European Review for Medical and Pharmacological Sciences 2021; 25: 4228-4235

Laparoscopic surgery for the treatment of colon cancer: the new standard?

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Abstract. – OBJECTIVE: Colon cancer is a major health problem worldwide with an overall 5-year survival rate of < 50%. Despite advances in the field of oncology proving that adjuvant chemotherapy may improve the outcome, the only treatment with curative intent is represented by surgical resection of the tumor. Over the past 30 years, surgical techniques for the treatment of colon cancer have improved considerably. Major doubts regarding the radicality of the resection and the long-term outcome have been overcome lately. The main objective of this study was to determine the feasibility of laparoscopic surgery for the treatment of colon cancer.

MATERIALS AND METHODS: Our goal with this paper was to conduct a narrative review of the literature about laparoscopic treatment in colon cancer and outline the essential principles of the procedure.

RESULTS: We found that laparoscopic resection has advantages over open surgery. These advantages include a shorter hospital stay, reduced incidence of surgical site infection, earlier return of bowel movements, and less immune suppression. As surgical centers with higher volume have very low complication rates, patients proposed for laparoscopic colonic resection for cancer should be referred to these hospitals.

CONCLUSIONS: Laparoscopic surgery is an important option in the radical treatment of colon cancer that can be used routinely and safely.

Key Words:
Colon cancer, Laparoscopy, Robotic surgery, Surgical treatment.

Introduction

Colon cancer is a major health problem with an overall 5-year survival rate of < 50%. Colorectal cancer is the third most common cancer in men and the second most common cancer in women; the highest incidence of colorectal cancer occurs in developed countries. The survival rate of colon cancer has increased significantly due to technical advances in the development of novel diagnostic and screening methods. In addition, identifying the optimal surgical treatment is essential for achieving a cure or a low recurrence rate. Surgical treatment involves removing the tumor and blood vessels, as well as at least 12 lymph nodes[1]. Surgical techniques have improved considerably over the past three decades. For example, following the successful use of laparoscopy in biliary surgery, the technique was applied to treat colon cancer. The first laparoscopic colectomy was successfully performed by M. Jacobs in 1991. Since then, laparoscopic colectomy has continuously improved. Although the success of the operation depends on the experience of the surgeon and patient-specific factors, such as the exact location and stage of the tumor, various adaptations, including single-incision laparoscopic surgery, intra and extracorporeal anastomosis, and robotic-assisted techniques, have been proposed and developed[2].

Laparoscopic colon resection is practiced worldwide. Laparoscopic surgery has advantages over open surgery, which include a shorter hospital stay, reduced incidence of surgical site infection, earlier return of bowel movements, and less immune suppression[3-5]. However, some studies[6-8] have reported that laparoscopic colon resections are associated with a significantly longer surgery time and higher intraoperative complication rates than open surgery[6]; the complications involved mainly intraoperative hemorrhage and small bowel injuries[7,8].

The traumatic impact of a laparoscopic procedure is also significantly lower than conventional open resection. This is because the high resolution and magnification of the laparoscope allows for the meticulous dissection of tissues[9].

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When laparoscopic colectomy was first implemented, researchers had concerns about the occurrence of early port site metastasis. However, randomized multicenter trials have proven that the incidence of port metastasis is comparable with open surgery[10]. The first published case report on wound recurrence was associated with the surgeon's lack of experience in extracting the specimen, as well as protecting the abdominal incisions. In the early 2000s, the majority of surgeons were reluctant to perform laparoscopic colon resection because of the lack of data on long-term results from the procedure[12-15]. Kehlet et al[16] reported on the low acceptance of the technique.

The degree of difficulty associated with performing laparoscopic surgery for colon cancer is higher than open surgery. Laparoscopic surgery involves the isolation, dissection, and ligation of the colonic vessels, as well as the creation of anastomoses[17]. These procedures involve complex movements that need experience in laparoscopic surgery. Technical advances in laparoscopic surgery have led to developments, such as ultrasound dissection, vascular sealing devices (i.e., LigaSure), and stapling devices for creating intracorporeal anastomosis[18]. These developments have enabled worldwide implementation of laparoscopic surgery over the past decade[19,20].

Materials and Methods

Our goal with this paper was to conduct a narrative review of the literature about laparoscopic treatment in colon cancer and outline the essential principles of the procedure. In this narrative review we did not used PRISMA-P protocols for meta-analysis.

Laparoscopy in Patients with T1-T3 Tumors

Several meta-analyses of randomized trials have shown that laparoscopic colectomies provide similar long-term survival rates and oncological outcomes to open surgery. One study[21] reported that patients with stage II colon cancer who underwent a laparoscopic resection had significantly higher disease-free and cancer-related survival rates compared with patients who underwent open surgery. The results of a study of 1,536 patients showed that the disease-free survival rates for patients treated with laparoscopic colectomy and open colectomy were 75.8% and 75.4%, respectively; moreover, the overall 3-year survival rate was also similar for the two groups: 82.2% and 83.5%, respectively[22].

The COST trial was a large study that enrolled 872 patients with colonic adenocarcinoma who underwent either laparoscopic surgery or open surgery; the surgeries were done by highly experienced surgeons who had performed at least 20 laparoscopic resections[23,24]. Interestingly, the median duration of the laparoscopic operation was approximately 1 hour longer than the open surgery: 150 min and 95 min, respectively. One-fifth of the laparoscopic operations were converted to open surgery. The length of hospital stay and analgesic use were both significantly reduced in the laparoscopic surgery group compared with the open colectomy group[24]. The two groups had comparable data for morbidity and mortality rates, reintervention, and incisional wound complications. After 7 years of follow up, no significant differences were observed in terms of 5-year disease-free survival or overall survival between the laparoscopic group and the open colectomy group: 69% versus 68% and 76% versus 75%, respectively.

Published data suggest that a lymphadenectomy during laparoscopic surgery is superior to open surgery. A higher number of lymph nodes are harvested after a laparoscopic colorectal resection compared with open surgery, which may relate to the higher survival rates observed in patients who undergo laparoscopic surgery[25,26].

The COST trial and the CLASICC trial[27] both showed a relatively high rate of conversion (20%) of laparoscopic surgery to open surgery. Conversion rates have been attributed to the inability to visualize the inferior mesenteric artery or the inferior mesenteric vein[28], as well as previous abdominal surgery and adhesion between the bowel and the abdominal wall[29].

Few studies[30] have determined whether surgical experience directly impacts conversion rates. Lacy et al[31] showed that laparoscopic resections of stage III colon cancer performed by experienced surgeons were significantly associated with higher survival rates compared with open surgery[29-31]. Capussotti et al[32] reported similar results for treatment outcomes for patients with stage III colon cancer treated with laparoscopic surgery and open surgery. Another study showed that a lack of experience by surgeons with laparoscopic surgery often leads to higher conversion rates and an increase in complications[33]. It should be noted that the COST and the CLASICC trials required sur-

geons to have performed at least 20 laparoscopic resections before enrolling in the study. However, other studies showed that expertise in laparoscopic colon resection is achieved only after performing 100 procedures[34].

The ALCCaS trial enrolled 425 patients with colon cancer and found that those who underwent a laparoscopic procedure had a better quality of life compared with patients who underwent open surgery[35]. Another major advantage of the laparoscopic approach is the lack of adhesion formation following the surgery. Gutt et al[36] suggested that the lack of adhesion formation in laparoscopic colon resections was due to the precise dissection of the tissue at the surgical site, which resulted in less overall trauma to the abdominal wall.

One study on patients with T3 colon cancer and positive lymph nodes found that chemotherapy was more frequently administered to patients who underwent laparoscopy compared with their open colectomy counterparts: 72% and 67%, respectively[37]. The low postoperative complication rate that was observed in patients who underwent a laparoscopic resection meant that the interval between the surgery and chemotherapy was reduced. Only patients who have completely recovered from surgery are eligible for chemotherapy[37].

Laparoscopy in Patients with Advanced Colon Cancer

The European Association of Endoscopic Surgery (EAES) recommends open resection in patients with advanced colon cancer. Laparoscopy is not recommended because, in many cases, additional structures, such as the abdominal wall, spleen, and small bowel, must also be resected[38]. In addition, it is often not possible to palpate the colon for tumors during a laparoscopy, which makes it difficult to distinguish inflammation from malignant invasion.

High conversion rates to open surgery are also observed in patients with locally advanced colon cancer. One trial showed that 50% of patients with advanced colon cancer required conversion to classic surgery[30]. However, another study showed that the conversion rate is related to the volume of laparoscopic procedures performed; high-volume centers have lower conversion rates[39].

Several large trials have compared the long-term outcomes from laparoscopic surgery and open colon resection in patients with locally advanced tumors[40-43]. For example, de'Angelis et al[44] reported that 106 patients with advanced colon cancer who underwent a laparoscopic colectomy had a shorter hospitalization than 106 patients treated with open surgery: 10.5 days versus 15.3 days, respectively ($p < 0.0001$); the laparoscopic group also had a faster recovery and less postoperative morbidity. The reported 5-year survival rates were comparable between the two groups ($p = 0.864$).

Another study investigated the long-term outcomes for patients with T4 colon cancer following laparoscopic resection. The results showed that in both the T4a and T4b subgroups, the technique was as safe and efficacious as conventional open surgery[45].

In conclusion, although the data were slightly inconsistent, studies have shown that laparoscopic surgery is feasible and safe at the T4a stage. However, it should only be performed by experienced surgeons who have performed at least 100 laparoscopic colon cancer procedures.

Single-Incision Laparoscopic Surgery

Single-incision laparoscopic surgery (SILS) was initially used in the 1990s to remove the appendix and gallbladder[46,47]. It was first used in colon cancer treatment in 2008 when Buchar et al[48] and Remzi et al[49] almost simultaneously published procedures on colorectal SILS. The advantages of SILS over traditional laparoscopic surgery or open surgery include a lower morbidity rate, superior cosmesis effects, less postoperative pain, and reduced inflammatory response[50].

Miyo et al[51], reported on the benefits associated with SILS colon resection. However, due to concerns about the oncological safety and the complexity of the procedure, the surgical community has been slow to adopt SILS. To perform SILS, surgeons must acquire new skills and use instruments that are designed to work in parallel, which limit movements in the abdominal cavity. The majority of studies have suggested that performing SILS to treat colon cancer requires more time than conventional laparoscopy[52].

Several non-randomized, controlled trials have shown that the operative time, blood loss, reoperation rate, morbidity, readmission, mortality, and survival after SILS are not superior to conventional laparoscopy[53,54]. The SILS technique was found to be comparable to conventional laparoscopy in terms of resected lymph nodes and R0 margins[55]. Data from several systematic reviews[56,57] indicated that SILS had no clear advantage over laparoscopic surgery, although it may be safely used to treat patients with colon cancer because it is the least invasive form of laparoscopic surgery.

The lack of adequate triangulation and the need for parallel instrument manipulation make the technique more suitable for experienced surgeons with high levels of expertise.

Currently, novel robotic systems are being tested and introduced into clinical practice[58,59]. These devices are capable of performing intracorporeal anastomoses with SILS with a 3D view and adequate triangulation.

Robotic-Assisted Laparoscopic Surgery

Conventional laparoscopic surgery is associated with various disadvantages, including a 2D view and limited mobility of the instruments. To overcome these disadvantages, robotic-assisted laparoscopic surgery (RALS) was first introduced in 1985. Since then, RALS has been continuously upgraded with state-of-the-art technology, such as infrared signals and slimmer robotic arms[60]. The most commonly used system for robotic surgery is the da Vinci™ surgical system (Intuitive Surgical, Sunnyvale, CA, USA), which obtained FDA approval in 2000.

Robotic procedures have major advantages over traditional laparoscopic surgery. Some advantages are the 3D view with depth perception, enhanced articulation, and no tremors, which can occur with human surgeons; RALS enhances dexterity and allows more precise movements[61]. Robotic systems also reduce surgeon fatigue, improve access to narrow spaces, such as the pelvic region, and decrease the learning curve after 35 cases. However, several issues that are associated with robotic procedures, such as prolonged operative times and the absence of tactile sensory input, must be addressed[62].

Colorectal surgery is one of the primary domains in which robotic surgery is changing medicine. Since Weber et al[63] reported the first robotic colectomy resection in 2001, the volume of data being generated on robotic-assisted surgery in colon cancer is growing rapidly. Several studies and meta-analyses have reported positive results on the safety and efficacy of RALS.

RALS has lower intraoperative hemorrhage rates and lower conversion rates than traditional laparoscopic surgery. Sheets[64] found that the use of robotic resections in colon cancer increased from 0.7% in 2006 to 10.9% in 2010 worldwide. In addition, there were no reported no differences in morbidity and pathological outcomes, although robotic surgery did have longer operative times and increased overall costs, which delayed its widespread use in many countries. Robotic surgery has been used to perform a lymphadenectomy and intracorporeal anastomoses[65].

Zhang et al[66] performed a retrospective analysis on 3,318 patients with colon and rectal cancer. The researchers showed that robotic surgery had a lower conversion rate compared with open surgery, and a lower intraoperative bleeding and shorter hospitalization period compared with laparoscopic surgery. In addition, the overall cost of robotic surgery was two to three times higher than laparoscopy[67]. A study on the comparative costs of robotic, laparoscopic, and open surgery showed that laparoscopic surgery has the lowest cost[68]. Although the hospital stay is shorter with robotic surgery, the overall cost, which includes the price of the robot and the costs of surgical devices, maintenance, and consumables, is very high[68].

Natural Orifice Transluminal Endoscopic Surgery

Natural orifice transluminal endoscopic surgery (NOTES) combines endoscopic and laparoscopic techniques. Because NOTES involves the use of natural orifices, there are no surgical incisions or abdominal wall-related complications, such as wound infections, incisional hernias, and pain.

The first NOTES procedure was a transgastric appendectomy that was performed in India by Rao et al[69]. However, NOTES has not gained much acceptance in colorectal cancer surgery mainly due to the complexity of the procedure and technical pitfalls associated with the parallel manipulation of the instruments and the loss of triangulation. Moreover, ethical issues associated with the use of NOTES, such as potential expose to intra-abdominal abscesses, the development of postoperative fistulae at the extraction site, have limited the development of this technique[70]. For colon resection using NOTES, access can be obtained using either a transvaginal or transanal approach. To date, few papers on the use of pure NOTES for colon resection have been published[70,71].

A hybrid NOTES method, which involves the use of conventional laparoscopic trocars, has gained acceptance over the years. First described in 2009[72], the laparoscopic-assisted transanal sigmoidectomy has undergone great development. Recently, a new technique, called natural orifice specimen extraction surgery (NOSES), has been developed. The NOSES technique involves complete intra-abdominal colic resection and reconstruction followed by transanal or transvag-

inal extraction of the specimen through a small incision in a hollow organ with extracorporeal communication. Bulian et al[73] analyzed 139 colon NOTES procedures that used the transvaginal or transanal hybrid technique and found that the method was safe and feasible. The main equipment used to perform NOSES is a conventional laparoscope, although novel equipment, such as a 3 D laparoscopic system and the da Vinci™ surgical system, are becoming popular[74]. Strict selection criteria for potential candidates for NOSES have been established. Eligible candidates should have a body mass index < 30 kg/m^2, tumor size < 5 cm, no incisions to the abdominal wall, and be clinically diagnosed with T1-3N0/1M0 colon cancer[75].

Extracorporeal vs. Intracorporeal Anastomosis

The debate between extracorporeal and intracorporeal anastomosis after a laparoscopic colectomy is a contentious topic. Randomized retrospective studies have suggested that intracorporeal anastomosis has some advantages over extracorporeal anastomosis. For example, one study reported that there was a marginal statistical difference between intracorporeal anastomosis and extracorporeal anastomosis in terms of a smaller abdominal incision, earlier return of bowel movements, and a decrease in analgesic consumption; the rates of intraoperative and anastomotic fistula complications were comparable between the two methods[76]. Hellan et al[77] determined that the type of anastomosis did not affect the medium and long-term oncological outcomes in patients who underwent a laparoscopic colorectal resection for cancer; thus, both intracorporeal anastomosis and extracorporeal anastomosis proved to be feasible over time. However, intracorporeal anastomoses may cause contamination of the peritoneal cavity, which can lead to intra-abdominal abscesses and other septic complications, although this has not been validated statistically[78]. In addition, studies have failed to establish a link between the type of anastomosis performed and an increase in mortality due to anastomotic fistula[77].

Regarding the novelties of this report, we show here that laparoscopic surgery is feasible and safe at the T4a stage. These procedures must be performed by experienced surgeons who have performed at least 100 laparoscopic colon cancer procedures.

Another novelty is the outlining of feasibility of a new technique, called natural orifice specimen extraction surgery (NOSES). The NOSES technique involves complete intra-abdominal colic resection and reconstruction followed by transanal or transvaginal extraction of the specimen through a small incision in a hollow organ with extracorporeal communication.

Conclusions

Laparoscopic surgery is an important option that can be used routinely and safely in the radical treatment of colon cancer. Various studies have found that laparoscopic surgery has advantages, such as a faster recovery, over open surgery. It also has similar postoperative morbidity and immediate mortality rates to open surgery. Postoperative outcomes in patients with colon cancer who underwent a laparoscopic colectomy were superior to the outcomes in patients who underwent open surgery. Numerous studies reported that these patients had less postoperative pain for a shorter duration, fewer intra-abdominal abscesses and septic complications, and a faster return to their daily activities; in addition, patients were mobilized within the first postoperative day. All these aspects had a positive impact on the quality of life of patients.

No significant differences have been observed in the safety between open surgery and laparoscopic surgery in the treatment of colon cancer. Laparoscopic surgery follows the same principles as traditional oncological surgery: isolating and high sectioning of the colonic vessels; harvesting a minimum of 12 lymph nodes; and minimal handling of the tumor.

Conflict of Interest

The Authors declare that they have no conflict of interests.

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