Open versus laparoscopic colorectal surgery in the era of multimodality treatment of cancer

Ann. Ital. Chir., 2013 84: 563-570
Published online 15 January 2013
pii: S0003469X13020587
www.annitalchir.com

Giuseppe Brisinda, Serafino Vanella, Piero Giustacchini, Camillo Cavicchioni, Anna Crocco, Giorgio Maria

General and Endocrine Surgery Operative Unit, Department of Surgery, Catholic School of Medicine, University Hospital Agostino Gemelli, Rome, Italy

Open versus laparoscopic colorectal surgery in the era of multimodality treatment of cancer

AIM: *To compares the efficacy and safety of laparoscopic surgery (LS) and open surgery (OS). To analyze early results of a single institution experience using adjuvant intraoperative radiation therapy (IORT) presacral boost in locally advanced cancer.*
MATERIAL OF STUDY: *264 patients with curable colorectal cancer undergoing laparoscopic (97) or open colorectal resection (167). In 41 patients (31 open and 10 laparoscopic resection) with locally advanced rectal cancer we performed IORT. Primary endpoints were the evaluation of postoperative clinical and oncologic results.*
RESULTS: *Twenty (21%) patients underwent conversion from laparoscopic to open surgery. The overall morbidity rates were 17.5% in the LS group and 20.9% in the OS group (P= 0.5). Average operative time was shorter in the OS than in the LS series (P= 0.01). Use of parenteral narcotics was shorter in LS than in OS group (P <0.001), but there were more stoma creations in LS group than in OS group (P= 0.001). All patients are alive at different follow-up periods.*
DISCUSSION: *Colorectal cancer is the second leading cause of death from malignancy in the industrialized world. The risk of local recurrence after treatment increases with tumor stage. The roles of radiochemotherapy and surgical procedures have been investigated extensively in the last decades, especially in locally advanced rectal cancer.*
CONCLUSIONS: *Laparoscopic techniques can be applied to colorectal malignancies without sacrificing oncologic results. Multimodality treatment with LS and IORT is safe and feasible.*

KEY WORDS: Colorectal cancer, Laparoscopy, Intraoperative radiation therapy, Laparoscopic colorectal resection, Multimodality treatment.

Introduction

Minimally invasive surgery revolutionized the way operations were performed. The possibility that this approach could benefit patients undergoing colectomy for colon cancer was first considered in 1990. Several studies have reported advantages of laparoscopic surgery (LS) over open surgery (OS) in the treatment of colorectal cancer, such as a reduction in pain, more rapid recovery of bowel function, shorter hospital stay and better cosmetic results[1-4]. Nevertheless, the effectiveness and safety of the procedure have been the subject of debate, and its use is still not widespread. The laparoscopic approach to colectomy is slowly gaining acceptance for the management of colorectal cancer. Initial concerns with laparoscopic colorectal surgery related to technical difficulty,

Pervenuto in Redazione Settembre 2012. Accettato per la pubblicazione Ottobre 2012
Correspondence to: Giuseppe Brisinda, Department of Surgery, University Hospital "A Gemelli" Largo Agostino Gemelli 8, I-00168 Rome, Italy (E-mail: gbrisin@tin.it)

steeper learning curve, and a need for specialized instrumentation. Secondary concerns have developed, including increased costs, questions about real improvements in outcome, and concerns regarding safety in neoplastic disease. Furthermore, recent reports of "fast-track" care for open colorectal surgery has blurred the distinctions between outcome of LS and OS because of the perception that length of postoperative stay can be reduced with OS. The rather steep learning curve is a limit to the application of this procedure also by experienced surgeons. Outcomes depend more on surgeons possessing advanced laparoscopic skills and adhering to accepted oncologic surgical principles in cases of malignancy, than on the size or location of the healthcare institution [5-11]. However, behind the great success of laparoscopic colorectal surgery, there are still many questions that remain unclear, including whether laparoscopic colorectal cancer surgery is radical or not, seldom reported superior short-term outcomes [12]. Laparoscopic colorectal surgery is still not considered standard treatment [13-15]. Furthermore, laparoscopic colorectal resection is associated with a significantly higher intraoperative complication rate than equivalent open surgery[14].

Radical surgery is the cornerstone in the management of patients with locally advanced rectal carcinoma (LARC) [16]. Incidences of local recurrences in contemporary reports range from 15% to 45% and are a formidable oncologic challenge, because they are associated with disabling symptoms that lead to catastrophic medical outcomes [17]. During the past two decades, several attempts have been made to improve the outcome of patients with locally advanced rectal cancer. Preoperative chemoradiotherapy (CRT) has also been found to improve overall survival as compared with surgery alone.[18, 19] It has been reported to be more dose efficient than postoperative radiotherapy and to induce a tumor downstaging effect, which potentially improves the probability of a complete resection and sphincter-preserving surgery indication, with a benefit in local control promotion [20, 21]. In analysis, combined treatment [CRT, radical surgery, and intraoperative radiation therapy (IORT)] reported attractive cancer control rates [22-25]. In this paper, we investigated the clinical outcomes of LS versus OS for colorectal cancer. We also assessed the postoperative complications in both groups of patients and report the data even in those patients undergoing IORT.

Patients and Methods

Between January 2005 and January 2010, patients who underwent radical colorectal surgery for cancer in General and Endocrine Surgery Operative Unit at University Hospital "Agostino Gemelli" of Rome were considered for this study. In this study, choice of the patients for the two groups does not correlate with randomized criterion selection. Casual selection in the two aforementioned groups was based on an arbitrary criterion extraneous to surgeon evaluation. The present clinical study was conducted by a single surgical group that performed both OS and LS using the same types of operations as well as oncologic and clinical criteria in both arms of the study. Inclusion criteria were a clinical diagnosis of colorectal adenocarcinoma (histologic confirmation was required at surgery) and an age of at least 18 years. A written informed consent was obtained from all patients before the investigation. Preoperatively, all the patients underwent colonoscopy with biopsy, abdominal ultrasound, chest X-ray, and if necessary abdomen and pelvis computed tomography (CT) scan, and pelvic magnetic resonance imaging (MRI).

Exclusion criteria included metastatic disease, emergency presentation, morbid obesity (defined as body mass index > 35 kg/m^2), a classification V physical status according to the American Society of Anesthesiologists (ASA). Inflammatory bowel disease, familial polyposis or pregnancy also precluded enrollment.

For neoadjuvant CRT and IORT, we selected patients with low and medium LARC (T3-4, N1-2, M0). The patients were previously informed about the extension of their illness and the program of the multidisciplinary treatment. The patients selected for neoadjuvant CRT received preoperative radiotherapy and concomitant chemotherapy with procedures established by a treatment protocol already published by the radiotherapists of our hospital [23]. Restaging was performed 5-9 weeks after preoperative treatment with CT scan, pelvic MRI and colonoscopy. The pathologic response was established according to the pTNM pathologic classification and by evaluating the tumor regression grade (TRG). The TRG was quantified, on surgical specimens, in five grades according to the Mandard score [26]. Surgery was performed 6-10 weeks after completion of CRT.

Preoperative preparations and surgical procedures

All patients underwent a standard preoperative protocol included bowel preparation with polyethylene glycol (PEG) electrolyte lavage solution performed 12 hours before surgery. Antibiotic prophylaxis with 400 mg of intravenous (IV) ciprofloxacin and 500 mg of IV metronidazole is administered 1 h before the intervention and continued for 24 h in all patients and 48 h in the IORT group. Antithrombotic prophylaxis with 4000 U of deltaheparine is administered daily from a day before the intervention and continued until discharge to home.

In both groups, we routinely practice wide oncologic resection with high legation of the vessels, extensive lymphadenectomy, total mesorectal excision en bloc with the rectum for rectal cancer patients, and correct clearance of the specimen's margins. The types of operations performed were: right colectomy, left colectomy, sigmoid resection, low anterior resection, and abdominoperineal resection.

In LS group, four 5- to 12-mm trocars are used. Pneumoperitoneum is created with the Veress needle, and the 30° optic is introduced with the Visiport device (Tyco Healthcare Group, USA). All dissections and vessel interruptions are performed using Ligasure Vessel Sealing System (Tyco Healthcare Group, USA). In the rectal resection series, the patient is placed in a Trendelenburg position, and the uterus (in female patients) is suspended to the anterior abdominal wall through a transfix suture. An incision is made on the peritoneum along the preaortic plane, and the right iliac vessels are taken as reference. The inferior mesenteric artery is interrupted. The detachment of the mesocolon is completed from medial to lateral, while the detachment of the parietocolic attachment proceeds, if necessary, up to the splenic flexure. The dissection of the mesorectum begins in the posterior face and proceeds to the anterior face until the tumor is overcomed.
Section of the rectum is performed with one or three hits of the EndoGIA (Tyco Healthcare Group, USA). The proximal bowel is delivered through a small Pfannenstiel incision of 7 cm and divided extracorporeally. A 7-cm Lapdisk (HS-Hospital Service, Italy) is first positioned to protect the abdominal wall.

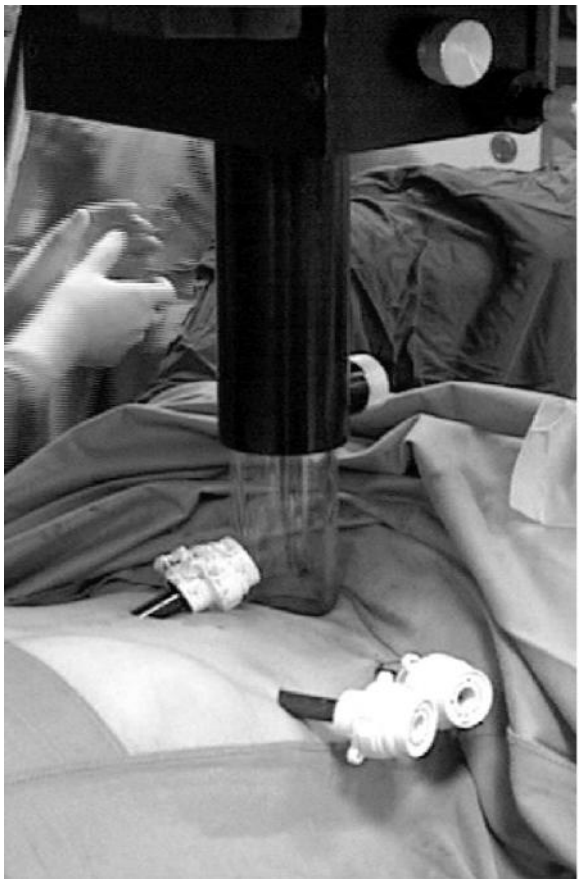

Fig. 1: Intraoperative positioning of the cone through the Pfannestiel incision in a patient already undergoing a laparoscopic anterior resection.

Abdominoperineal resection is performed when the inferior limit of cancer is less than 5 cm from anal margin in the original staging. The initial operative step is the same as previously described. As soon as dissection of the rectum is completed, the colon is sectioned, and then the perineal phase begins. After the specimen is removed, the operative field is prepared for IORT. The bowel is protected with gauzes, and the cone is introduced through the Pfannenstiel incision (Fig. 1). In abdominoperineal resection, the cone is introduced through the perineal incision. The patient is transferred to the radiotherapy room, and radiant therapy is performed. The cone previously introduced in the patient is attached to the accelerator machine so radiotherapy can begin.
A boost of 10 Gy is delivered by electron beam on the parietal fascia of the mesorectum. The patient then is brought again to the operating theater. After restoration of pneumoperitoneum, an intracorporeal terminolateral colorectal anastomosis is performed with an EEA stapler.
A perianastomotic aspirative drainage is left in place. In abdominoperineal resection, a terminal colostomy is made in the left iliac fossa. Conversion to open colectomy was at the discretion of the surgeon based on concerns regarding patient safety, technical difficulties, or associated conditions requiring treatment by laparotomy.

Perioperative and postoperative surveillance

Demographic and operative data were obtained regarding age, gender, ASA score, comorbidities, history of previous abdominal surgery, tumor location, surgical intervention, operative time, blood loss, proximal and distal margin length, number of retrieved lymph nodes and lymph node metastases, pathological differentiation and clinical stage. Postoperative data included analgesic usage, peristalsis recovery time, time until flatus, time until first normal diet, postoperative duration of hospital stay and perioperative complications were recorded. Patients enrolled in the present study were managed postoperatively by the same group of surgeons.

Statistical analysis

Analysis were conducted with Statistics for Windows (Statsoft, Tulsa, Okla.). The results are expressed as means ±SD; differences between the treatment groups were compared with use of Student's t-test, and differences in percentages were analyzed with use of Fisher's exact test. All P values are two- tailed. P values of less than 0.05 were considered to indicate statistical significance.

Results

A total of 264 patients were included in the study. Clinical and surgical data are reported in Table I. A total of 167 patients underwent open colorectal resection, and 97 were treated with laparoscopically assisted colorectal resection (Table II). The procedure was converted to open colectomy for 20 patients (two patients for urinary tract lesion; 10 for large tumors; 6 for intraoperative haemorrhage; 2 for small bowel injuries) assigned to laparoscopically assisted surgery (21%).

Operating times were significantly longer in the LS group than the OS group (189 ±86.1 minutes and 138.9 ±52.1 minutes, respectively, P =0.01). The extent of resection was similar in both groups; bowel margins were less than 5 cm in 6% of the patients in the OS group and 5% in the LS group (P =0.5). Margins infiltrated by tumor were not documented in any patients. The median number of lymph nodes examined was 9.6 ±4.6 for OS group and 9.3 ±4.9 for LS group (P =0.7). The nasogastric tube was left in place for 24 h. All the patients had a rapid bowel function recovery (3.6 ±1.3 days for OS group and 3 ±1.3 days for LS group, P =0.02), and oral intake was restored by postoperative 8.1 ±1.8 days for OS group and 7.4 ±1.8 days for LS group (P =0.04). In all patients, the duration of hospitalization was 10.7 ±6.8 days in the OS group and 8.8 ±3.5 days in LS group (P = 0.09). No perioperative mortality has been

TABLE I - *Demographic data.*

	OS Group	LS Group	*P*
Number of patients	167	97	-
Age (years, mean ±SD)	65.2 ±10.9	62.6 ±8.7	0.04
Female Sex	73 (43.7%)	39 (40.2%)	0.6
Tumor site			
Colon	108 (64.7%)	66 (68%)	0.5
Rectum	59 (35.3%)	31 (32%)	
Type of procedure	18 (10.8%)	4 (4,1%)	0.06
Right hemicolectomy	48 (28.7%)	44 (45.4%)	0.007
Sigmoid colectomy	23 (13.8%)	10 (10.3%)	0.4
Left hemicolectomy	51 (30.5%)	29 (29.9%)	1.0
Low anterior resection	7 (4.2%)	2 (2.1%)	0.4
Abdominoperineal resection	20 (12%)	8 (8.2%)	0.4
Other			
TNM Stage			
I	56 (33.5%)	54 (55.7%)	0.0005
II	49 (29.3%)	10 (10.3%)	0.0004
III	62 (37.1%)	33 (34%)	0.6

TABLE II - *Operative results and clinical outcomes.*

	OS Group	LS Group	*P*
Number of patients	167	97	–
Duration (min)	138.9 ±52.1	189 ±86.1	0.01
Blood transfusion	44 (26.6%)	21 (21.6%)	0.4
Stoma creation	44 (26.6%)*	45 (46.4%)†	0.001
Drainage stay (days)	8.4 ±3.5	6.1 ±1.7	0.0001
Drainage loss (ml)	118.75 ±47.5	110.15 ±87.5	0.009
Number of resected lymph nodes	9.6 ±4.6	9.3 ±4.9	0.7
Use of analgesic (days)	6.4 ±2.7	4.4 ±2.0	0.001
First flatus (days)	3.6 ±1.3	3 ±1.3	0.02
Normal diet (days)	8.1 ±1.8	7.4 ±1.8	0.04
Postoperative hospital stay	10.7 ±6.8	8.8 ±3.9	0.09
Overall morbidity	35 (20.9%)	17 (17.5%)	0.5

* Only rectal resection. † All rectal resections and 14 sigmoid colectomies.

TABLE III - *Intra- and postoperative complications (the number in parentesis represents the percentage in relation to total).*

	OS Group	LS Group	*P*
Anastomotic bleeding	8 (4.8%)	6 (6.2%)	0.7
Anastomotic leaks	4 (2.4%)	2 (2.1%)	1.0
Prolonged ileus	4 (2.4%)	2 (2.1%)	1.0
Intrabdominal collection	1 (0.6%)	0	1.0
Wound infection	11 (6.6%)	1 (1.0%)	0.06
Pneumonia	4 (2.4%)	2 (2.1%)	1.0
Urinary tract lesions	1 (0.6%)	3 (3.1%)	0.1
Atrial fibrillation	2 (1.2%)	1 (1.0%)	1.0

TABLE IV - *Operative results and clinical outcomes in IORT group of patients.*

	OS Group	LS Group	P
Number of patients	31	10	-
Duration (min)	233.3 ±40.9	285.2 ±67.2	0.03
Blood transfusion	10 (32.3%)	2 (20%)	0.6
Stoma creation	16 (51.6%)	7 (70%)	0.4
Drainage stay (days)	7.8 ±2.2	5.9 ±2.5	0.05
Drainage loss (ml)	114.2 ±53.0	80.8 ±29.1	0.06
Number of resected lymph nodes	9.7 ±4.8	8.4 ±2.9	0.4
Use of analgesic (days)	5 ±2.0	3.5 ±1.0	0.02
First flatus (days)	4.7 ±1.0	3.1 ±1.8	0.01
Normal diet (days)	7.8 ±2.1	6.1 ±1.2	0.02
Postoperative hospital stay	8.1 ±2.7	10 ±2.7	0.1
Overall morbidity	13 (41.9%)	4 (40%)	0.6

TABLE V - *Intra- and postoperative complications in IORT group of patients (the number in parentesis represents the percentage in relation to total).*

	OS Group	LS Group	P
Anastomotic bleeding	0	2 (20%)	0.05
Anastomotic leaks	2 (6.5%)	1 (10%)	1.0
Intrabdominal collection	1 (3.2%)	0	1.0
Wound infection	6 (19.3%)	0	0.3
Pneumonia	4 (12.9%)	0	0.5
Urinary tract lesions	0	1 (10%)	0.2

observed. Postoperative complications were observed in 20.9% and 17.5% (P = 0.5) of patients in the OS and LS groups, respectively. Data regarding intra- and postoperative complications are reported in Table III.

In the IORT series (Table IV), conversion to open procedure was required for two patients due to urinary tract lesion. The average operative time was significantly longer in the laparoscopic group (285.2 ±67.2 minutes in LS group and 233.3 ±40.9 minutes in OS group, P =0.03). Blood transfusion during surgery (32.3% in OS group and 20% in LS group, P =0.6) was higher in OS group while stoma creation (51.6% in OS group and 70% in LS group, P =0.4) was higher in LS group. In LS group duration of postoperative analgesia (3.5 ±1.0 days), first flatus (3.1 ±1.8 days) and time of resumption of normal diet (6.1 ±1.2 days) were significantly shorter than OS group (5.0 ±2.0 days, P =0.02; 4.7 ±1.0 days, P =0.01; 7.8 ±2.1 days, P =0.02, respectively). There were non significant differences in duration of hospital stay (8.1 ±2.7 days in OS group and 10.0 ±2.7 days in LS group, P =0.1), number of dissected lymph nodes (9.7 ±4.8 lymph nodes in OS group and 8.4 ±2.9 lymph nodes in LS group, P =0.4), drainage loss (114.2 ±53.0 ml in OS group and 80.8 ±29.1 ml in LS group, P =0.06) and drainage stay (7.8 ±2.2 days in OS group and 5.9 ±2.5 days in LS group, P =0.05). Postoperative complications were observed in 41.9% and 40% (P =0.6) of patients in the OS and LS groups, respectively. Data regarding perioperative complications in IORT series are reported in Table V. Ileostomy closure was performed for all the patients about 2 months after the original intervention.

Discussion

Most trials that have evaluated LS for colorectal cancer (many of which were nonrandomized and with small sample sizes) have focused on short-term outcomes; typically they have shown the technique to provide better results in terms of postoperative morbidity and other early variables [13, 27-34]. Recently, a number of trials have been undertaken with longer follow-up time and larger sample sizes. These provide a better quality of evidence regarding the efficacy and safety of the procedure. Long-term outcomes – overall survival, disease-free survival and local recurrence – in patients undergoing laparoscopic resection of colorectal cancer are as good with LS as with OS [15, 32, 35].

There has been little disagreement that the complications of laparoscopically assisted and open colon resections are similar, because the critical steps of the procedures are essentially the same. Other operative factors, including the extent of resection – specifically, the number of lymph nodes sampled, the length of bowel and mesentery resected, and the bowel margins – did not differ significantly between patients who underwent laparoscopically assisted surgery and those who underwent open colectomy. Theoretically, laparoscopy may be inferior owing to the loss of tactile information provided by traditional surgical techniques. In practice, laparoscopy coupled with solid-organ imaging offers visual capabilities that seem to provide adequate staging information [36, 37]. Our report confirms the benefits of LS in terms of a decreased duration of hospitalization and decreased narcotic use. However, this finding must be balanced against 21% rate of conversion to OS, the increased operative times and the increased rate of stoma creation associated with the laparoscopic procedure. On the whole, these

data suggest that because laparoscopically assisted colectomy provides no additional risk of cancer, it is an acceptable alternative to OS for colon cancer. However, 21% rate of conversion from LS to OS in our study is consistent with previously reported rates. We believe that such a high conversion rate is mainly due to the learning curve and the intraoperative findings of large size tumors with local infiltration. In our experience, in fact, conversion to open surgery was necessary for intraoperative complications (10 cases) that we failed to deal with laparoscopy and malignancies of considerable size with locoregional infiltration (10 cases). Similarly we believe that the use of ostomy, at least in part, attributable to the learning curve. It should be emphasized, however, that, as in open surgery, the ileostomy is mandatory in patients with low or ultralow rectal resection with associated IORT. Furthermore, we have noted that operating times were significantly longer in the LS group than the OS group. However, the extent of resection and the median number of lymph nodes examined were similar in both groups. Postoperative complications were observed in 20.9% and 17.5% (P = 0.5) of patients in the OS and LS groups, respectively.

The laparoscopic approach to the surgical treatment of operable rectal cancer does not seem to entail any oncologic disadvantages [33, 34]. The mortality of rectal cancer has been decreased due to an improved surgical technique as well as interdisciplinary efforts, especially the routine use of combined CRT in a multimodality treatment strategy. Preoperative radiotherapy trials have been conducted over many years while significant improvements in staging, radiotherapy, surgical techniques and sophistication in trial design has been occuring since the earliest studies. Previous meta-analysis have highlighted differences in biological effect expected from shorter lower dose versus longer higher dose radiotherapy regimen [22]. Local control benefits were greater when using appropriate biological effective dose and when contemporary radiotherapy fields are used.[22] The adoption of CRT have not provide incremental survival advantage compared with radiotherapy alone, and did not translate into benefits in increasing proportion of sphincter sparing surgery. When chemotherapy is indicated, the benefits of chemotherapy appear to be independent on the timing of when it was given [38]. Selective postoperative – with or without chemotherapy – strategy did not appear to be as effective as a preoperative approach in improving local control although much information on the effect of a close resection margin and the associated risk of local recurrence with or without radiotherapy were made available through these trials, and would likely be crucial to guiding strategy designs [20].

Preoperative CRT improve resectability and local control, and after a median follow-up of 5 years, there is a difference in disease-free survival and cancer-specific survival [39]. An additional radiation boost delivered during surgery can overcome these dose limitations. IORT integrated in the multimodality concept of CRT and resection is a feasible method to provide the necessary dose escalation to the high-risk region without harming neighboring organs [22, 40]. The advantages of IORT are that the radiation dose can be applied very specifically to the area of risk, under direct visual control, and with the possibility of shielding or mobilizing the surrounding dose-limiting structures out of the radiation field. Although no randomized trials concerning IORT have been performed, data from recent studies seem to suggest that IORT may influence local control and survival positively. In the present study, in the IORT series, conversion to open procedure was required for two patients. The average operative time was significantly longer in LS. Blood transfusion during surgery was higher in OS group while stoma creation was higher in LS group. In LS group duration of postoperative analgesia, first flatus and time of resumption of normal diet were significantly shorter than OS group. There were non significant differences in duration of hospital stay, number of dissected lymph nodes, drainage loss and drainage stay. Postoperative complications were observed in 41.9% and 40% of patients in the OS and LS groups, respectively.

Conclusions

Outcomes in patients undergoing laparoscopic resection of colorectal cancer are as good as with OS. The absence of oncologic risk and the resulting marginal short-term benefits counterbalance the longer operative times and greater rates of stoma creation. The laparoscopic approach in a multimodality treatment strategy does not seem to entail any oncologic disadvantages. Our experience shows that laparoscopic rectal resection with IORT is feasible and safe.

Riassunto

Diversi studi hanno riportato i vantaggi della chirurgia laparoscopica rispetto alla chirurgia aperta nel trattamento del tumore colorettale (riduzione del dolore, più rapido recupero della funzione intestinale, degenza ospedaliera più breve e migliori risultati estetici). L'efficacia e la sicurezza della procedura sono tuttavia oggetto di dibattito, e l'utilizzo della laparoscopia non è ancora diffuso. Nonostante siano riportati migliori risultati a breve termine, la chirurgia laparoscopica del colon-retto non è ancora considerato un trattamento standard.

La chirurgia radicale rimane la pietra miliare nel trattamento di pazienti con carcinoma rettale localmente avanzato. L'incidenza di recidive locali varia dal 15% al 45% e sono una sfida formidabile oncologica, perché sono associate a sintomi disabilitanti che portano a catastrofici risultati medici. Nel corso degli ultimi due decenni, diversi tentativi sono stati fatti per migliorare la prognosi di pazienti con cancro rettale localmente avanzato. In

sintesi, il trattamento combinato (chirurgia variamente associate a trattamenti radio- e/o chemioterapici) permette di ottenere interessanti tassi di controllo della malattia. In questo lavoro, abbiamo studiato gli esiti clinici dell'approccio laparoscopico rispetto al trattamento convenzionale in pazienti affetti da cancro del colon-retto. Abbiamo anche valutato le complicanze post-operatorie in entrambi i gruppi di pazienti e riportato i dati anche in quelli sottoposti a radioterapia intraoperatoria.

Authors' contributions. GB, SV and GM conceived the study, and participated in its design and coordination as well as drafting of the manuscript. GB, GM, PG and CC carried out the perioperative management for all patients in this study, participated in the operation. SV and AC managed the equipment and instruments for the surgery as well as the intraoperative data collection. All authors have read and approved the final manuscript.

References

1. Group CS: *COLOR: A randomized clinical trial comparing laparoscopic and open resection for colon cancer*. Dig Surg, 2000; 17(6):617-22.

2. Itah R, Greenberg R, Werbin N, et al.: *Current changes in the management and outcome of patients with curable colorectal cancer.* Isr Med Assoc J, 2011; 13(5):300-03.

3. Cima RR, Pendlimari R, Holubar SD, et al.: U*tility and short-term outcomes of hand-assisted laparoscopic colorectal surgery: A single-institution experience in 1103 patients.* Dis Colon Rectum, 2011; 54(9):1076-81.

4. Sun J, Jiang T, Qiu Z, et al.: *Short-term and medium-term clinical outcomes of laparoscopic-assisted and open surgery for colorectal cancer: A single center retrospective case-control study*. BMC Gastroenterol, 2011; 11:85.

5. Hazebroek EJ, COLOR Study G.: C*OLOR: A randomized clinical trial comparing laparoscopic and open resection for colon cancer*. Surg Endosc, 2002; 16(6):949-53.

6. Clinical Outcomes of Surgical Therapy Study G.: *A comparison of laparoscopically assisted and open colectomy for colon cancer.* N Engl J Med, 2004; 350(20):2050-59.

7. Tekkis PP, Senagore AJ, Delaney CP, et al.: Ev*aluation of the learning curve in laparoscopic colorectal surgery: Comparison of right-sided and left-sided resections*. Ann Surg, 2005; 242(1):83-91.

8. Reichenbach DJ, Tackett AD, Harris J, et al.: *Laparoscopic colon resection early in the learning curve: what is the appropriate setting? A: Results of a National Questionnaire on "Treatment of the subperitoneal rectal cancer". Comparision among the international guidelines and meta-analysis.* Ann Ital Chir, 2010; 81(4):275-81; discussion 283.

10. Pappalardo G, Spoletini D, Nunziale A, et al.: *The surgical tratment of the subperitoneal rectal cancer*. Ann Ital Chir, 2010; 81(4):255-63; discussion 283.

11. Pappalardo G: *Symposium: The treatment of cancer of the subperitoneal rectum*. Ann Ital Chir, 2010; 81(4):237.

12. Curet MJ: *Laparoscopic-assisted resection of colorectal carcinoma.* Lancet, 2005; 365(9472):1666-668.

13. Jayne DG, Guillou PJ, Thorpe H, et al.: *Randomized trial of laparoscopic-assisted resection of colorectal carcinoma: 3-year results of the UK MRC CLASICC Trial Group*. J Clin Oncol, 2007; 25(21):3061-98.

14. Sammour T, Kahokehr A, Srinivasa S, et al.: *Chemoradiotherapy for rectal cancer. When, why, and how?* N Engl J Med, 2004; 351(17):1790-792

15. Fleshman J, Sargent DJ, Green E. et al.: *Laparoscopic colorectal surgery is associated with open surgery based on 5-year data fronm the COST Study Group Trial*. Ann Surg, 2007; 246(4):655.-62: discussion 662-64.

16. Bonjer HJ, Hop WC, Nelson H, et al.: *Laparoscopic assisted ve open colectomy for colon cancer: A meta-analysis*. Arch Surg, 2007; 142(3): 298-303.

17. Madoff RD: C*hemoradiotherapy for rectal cancer: When, why and how?* N Engl J Med, 2004; 351(17):1790-792.

18. *Improved survival with preoperative radiotherapy in resectable rectal cancer. Swedish Rectal Cancer Trial*. N Engl J Med, 1997; 336(14):980-87.

19. Camma C, Giunta M, Fiorica F, et al.: Re*sults of European pooled analysis of IORT-containing multimodality treatment for locally advanced rectal cancer: Adjuvant chemotherapy prevents local recurrence rather than distant metastases*. Ann Oncol, 2010; 21(6):1279-84.

23. Valentini V, Morganti AG, De Franco A, et al: *Chemoradiation with or without intraoperative radiation therapy in patients with locally recurrent rectal carcinoma: Prognostic factors and long term outcome*. Cancer, 1999; 86(12):2612-624.

24. Guillem JG, Chessin DB, Cohen AM, et al.: L*ong-term oncologic outcome following preoperative combined modality therapy and total mesorectal excision of locally advanced rectal cancer.* Ann Surg, 2005; 241(5):829-36; discussion 836-8.

25. Civello IM, Brisinda G, Brandara F, et al.: Lap*aroscopic rectal resection with intraoperative radiotherapy in locally advanced cancer: Preliminary results*. Surg Oncol, 2007; 16 Suppl 1:S97-100.

26. Mandard AM, Dalibard F, Mandard JC, et al.: *Meta-analysis of short-term outcomes after laparoscopic resection for colorectal cancer*. Br J Surg, 2004; 91(9):1111-124.

32. Jayne DG, Thorpe HC, Copeland J, et al.: *Five-year follow-up of the Medical Research Council CLASICC trial of laparoscopically assisted versus open surgery for colorectal cancer.* Br J Surg, 2010; 97(11):1638-945.

33. Lezoche G, Baldarelli M, Campagnacci R, et al.: *Laparoscopic surgery of rectal cancer: State of art and long-term results.* Ann Ital Chir, 2010; 81(4):265-68; discussion 283.

34. Del Rio P, Dell'Abate P, Gomes B, et al.: *Analysis of risk factors for complications in 262 cases of laparoscopic colectomy*. Ann Ital Chir, 2010; 81(1):21-30.

35. Miccini M, Borghese O, Scarpini M, et al.: *Anastomotic leakage and septic complications: Impact on local recurrence in surgery of low rectal cancer.* Ann Ital Chir, 2011; 82(2):117-23.

36. Pata G, Casella C, Nascimbeni R, et al.: *Adverse effects of preoperative radiation therapy for rectal cancer: Long-term follow-up of the Swedish Rectal Cancer Trial.* J Clin Oncol, 2005; 23(34):8697-705.

37. Jovine E, Talarico F, Bolchini F, Landolfo G, Mastrangelo L, Lerro MF, Martuzzi F, Selleri S, Lazzari A, Iusco DR, Gizzi G: *Laparoscopic colorectal surgery: Is the "learning curve" necessary.* Ann Ital Chir, 2005; 76:183-87.

38. Bosset JF, Collette L, Calais G, Mineur L, Maingon P, Radosevic-Jelic L, Daban A, Bardet E, Beny A, Ollier JC: EORTC Radiotherapy Group Trial 22921: *Chemotherapy with preoperative radiotherapy in rectal cancer.* N Engl J Med, 2006; 355(11):1114-123. Erratum in: N Engl J Med, 2007; 357(7):728.

39. Braendengen M, Tveit KM, Berglund A, Birkmeyer E, Frykholm G, Pahlman L, Wiig JN, Byström P, Bujko K, Glimelius B: *Randomized phase III study comparing preoperative radiotherapy with chemoradiotherapy in nonresectable rectal cancer.* J Clin Oncol, 2008; 26(22):3687-694. doi: 10.1200/ICO.2007.15.3858.

40. Birgisson H, Påhlman L, Gunnarsson U, Glimelius B; Swedish Rectal Cancer Trial Group: *Adverse effects of preoperative radiation therapy for rectal cancer: Long-term follow-up of the Swedish Rectal Cancer Trial.* J Clin Oncol, 200; 23(34):8697-705.