Abstract

Open surgery for colorectal disease has progressed significantly over the past century from humble beginnings to form the mainstay of treatment for colorectal cancer and a number of benign conditions. Following the introduction of laparoscopic abdominal surgery, the next stage in the evolution of the specialty began in the 1990s with the first laparoscopic colonic resection. Following some early concerns regarding its safety and oncological efficacy during the latter part of that decade, laparoscopic colorectal surgery rapidly came into mainstream use in the early part of the current century with evidence supporting its use being made available from large scale randomised controlled trials. This article provides an evidence-based summary of this evolutionary process as it relates to both benign and malignant colorectal disease, as well as discussion of the next phase of new technologies such as robotic surgery.

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Key words: Colorectal surgery; Colorectal cancer; Pelvic

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Core tip: This article provides a historical perspective on the development of minimally invasive surgery for colorectal disease, as well as a summary of the key evidence supporting its use for treating both benign and malignant disease. We further discuss new minimally-invasive technologies which represent the next step in the evolution of colorectal surgery.

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INTRODUCTION

The term “laparoscopy” is derived from the Greek words “lapara”, meaning “the soft parts of the body between the rib margins and hips”, and “skopein”, meaning, “to see, view or examine”. Laparoscopy has therefore come to describe the process of viewing the contents of the abdominal cavity indirectly, *i.e.*, using specially designed instruments and a camera system controlled by the surgeon from outside the abdomen.

Following the work of early pioneers of open colonic resection, such as Sir William Arbuthnot-Lane at Guy’s Hospital in London during the early part of the 20th century^[1], open surgery to resect the colon and rectum for a wide range of diseases developed rapidly during the last century. Although Lane was ridiculed in 1913 for performing total colectomy for patients with chronic constipation, the technique soon became widely accepted for the management of a wide range of elective and emergency conditions, both benign and malignant.

DEVELOPMENT OF LAPAROSCOPIC ABDOMINAL SURGERY

The 1980s heralded the development of laparoscopic general surgical procedures, with the first laparoscopic cholecystectomy being performed by Mühe in Germany on September 12th 1985^[2]. This was followed in 1991 by the first reports of colonic resection performed with laparoscopic assistance by Jacobs in Miami, Florida^[3], and separately by Fowler *et al*^[4] in Kansas. The subsequent development of laparoscopic surgery resulted in the development of a variety of new instruments that have allowed increasingly complex procedures to be performed in a safe and efficient manner. Laparoscopic camera equipment is now available which can focus automatically, and even produce three-dimensional images if required. A wide variety of instruments are now available for retraction and dissection of tissues, as well as laparoscopic stapling devices to efficiently and safely divide both bowel and vascular pedicles, even deep in the pelvis. Several different types of energy devices have been developed or adapted from equipment used in open surgery to dissect tissues and seal vessels, including monopolar electrocautery scissors, ultrasonic coagulating shears and electrothermal bipolar vessel sealers. The precise type of device employed is largely determined by cost and surgeon preference, with no clear evidence suggesting the superiority of any particular energy device^[5].

EARLY DEVELOPMENT OF LAPAROSCOPIC COLORECTAL TECHNIQUES

Throughout the 1990s concerns regarding the oncological safety and efficacy of laparoscopic colorectal resection, with little robust evidence as to its advantages over open surgery, limited uptake of the procedure. These concerns included high rates of abdominal port-site metastases reported in small case series and various theories were proposed to explain this phenomenon, including direct implantation of tumour cells either through close contact of instruments coated with tumour cells and the port, during the release of the pneumoperitoneum, or during extraction of the specimen through a small incision. It was also thought to be a possibility that manipulation of the bowel using laparoscopic instruments may lead to increased exfoliation of tumour cells in comparison with open techniques, or even that the gas used to create the pneumoperitoneum could somehow be stimulating tumour growth^[6,7]. Further data from larger series in the latter part of the decade, showed that the incidence of abdominal wall metastases could be reduced to an acceptable rate which was similar to that observed for open surgery with the use of wound protection devices at the extraction site^[8]. Despite these concerns surrounding surgery for colorectal cancer, the development of laparoscopic procedures for benign conditions continued,

particularly for rectal prolapse in the form of rectopexy. There is no doubt that colorectal disease associated with a significant degree of inflammation, such as complicated diverticular or inflammatory bowel disease, can present a formidable challenge for the laparoscopic surgeon, which has been reflected in evidence from large scale trials supporting laparoscopic resection for these indications lagging behind those relating to surgical oncology. This evidence, however, does support the view that this surgery can be performed safely and effectively^[9].

One might wonder if the early development of new surgical techniques such as laparoscopic resection might more appropriately be applied to benign conditions rather than malignancy due to concerns over possible inadequacy of oncological clearance, and it would appear that this paradox is being replicated in the development of robotic colorectal surgery. Perhaps this situation has arisen due to concerns over the technical difficulties of resecting inflammatory disorders such as diverticular disease or inflammatory bowel disease, which frequently involves adjacent structures, as opposed to relatively early colorectal tumours, or a desire to pioneer new techniques on the colon as opposed to in the relatively inaccessible pelvis, for example to treat pelvic floor disorders. Another theory is that this situation reflects caseload mix, with a larger number of resections being performed for malignant disease.

BRIDGING THE DIVIDE

Several variations to the technique of laparoscopic colorectal surgery have developed in an effort to bridge the gap between conventional open surgery and minimally invasive approaches.

Laparoscopic-assisted techniques

Most surgeons would consider a laparoscopic colorectal resection to imply intracorporeal division and control of the major vascular pedicle involved, with bowel reanastomosis being performed either intra- or extracorporeally *via* a small extraction site made in the abdominal wall. It is important to bear in mind that there is no universally accepted definition of what actually constitutes “laparoscopic assistance” or even “conversion” from a laparoscopic to an open procedure, resulting in significant differences in reporting of the rates that they occur and are compared^[10]. Various degrees of “laparoscopic assistance” can be employed either due to complication or expediency, such as laparoscopic mobilisation of the left colon and division of the inferior mesenteric pedicle for anterior resection, with subsequent rectal dissection being performed open *via* a low midline or Pfannenstiel incision, avoiding a high midline wound which would potentially be more painful and reduce cosmesis.

Hand-assisted techniques

A hybrid technique, which attempts to provide the advantages of laparoscopic surgery while reducing the tech-

Table 1 Summary of key papers on laparoscopic resection for colorectal cancer

Trial	Year of publication	Type of study	Numbers of patients	Key findings
Barcelona trial ^[14] Lap-assisted <i>vs</i> open colectomy	2002	RCT Single centre	219	Improved perioperative outcomes and hospital stay in lap group Survival benefit in stage III disease for lap group
COST study ^[15] Lap <i>vs</i> open colectomy	2004	RCT Multicentre	872	Longer operating time but quicker recovery for lap No difference in morbidity, mortality, recurrence or survival
COLOR trial ^[16] Lap <i>vs</i> open colectomy	2009	RCT Multicentre	1248	Supported findings of COST
CLASICC trial ^[17,19] Lap <i>vs</i> open colon and rectal cancers	2005 2010 (5 yr follow-up)	RCT Multicentre	794 (2:1 lap: open)	Equivalent perioperative and oncological outcomes 29% conversion rate Higher CRM involvement for rectal cancers with lap
Abraham <i>et al</i> ^[48] Short-term outcomes of lap <i>vs</i> open	2004	Meta-analysis of RCTs	2521 12 RCTs	Longer operative times, less morbidity and quicker recovery for lap Mortality and oncological outcomes equivalent
Cochrane review ^[18] Short-term outcomes after lap	2005	Systematic review		Less morbidity and quicker recovery for lap
Cochrane review ^[20] Long-term results after lap	2008	Systematic review		Equivalent oncological outcomes for lap <i>vs</i> open

RCT: Randomized controlled trial.

nical difficulty and increased operative time, is the hand-assisted approach. The authors believe that this technique can be particularly useful for surgeons who are relatively new to laparoscopic surgery as a useful adjunct to becoming proficient in fully laparoscopic colorectal surgery. This technique involves the insertion of a bespoke port into the abdominal wall that allows the surgeons' hand to enter the abdominal cavity to assist in the operation while maintaining a pneumoperitoneum and therefore continued visualisation of the abdominal contents with the laparoscope. Although data comparing hand assisted and laparoscopic colorectal surgery is limited in comparison to that comparing laparoscopic and open procedures, a Cochrane review of randomised controlled trials concluded that there was a significant decrease in conversion rates in the hand assisted group, although there was no difference in complications or operating times^[11].

EVIDENCE FOR LAPAROSCOPIC COLORECTAL CANCER RESECTION

Although the concern regarding port site metastases had been addressed by the turn of the century, and uptake of laparoscopic colorectal surgery began to increase as a niche interest, a lack of long term data evaluating oncological outcomes following cancer resection prevented its use as a mainstream technique in the majority of units. At this time, data from large, multicentre randomised controlled trials across the world was published which suggested that short term outcomes were at least equivalent to open surgery and may have some advantages on perioperative outcomes. When patients were then surveyed on their quality of life following both forms of surgery using validated questionnaires, the authors of a recent systematic review of all available randomised controlled trials on this subject involving 2263 patients concluded that: "based on presently available high-level evidence,

this systematic review showed no clinically relevant differences in postoperative quality of life between laparoscopic and open colorectal surgery"^[12] (Table 1).

What, therefore, are the advantages of laparoscopic compared to open colorectal surgery? The smaller incisions required for insertion of laparoscopic ports obviously result in less surgical trauma to the abdominal wall, and studies have demonstrated a reduced inflammatory response, possibly as a result of less manipulation of the small intestine during surgery^[13].

Several landmark trials then emerged to mark the turning point in laparoscopic colorectal cancer surgery. In 2002, the Barcelona group published a randomised trial of 219 patients in the *Lancet* comparing laparoscopically-assisted with open colectomy for colon cancer, in terms of both short term perioperative outcomes as well as, for the first time in a large scale randomised trial, tumour recurrence and disease-specific survival^[14]. The results of this study suggested that there was a significant benefit for the laparoscopic group in terms of perioperative morbidity and hospital stay, with superior rates of tumour recurrence and disease-specific survival for patients with stage III disease. However, the trial was criticised for a 14% increased recurrence rate in the open group and a poor lymph node harvest in both groups. Soon after, the larger multicentre randomised COST trial reported from the United States on the results of 872 patients treated at 48 institutions for colon cancer by surgeons who had completed at least 20 laparoscopic resections^[15]. This trial supported the findings of the Barcelona group that hospital stay was shorter in the laparoscopic group, but there was no significant difference in morbidity. There was also equivalence in terms of recurrence and overall survival at three years. This trial also largely answered the concern over port-site recurrence, with the rate for both groups being less than 1%. Further long-term data on the equivalence of laparoscopic and open surgery for colon



Figure 1 The author performing a laparoscopic rectopexy for rectal prolapse.

cancer in terms of disease-free survival has since been provided by the European Colon Cancer Laparoscopic or Open Resection (COLOR) trial of 1248 patients published in 2009^[16]. The large, multicentre, randomised CLASICC trial was the first major trial including rectal resections as well as colectomy to report that short-term outcomes for laparoscopic compared to open colorectal cancer resection were at least equivalent, but was limited by the relative inexperience in laparoscopic surgery of many participating surgeons. This probably accounted for the high conversion rate to open surgery of 29% in the laparoscopic group and the non-significantly higher rate of circumferential resection margin involvement for rectal cancers^[17]. These concerns of increased rates of CRM involvement did not, however, translate to a difference in local recurrence at three years. Meta-analysis of randomised controlled trials evaluating the differences in short term outcomes have shown that laparoscopic surgery is associated with less intraoperative blood loss, reduced postoperative pain and ileus, and improved pulmonary function, resulting in reduced postoperative stay in hospital^[18]. Further results from the CLASICC trial reported in 2010, as well as a Cochrane review, have demonstrated that oncological outcomes following laparoscopic surgery are not inferior to those in patients undergoing open resection^[19,20].

Concerns regarding the safety of laparoscopic surgery for rectal cancers are further being addressed by the COLOR II trial, which has randomised 1103 patients with rectal cancer to laparoscopic or open resection with a 2:1 ratio at 30 centres in 8 countries between 2004 and 2010. Initial results published at the beginning of this year showed improved perioperative outcomes in the laparoscopic group in terms of blood loss and hospital stay, with longer operative times, and there was equivalence in terms of completeness of excision and perioperative morbidity and mortality^[21]. Data on rates of locoregional recurrence are expected soon.

LAPAROSCOPIC SURGERY FOR BENIGN COLORECTAL DISEASES

Pelvic floor dysfunction

Much of the early experience of laparoscopy for functional colorectal disorders has been focussed on rectal prolapse syndromes, including rectocele, intussusception and procidentia. A case series of 84 patients undergoing laparoscopic ventral mesh rectopexy for symptomatic complex rectocele published in 2011 by this author showed a significant decrease in vaginal discomfort and obstructed defaecation symptoms, with 88% of patients reporting an improvement in overall well-being (Figure 1). There was an acceptable conversion rate of 3.6% and a perioperative morbidity rate comparable to open rectopexy at 4.8% with no mortality, suggesting that the laparoscopic technique is safe and effective for treating symptomatic rectocele^[22]. The advantages of laparoscopy compared to open surgery in terms of short term perioperative outcomes, such as reduced blood loss, pain and postoperative stay in hospital, demonstrated in trials comparing the two techniques for colorectal cancer resection, have also been demonstrated in randomised trials comparing laparoscopic and open surgery for benign indications such as rectopexy for rectal prolapse^[23].

Inflammatory bowel disease

The available evidence would suggest that laparoscopic surgery for small bowel Crohn's disease is at least as safe as open surgery, although there may be less of an advantage in terms of short term outcomes than for other indications^[24]. One of the areas in which the benefits of a laparoscopic approach may be most obvious is in colectomy for ulcerative colitis necessitating ileostomy formation, whereby the colectomy specimen may be extracted *via* the ileostomy site prior to formation of the stoma, avoiding the need to make a separate abdominal incision for extraction. The results of a meta-analysis of trials comparing laparoscopic and open surgery for this indication published in 2007 seemed to support this view, with reduced morbidity and hospital stay in the laparoscopic group^[25].

EMERGENCY LAPAROSCOPIC COLORECTAL PROCEDURES

The initial experience with laparoscopic colorectal surgery was almost exclusively restricted to elective procedures, and there is little robust data to evaluate the role of laparoscopy for colorectal emergencies. As colorectal surgeons become increasingly experienced in laparoscopic techniques, many are turning towards laparoscopy as a tool for managing acute conditions such as complicated diverticular disease and inflammatory bowel disease as one of the new frontiers in our specialty. In 2008, a study was published of 100 patients who had undergone laparoscopy for perforated diverticulitis. The authors proceeded to convert to standard open surgery if faecal peritonitis was

revealed, with the remaining 92 receiving laparoscopic lavage and drainage without bowel resection. The results were encouraging, with low mortality and morbidity, and only 2 patients being readmitted with recurrent diverticulitis at a median follow-up of three years^[26]. These results have subsequently been replicated in meta-analysis^[27], and the results of ongoing randomised trials are awaited^[28].

TRAINING IN LAPAROSCOPIC COLORECTAL SURGERY

There is no doubt that the surgical techniques required to perform laparoscopic colorectal surgery are demanding, both for surgeons in training and for those experienced in open colorectal surgery. A recent systematic review and international multicentre analysis of 4852 cases performed by surgeons on this learning curve suggests that it is indeed steep, at between 88 cases for blood loss and 152 cases for conversion to an open procedure^[29]. The results of this review also suggest that body mass index and pelvic dissection, particularly in male patients, increased the risk of complications and conversion, and that increasing T stage of tumours and complicated inflammatory disease increased the complexity of the case.

NEW TECHNOLOGIES

In recent years, further techniques utilising minimally invasive techniques have begun to be employed by colorectal surgeons, and technologies involving robotic, single port and natural orifice instrumentation are now available in many units across the world, although the paucity of robust evidence on the effectiveness of these procedures means that their role remains unclear^[30].

Robotic colorectal surgery

The use of robotic systems for performing minimally invasive colectomy was first reported in 2002 by Weber *et al*^[31], following earlier work in the fields of urological and cardiac surgery. Indeed, over 50000 robotic prostatectomies were performed in the United States in 2007^[32]. There is no doubt that these robotic systems are significantly more expensive than conventional laparoscopic or indeed open colorectal procedures, so it is important that the evidence base for these procedures is strengthened in the future. To date, only one randomised study from South Korea comparing robotic with conventional laparoscopic surgery has been published, which focused on total mesorectal excision for rectal cancers and consisted of only 18 patients in each group^[33]. This limited study did suggest that short-term outcomes for robotic surgery were at least equivalent, with acceptable specimen quality on pathological analysis for oncological status. Further data from the international, multicentre randomised ROLARR trial comparing robotic-assisted versus standard laparoscopic surgery for rectal cancer in terms of both short term perioperative and longer term outcomes is awaited in the coming years^[34]. Meta-analysis of the available non-

randomized studies comparing robotic and laparoscopic rectal resection including a total of 854 patients suggests a lower conversion rate to open surgery for robotic procedures, with similar operative times and other short-term outcomes^[35]. It may be that the maximum benefit of robotic surgery for colorectal resection may be in dissection of the rectum within the bony pelvis, where the more stable platform provided by the robot to eliminate tremor of the surgeons hand, improved imaging in three dimensions controlled by the surgeon rather than assistant and wrist movement of robotic instruments allows for more precise dissection of tissue planes^[36]. A number of authors had reported reduced rates of circumferential resection margin involvement and autonomic nerve dysfunction in patients undergoing robotic total mesorectal excision^[33,37,38]. Although most of the published literature on robotic colorectal resection is focused on rectal resection, presumably due to the perceived advantages being maximal in this area, data from meta-analysis of 39 case series or comparative non-randomised studies combining both rectal resections and abdominal colectomies also concluded that conversion rates and perioperative morbidity was similar for the colectomy group, and considerably lower for robotic anterior resection of the rectum, with an adequate lymph node harvest^[39].

In more recent years the range of procedures and indications relating to prolapse of the pelvic floor has expanded and begun to involve robotic technology. A recent prospective analysis of 63 consecutive patients undergoing robotic-assisted or laparoscopic ventral mesh rectopexy for symptomatic complex rectocele showed a significantly longer operating time in the robotic group, but slightly less blood loss, with similar conversion rates and hospital stay^[40].

Single incision laparoscopic colorectal surgery

Other devices have been developed to allow colorectal procedures to be performed endoscopically *via* a single incision as opposed to multiple ports, even in some centres utilising robotic systems to access the abdomen *via* a single-access port. Evidence as to the efficacy of these procedures from randomised trials is lacking, but several reports including an early feasibility study by the authors shown the safety and feasibility of such an approach in right hemicolectomy^[41]. The authors followed-up their experience with a case cohort comparison of short-term outcomes in 144 consecutive cases of laparoscopic and single-incision right hemicolectomy performed at our unit showed that there was at least no disadvantage of the single-incision technique, with no significant difference in operative time, lymph node clearance or recovery parameters (pain score, length of stay and complications^[42]). These findings have been replicated in much larger meta-analyses, with a study including 1075 procedures from 15 studies comparing single-incision approach with conventional laparoscopy finding no difference in conversion rates or operation times between the two groups, with a significantly shorter length of postoperative stay in hos-



Figure 2 The author at the Da Vinci Si robotic console performing a robotic-assisted ultra-low anterior resection for rectal cancer.



Figure 3 The 4-arm Da-Vinci Si robotic setup for low rectal cancer resection.

pital in the single-incision group^[43]. However, the authors believe that the case for single-incision approach has not yet been conclusively made, with evidence from a large-scale randomised trial being needed.

DISCUSSION

In the United Kingdom and United States, the National Institute of Clinical Excellence and the Society of American Gastrointestinal and Endoscopic Surgeons respectively, now support laparoscopic resection for colorectal cancer performed by suitably experienced surgeons^[44,45]. An audit of the proportion of colectomies performed laparoscopically in the United States for the years 2008 and 2009 showed that of 9075 patients identified retrospectively from administrative data, 50% were performed laparoscopically^[46]. In the United Kingdom, data from the 2013 National Bowel Cancer Audit suggest that this figure has improved from 25% in 2008 to over 40% of resections for both colon and rectal cancer in 2012.

In conclusion, laparoscopic surgery for colorectal disease has moved from being an experimental proce-

dure performed by a small number of pioneers in the early 1990s, to today being firmly established in the mainstream around the world. This has occurred despite the fact that laparoscopic surgery is more expensive and requires a longer operating time than the equivalent open colorectal procedure^[47]. Large-scale international multi-centre randomised trial data has established that laparoscopic colorectal surgery is safe both in terms of short-term perioperative outcomes and long-term oncological efficacy, and we are now into the robotic era as perhaps the next stage of minimally invasive colorectal procedures (Figures 2 and 3).

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