**Name of journal:** *World Journal of Gastroenterology*

**ESPS Manuscript NO: 17702**

**Manuscript Type: ORIGINAL ARTICLE**

***Retrospective Study***

**Laparoscopic *vs* open ab****dominoperineal resection in multimodality management of low rectal cancers**

Wang YW *et al.* Laparoscopic *vs* open abdominoperineal resection

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**Institutional review board statement:** The study was reviewed and approved by the Ethical Committee and Institutional Review Board of Fudan University Shanghai Cancer Center.

**Informed consent statement:** All study participants, or their legal guardian, provided informed written consent prior to study enrollment.

**Conflict-of-interest statement:** All of the authors declared no conflict-of-interest.

**Data sharing statement:** Technical appendix, statistical code, and dataset available from the corresponding author at lxx1149@163.com. Consent was not obtained but the presented data are anonymized and risk of identification is low.

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**Telephone:** +86-21-65642222

**Received:** March 19, 2015

**Peer-review started:** March 20, 2015

**First decision:** April 23, 2015

**Revised:** May 12, 2015

**Accepted:** July 15, 2015

**Article in press:**

**Published online:**

**Abstract**

**AIM:** To evaluate the safety and feasibility of laparoscopic abdominoperineal resection compared with open procedure in multimodality management of rectal cancer.

**METHODS:** A total of 106 rectal cancer patients underwent open abdominoperineal resection (OAPR) were matched against 106 patients who underwent laparoscopic abdominoperineal resection (LAPR) in a 1 to 1 fashion, during the same period between 2009 and 2013 from Fudan University Shanghai Cancer Center. Propensity score matching was carried out based on age, gender, pathological staging of the disease and administration of neoadjuvant chemoradiation. Data regarding preoperative staging, surgical technique, pathological results, postoperative recovery and complications were reviewed and compared between LAPR and OAPR groups. Perineal closure around the stoma and pelvic floor reconstruction were performed only in OAPR, not in LAPR. Therefore, Abdominoperineal resection procedure specific surgical complications including parastomal hernia and perineal wound complications was compared between open and laparoscopic procedure. Regular surveillance of the two cohorts was carried out to gather prognostic data. Disease-free survival was analyzed using Kaplan-Meier estimate and log-rank test. Subgroup analysis was performed among patients with locally advanced disease treated with preoperative chemoradiation followed by surgical resection.

**RESULTS:** No significant difference was found between LAPR cases and OAPR cases in terms of clinicopathological features. The operation time (180.8 ± 47.8 min *vs* 172.1 ± 49.2 min, *P =* 0.190), operative blood loss (93.9 ± 60.0 mL *vs* 88.4 ± 55.2 mL, *P =* 0.494), total number of retrieved lymph nodes (12.9 ± 6.9 *vs* 12.9 ± 5.4, *P =* 0.974), surgical complication (12.3% *vs* 15.1%, *P =* 0.549) and pathological characteristics were comparable between LAPR and OAPR group, respectively. Compared with OAPR cases, LAPR showed significantly shorter postoperative analgesia (2.4 ± 0.7 d *vs* 2.7 ± 0.6 d, *P <* 0.001), earlier first flatus pass (57.3 ± 7.9 h *vs* 63.5 ± 9.2 h, *P <* 0.001) shorter time of urinary drainage (6.5 ± 3.4 *vs* 7.8 ± 1.3, *P <* 0.001), and shorter postoperative admission (11.2 ± 4.7 d *vs* 12.6 ± 4.0 d, *P* = 0.014). Regarding to APR specific complications (perineal wound complication and parastomal hernia), there were no significant differences between the two groups. Similar results were found in the 26 pair of patients administrated with neoadjuvant chemoradiation in subgroup analysis. During the follow-up period, no port site recurrence was observed.

**CONCLUSION:** Laparoscopic abdominoperineal resection for multidisciplinary management of rectal cancer is safe, and associated with earlier recovery and shorter admission time in combination with neoadjuvant chemoradiation.

**Key words:** Abdominoperineal resection; Laparoscopy; Rectal cancer; Total mesorectal excision; Neoadjuvant chemoradiation

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**Core tip:** This retrospective, case-matched study demonstrated that, for abdominoperineal resection of low rectal cancer, laparoscopy improve postoperative recovery, reduce admission time without jeopardizing clear circumferential resection margin, lymph nodes yield and surgical complications. Especially, risks of abdominoperineal resection specific surgical complications, including perineal wound reintervention and parastomal hernia, were comparable between laparoscopy and open procedure. No significant difference regarding local recurrence and metachronous metastasis was detected. Laparoscopy in combination with neoadjuvant chemoradiation for multidisciplinary management of low rectal cancer is also safe, and associated with earlier recovery.

Wang YW, Huang LY, Song CL, Zhuo CH, Shi DB, Cai GX, Xu Y, Cai SJ, Li XX. Laparoscopic *vs* open abdominoperineal resection in multimodality management of low rectal cancers. *World J Gastroenterol* 2015; In press

**INTRODUCTION**

Oncological outcomes of patients with rectal cancer has been improved by multimodal treatment with adjuvant/neoadjuvant chemoradiation, total mesorectal excision (TME) over the last decades[1,2]. With introduction and popularization of TME by Heald and coworkers since 1982[3], the rate of local recurrence and positive circumferential resection margin (CRM) has been greatly reduced[4,5]. Improvement of local control *via* neoadjuvant chemoradiation (neoCRT) has also been supported by high level evidence from long-term follow-up of random clinical trials, especially in patents with involved nodes[6-10]. Laparoscopic TME as a minimally invasive approach for treatment of rectal cancer has been proven technically feasible and safe with fewer complications and faster postoperative recovery than open TME[11-16]. Long term oncologic equivalence of laparoscopic *vs* open surgery for rectal cancer has also been confirmed by several randomized clinical trials[17-20] and meta-analysis[21].

Nevertheless, surgical resection remains to play a central role in curative treatment[22]. As one of the standard operations for low rectal cancer, abdominoperineal resection (APR) once known as Miles operation was introduced in the late nineteenth century[23]. In spite of the increasing of sphincter-preserving operations combined with neoadjuvant chemoradiation[24], APR remains the only option for 30% or more proportion of cases[25]. Tumors involving the levator ani muscle or the external anal sphincter, and inability to guarantee negative distal margin *via* sphincter-preserving operation, are still clear indications for APR[24] .

Most of those studies mentioned above, enrolled patients underwent low anterior resection (LAR) together with those underwent APR. However, APR is a completely different form of procedure from LAR in case of approaches, incisions, field, area, digestive tract reconstruction, complications and difficulty[23,26,27]. There lacks investigations to compare the short-term clinicopathological outcomes and long-term oncological equivalence between laparoscopic and conventional open approach to perform abdominoperineal resection in rectal cancer of all stages, especially in the era of multimodality. The present study was therefore conducted to evaluate the safety and feasibility of laparoscopic abdominoperineal resection (LAPR) with open abdominoperineal resection (OAPR) in multidisciplinary treatment of rectal cancer with/without neoCRT.

**MATERIALS AND METHODS**

A total of 106 patients with rectal cancer underwent LAPR in Fudan University Shanghai Cancer Center between March 2009 and December 2013 were enrolled in this study. According to the principle of intent-to-treat, patient who received conversional open procedure were included in the LAPR group. The diagnosis of adenocarcinoma, mucinous adenocarcinoma or signet-ring carcinoma of the rectum (≤ 10 cm from the anal verge) were confirmed pathologically. The exclusion criteria were patients with other gastrointestinal disease that require surgical intervention; previous malignant tumors; previous laparotomies; graded ASA Ⅳ or Ⅴ.

In order to minimize confounding effect of selection bias, 1:1 propensity score matching was performed to select a control group of 106 patients who underwent conventional OAPR during the same period from a cohort of 466 patients. Age, sex, BMI, ASA score, neoCRT, distance from tumor to anal verge and postoperative pathological staging were selected as covariates in the logistic regression model to estimate the propensity scores. These covariates were matched between OAPR and LAPR group because they may have influence on short-term clinical outcomes.

Before surgery, all patients were assessed systemically by physical examination, biochemical analysis, colorectal cancer marker panel (carcinoembryonic antigen, carbohydrate antigen 19-9, cancer antigen 724, cancer antigen 242 and cancer antigen 125 for females) assay. Computed tomography of the chest, abdominal, pelvic or whole body positron emission tomography (PET), were performed to detect distant metastasis. Magnetic resonance imaging or endorectal ultrasound was performed to determine the preoperative cT category and cN category of the primary tumor. Patients preoperative staged at cT3/4 or cN+ with any cT were administrated with neoCRT in the absence of contraindications.

An interval time of 6~8 weeks between surgery and preoperative chemoradiation were ensured. All performed open or laparoscopic abdominoperineal procedure followed the standard TME principles as described previously[16]. TME consists of maintaining the integrity of mesorectal fascia and preservation of autonomic nervous system with emphasis on sharp dissection under direct visualization. Regarding to the extension of en bloc resection of the distal rectum, conventional method instead of extralevator approach was adopted in all cases. All the operations in this study were performed by the same surgical team (Li XX, Ye X and Cai GX) with experience of more than 100 laparoscopic and open colorectal cancer surgeries annually at Department of Colorectal Surgery of Fudan University Shanghai Cancer Center.

Routine follow up were carried out among all the enrolled patients 2 wk after surgery, every 3 mo for the first year, every 6 mo for the second year and every year afterwards. Adjuvant chemoradiation were administrated adhering to the NCCN guideline to treat rectal cancer based on TNM staging[28].

Data regarding demographics, preoperative evaluation and staging, surgical technique, pathological results, postoperative recovery and complications were collected by chart reviewing. The laparoscopic rectal cancer surgery program of our institution was approved by the Ethical Committee of Shanghai Cancer Center, Fudan University. Informed consent were obtained from all patients.

Parametric variables were demonstrated as mean ± SD. The Student’s *t* test was used to assess differences of continuous variables. The *χ*2 test or Fisher’s exact test were performed to compare proportions between two groups when appropriate. Difference of disease-free survival was evaluated using log-rank test with survival curves generated by Kaplan-Meier method. A two-sided *P* < 0.05 was considered statistically significant. SPSS version 20.0 software package for Windows (SPSS Inc., Chicago, IL) was used to conduct all statistical analysis. This study was reviewed and approved by the ethics committee of Fudan University Shanghai Cancer Center, and informed consent was acquired from each patients enrolled in the study.

The statistical methods of this study were reviewed by center of medical biostatistics of Fudan University Shanghai Cancer Center.

**Results**

***Patient demographics***

In the present study, 106 patients underwent LAPR and were matched against 106 patients who underwent OAPR. The proportion of patients administrated with neoCRT were 24.5% (26/106) in both groups. Patients’ demographics and preoperative evaluation were summarized in Table 1. 55 (51.9%), and 51 (48.1%) patients are male in both groups, respectively (*P =* 0.583). The mean ages are 58.01 and 56.78 in the LAPR and OAPR group, respectively (*P =* 0.454). The mean body mass index (BMI) are comparable between the two groups (23.13 *vs* 22.97, *P =* 0.690). The mean distance from primary tumor to anal verge was 3.87 and 3.58 in the LAPR and OAPR group, respectively (*P =* 0.099).

***Quality of surgery***

Positive margin was defined as present of tumor cell at or within 1mm from the margin[29]. In the present study, negative circumferential, distal and proximal margin were confirmed microscopically among all cases. The resections were considered curative (R0 resection) in all patients except for those with preoperatively confirmed isochronous metastatic disease. Conversion to open procedure were required in 3 cases (3/106, 2.83%). The reasons for conversion was massive adhesion of intestine and the peritoneum in two cases and severe invasion of the primary tumor to the bladder and seminal vesicle in one case.

Intraoperative blood loss was greater (93.87 mL *vs* 88.44 mL, *P =* 0.494) and operating time was longer (180.83 min *vs* 172.07 min, *P =* 0.190) in the LAPR group compared with OAPR group, however, the difference were not statistically significant (Table 2).

***Pathological results and postoperative recovery***

Pathological staging were comparable between the groups (*P =* 1.000). No statistical differences were detected between LAPR and OAPR groups regarding mucinous adenocarcinoma (8.5% *vs* 7.5%, *P =* 1.000), poorly differentiated (23.5% *vs* 26.1%, *P =* 0.687), perineural invasion (19.8%, 15.1%, *P =* 0.366), lymphovascular invasion (14.2% *vs* 15.2%, *P =* 0.846), mean tumor size (3.08cm *vs* 3.48cm, *P =* 0.055) and mean retrieved lymph nodes (12.88 *vs* 12.91, *P =* 0.974, Table 1).

Patients in LAPR groups experienced significantly shorter time to first pass of flatus (*P <* 0.001), time of postoperative analgesia (*P <* 0.001), duration of urinary (*P <* 0.001) and postoperative admission days (*P =* 0.014, Table 2).

***Surgical complications***

Nine (84.9%) and 13 (12.3%) patients suffered from postoperative complications in LAPR and OAPR group with *P =* 0.500. Abdominal wound infection occurred in 3 and 5 cases and postoperative bowel obstruction was detected in 1 and 2 patients in LAPR and OAPR group, respectively. One patient experienced ureter damage in each of the groups. 1 urethral damage happened in LAPR group. With special consideration, as two of APR specific surgical complications, perineal wound complication required reintervention (1 case *vs* 2 cases) and parastomal hernia (1 case *vs* none) were also comparable between the two groups. There was no perioperative mortality or readmissions or relaparotomies among all cases. The distribution of complications was not statistically different (*P =* 0.616, Table 3).

***Follow-up***

Short-term follow-up was carried out among all the enrolled patients with a median follow-up time of 16 mo (range: 1-67 mo). Metachronous metastasis was detected in 15 cases (9 lung, 5 liver, 2 bone, 1 inguinal lymph node and 2 peritoneum). 4 cases were diagnosed with local recurrence. 2 and 3 cases of mortality occurred in LAPR and OAPR group resulting from cachexia caused by metastatic disease. The number of metachronous metastasis was comparable between LAPR and OAPR (3 cases *vs* 12 cases, *P =* 0.275). Similarly, number of local recurrence was not significantly different between LAPR and OAPR group (3 *vs* 1, *P =* 0.337). 3-year disease-free survival rate was 88.1% and 71.9% in LAPR and OAPR group, respectively (*P =* 0.317, Figure 1). No port site recurrence was observed among all patients during the follow-up period.

***Neoadjuvant chemoradiation***

Sub-group analysis was carried out by dividing the enrolled patients by preoperative chemoradiation. 24.5% (26/80) patients in each of the LAPR and OAPR group were administrated with preoperative chemoradiation. Among patients with preoperative chemoradiation, 2 cases in the LAPR group (7.7%) and 3 cases in the OAPR group (11.5%) achieved complete pathological remission.

The demographics of the patients, clinicopathological features of the tumors and surgical complications were comparable between LAPR and OAPR group among patients with or without neoCRT (Table 4). Mean lymph nodes yield were significantly lower in patients with neoCRT (8 *vs* 14, *P <* 0.001). Among locally advanced patients treated with neoCRT, the intraoperative blood loss (*P =* 0.451), operation time (*P =* 0.301), postoperative analgesia (*P =* 0.094) and postoperative hospital stay were comparable LAPR and OAPR group, while time to first pass of flatus (*P <* 0.001) and duration of urinary drainage (*P <* 0.001) was significantly shorter in LAPR group compared with OAPR group. Detailed comparative data were summarized in Tables 5 and 6.

**DISCUSSION**

Laparoscopy has been applied in colorectal surgery for more than 20 years. While waiting for long-term outcomes to confirm its oncological equivalence, according to meta-analysis of short-term results of multiple non-randomized and randomized trials, laparoscopic resection of rectal cancer have been proved feasible, effaceable and safe with reduced risks for postoperative morbidity and mortality[30,31]. However, what worth noting is that none of these trials or meta-analysis provided any subgroup analysis to address this issue among patients received APR procedure, nor did they report sphincter-preserving rate. Taking into account that APR procedure is different from sphincter-preserving procedure in nature resulting in perineal wound, end-sigmoid-colostomy prolonged postoperative recovery, increased incidence and broadened spectrum of surgical complications, the effect of laparoscopy on APR procedure could be overemphasized or underestimated according to these evidence.

As shown in the present case-matched study, low rectal cancer patients underwent LAPR performed by extensively experienced surgeons demonstrated improved postoperative recovery and equal risks of complications, and retrieved lymph nodes, compared with OAPR. All of the non-metastatic patients were radically resected with negative CRM. No readmission, reoperation, perioperative mortality, port site or local recurrence was observed in both groups, indicating the safety, feasibility and oncological equivalence of LAPR. Furthermore, among patients received neoCRT, LAPR decreased time to first flatus pass and duration of urinary drainage, while maintaining similar risks of complications and comparable retrieved lymph nodes. During short-term follow-up, the rate of metachronous metastasis was comparable between LAPR and OAPR.

Meta-analysis of trials including both AR and APR since 2000s have shown that patients benefit from laparoscopic rectal surgery with respect to improved postoperative recovery, improved abdominal cosmesis, reduced surgical complications, less abdominal wound infection and ventral hernias[32]. Similarly, as demonstrated in previous studies including only APR, laparoscopic APR provided less blood loss[33] and reduced postoperative pain, shortened postoperative ileus, earlier return of bowel function, earlier mobilization[34] which was in consistence with our findings. Greater magnification and illumination of the surgical field by laparoscopy allows better exposure and protection of the autonomic nerves probably resulting in shorter urinary drainage. Minimally invasion approach with smaller abdominal wound and less blood loss may be the reason for less analgesic requirement and improved recovery.

In case of surgery quality and oncological radicality reflected by CRM and lymph node yield, respectively, short-term results of major multicenter randomized trials: CLASICC[35] and COLOR[19] comparing conventional open and laparoscopic rectal surgery showed that the rate of positive CRM and lymph node yield were not statistically different. Meta-analysis of randomized clinical trials by Aziz *et al*[14] , Anderson et al[36] and Huang et al[21] also indicated comparable rate of positive CRM and lymph node yield between open and laparoscopic procedure for resection of rectal cancer which supported the results from the present study. In our study, lymph nodes yield were 8 and 14 in patients with or without neoCRT which was comparable as reported by previous studies.

APR were concluded by a number of studies to have greater risks of postoperative morbidity, prolonged recovery, worse survival and local control than sphincter-saving procedures[26,27,37-39]. Despite that patient- and tumor-related factors such as older age, higher tumor stage[40,41], the procedure itself also contribute to the worse short-term outcomes of APR due to the extensive surgical field leading to perineal wound and greater chances of tumor perforation, involved resection margin and damage of adjacent structures such as urethra, also, the stoma-related complications resulted from inevitable permanent end colostomy. Intensified treatment of lower rectal cancer with neoadjuvant chemoradiotherapy have been found to increase the chances of perineal wound complications[42,43]. However, detailed comparatives of equivalence between laparoscopy and conventional open procedure regarding perineal wound and parastomal problems is lacking in most studies. In the present study, we compared the number of cases suffered from perineal wound dehiscence and deep pelvic abscess resulting in reintervention of perineal wound, and also the number of parastomal hernias. The results showed that LAPR and OAPR shared similar chances of perineal wound reintervention and parastomal hernia. Although LAPR avoids midline incision, LAPR patients showed only slightly decreased chances of abdominal wound infection. The underline reason could be the inability to detect difference due to low event rate.

Toxicity from chemotherapeutic agents and radiation effects resulted in increased operative blood loss and operation time, greater risk of surgical complications which exert negative influence on postoperative recovery and surgical complications[44,45]. Intensified treatment of lower rectal cancer with neoCRT have been found to increase the chances of perineal wound complications[42,43]. According to our results, among neoadjuvant treatment patients, laparoscopy showed improved postoperative recovery of bowel and bladder function, while maintained comparable rate of APR specific complication. The intraoperative blood loss, operation time, postoperative admission day and APR specific complications were all comparable between LAPR and OAPR group.

There exists several limitations in our study. Firstly, due to limited sample size, only 26 patients received neoCRT in each OAPR and LAPR group which could diminish the ability to distinguish the potential difference of postoperative recover and complication risks. Secondly, because of retrospective design of our study, selection bias could interference the interpretation of the statistical results. The majority of analyzed patients were ASA score Ⅰ and Ⅱ resulting lower postoperative complication rate. Also, in each group, almost 60% patients were pathological stage Ⅰ and Ⅱ. The ability of larparscopy in improvement of postoperative recovery and morbidity of late stage rectal cancer need to be tested in future study with larger sample size in the subgroup. Lastly, since the median follow-up time is much shorter than 5 years, only short-term but not long-term results was reported in this study. The equivalence of laparoscopy in multidisciplinary treatment of rectal cancer need further data to analysis.

In conclusion, our single-center, retrospective, case-matched study demonstrated that, among patients with low rectal cancer requiring abdominal perineal resection of primary tumor, laparoscopy improve postoperative recovery without jeopardizing clear circumferential resection margin, lymph nodes yield and surgical complications. Especially, risks of APR specific surgical complication, perineal wound reintervention and parastomal hernia were comparable in LAPR and OAPR group.

**COMMENTS**

***Background***

Optimal perioperative chemoradiation, standard total mesorectal excision (TME) as well as multidisciplinary meeting have contributed greatly in reducing local recurrence of rectal cancer. Abdominoperineal resection (APR) is a highly complex procedure and the associated surgical complication and mortality rate are prominent. Nevertheless, APR remains to be the only curative option for more than 30% of low rectal cancer.

***Research frontiers***

Laparoscopy as a minimal invasive procedure, has been the gold standard in treatment of cholecystitis and gained tremendous value in resection of colon cancer. More recently, high-level evidence suggested equivalent oncological outcomes between laparoscopic and open TME of rectal cancer, as well as improved posteroperative recovery of laparoscopic TME.

***Innovations and breakthroughs***

The present study demonstrated improved postoperative recovery and shorter admission time after laparoscopic abdominoperineal resection (APR), compared with conventional open procedure. Laparoscopic APR is safe and equal in terms of surgical and oncological outcome. Moreover, APR specific complications including perineal wound reintervention and parastomal hernia are comparable between laparoscopy and open surgery.

***Applications***

In the era of individualized and multidisciplinary oncology, increasing application of laparoscopy to perform APR is another milestone and will benefit more patients with low rectal cancer patients.

***Terminology***

APR, also called Miles operation, involved surgical removal of the anus, the rectum and part of distal pelvic colon together with mesocolon and lymph nodes, specimen taken out through perineal incision and end-sigmoidostomy. Laparoscopy, as a minimal invasive procedure avoiding mid-line incision, provide greater magnification and illumination of the surgical field.

***Peer-review***

This article is well written and well documented. The number of patients is important, and the team has good surgical results. Laparoscopy offers clear advantages found in large series and in your study. But we must not forget that the oncological outcome prevails. Laparoscopy and open surgery gives similar oncologic results. The surgeon must perform the procedure using the technique he mastered the best (even if open surgery is chosen).

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**P-Reviewer:** Falletto E, Kotzampassakis N **S-Editor:** Yu J **L-Editor:** **E-Editor:**

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**Figure 1 Among 161 patients with non-metastatic disease upon diagnosis and follow-up time more than 1 mo, survival curves was carried out using log-rank test and Kaplan-Meier estimate.** The 3-year disease-free survival of LAPR and OAPR group was 88.1% and 71.9%, respectively (*P =* 0.317). LAPR: Laparoscopic abdominoperineal resection; OAPR: Open abdominoperineal resection.

**Table 1 Summarized clinicopathological features**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | | **LAPR** | |  | **OAPR (%)** | |  |
| mean, *n* | SD (%) |  | mean, *n* | SD (%) | *P* value |
| Age (yr) |  | 58.01 | 11.64 |  | 56.78 | 12.28 | 0.454 |
| BMI |  | 23.13 | 3.01 |  | 22.97 | 2.85 | 0.690 |
| Gender |  |  |  |  |  |  | 0.583 |
|  | Male | 55 | 51.9 |  | 51 | 48.1 |  |
|  | Female | 51 | 48.1 |  | 55 | 51.9 |  |
| ASA score |  |  |  |  |  |  | 0.783 |
|  | Ⅰ | 54 | 50.9 |  | 52 | 49.1 |  |
|  | Ⅱ | 51 | 48.1 |  | 53 | 50.0 |  |
|  | Ⅲ | 1 | 0.9 |  | 1 | 0.9 |  |
| Neoadjuvant |  |  |  |  |  |  | 1.000 |
|  | No | 80 | 75.5 |  | 80 | 75.5 |  |
| Yes | 26 | 24.5 |  | 26 | 24.5 |  |
| Histology |  |  |  |  |  |  | 1.000 |
|  | Adenocarcinom | 97 | 91.5 |  | 98 | 92.5 |  |
| Mucinous adenocarcinoma | 9 | 8.5 |  | 8 | 7.5 |  |
| Pathological stage |  |  |  |  |  |  | 1.000 |
|  | pCR | 2 | 1.9 |  | 3 | 2.8 |  |
|  | Ⅰ | 43 | 40.6 |  | 41 | 38.7 |  |
|  | Ⅱ | 24 | 22.6 |  | 24 | 22.6 |  |
|  | Ⅲ | 25 | 23.6 |  | 25 | 23.6 |  |
|  | Ⅳ | 12 | 11.3 |  | 13 | 12.3 |  |
| Lymphovascular invasion |  |  |  |  |  |  | 0.846 |
|  | No | 91 | 85.8% |  | 90 | 84.9 |  |
|  | Yes | 15 | 14.2% |  | 16 | 15.1 |  |
| Perineural invasion |  |  |  |  |  |  | 0.366 |
|  | No | 85 | 80.2% |  | 90 | 84.9 |  |
|  | Yes | 21 | 19.8% |  | 16 | 15.1 |  |
| Grade |  |  |  |  |  |  | 0.451 |
|  | NA | 25 | 23.6 |  | 18 | 17.0 |  |
|  | Ⅲ/Ⅳ | 19 | 17.9 |  | 23 | 21.7 |  |
|  | Ⅰ/Ⅱ | 62 | 58.5 |  | 65 | 61.3 |  |
| pT category |  |  |  |  |  |  | 0.612 |
|  | pT0 | 4 | 3.8 |  | 4 | 3.8 |  |
|  | pT1 | 12 | 11.3 |  | 15 | 14.2 |  |
|  | pT2 | 40 | 37.7 |  | 31 | 29.2 |  |
|  | pT3 | 50 | 47.2 |  | 56 | 52.8 |  |
| pN category |  |  |  |  |  |  | 0.543 |
|  | pN0 | 74 | 69.8 |  | 70 | 66.0 |  |
|  | pN1 | 23 | 21.7 |  | 22 | 20.8 |  |
|  | pN2 | 9 | 8.5 |  | 14 | 13.2 |  |
| Total examed nodes |  | 12.88 | 6.93 |  | 12.91 | 5.40 | 0.974 |
| Distance (cm) |  | 3.87 | 1.34 |  | 3.58 | 1.28 | 0.099 |

LAPR: Laparoscopic abdominoperineal resection; OAPR: Open abdominoperineal resection; BMI: Body mass index; ASA: American society of anesthesiologists; pCR: Pathological complete remission.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Table 2 Postoperative recovery** | | | | | | |
|  | | **LAPR** | | **OAPR** | |  |
| mean | SD | mean | SD | *P* value |
| Intraoperative blood loss (mL) | | 93.87 | 60.04 | 88.44 | 55.15 | 0.494 |
| Operation time (min) |  | 180.83 | 47.83 | 172.07 | 49.16 | 0.190 |
| Time to first pass of flatus (h) | | 57.31 | 7.91 | 63.51 | 9.20 | 0.000 |
| Postoperative analgesia (d) | | 2.35 | 0.65 | 2.66 | 0.63 | 0.000 |
| Urinary drainage (d) |  | 6.45 | 3.40 | 7.75 | 1.30 | 0.000 |
| Postoperative hospital stay (d) | | 11.15 | 4.72 | 12.63 | 3.96 | 0.014 |

LAPR: Laparoscopic abdominoperineal resection; OAPR: Open abdominoperineal resection.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Table 3 Summary of complications** | | | | | |
|  | **LAPR** |  | **OAPR** |  |  |
| *n* |  | *n* |  | *P* value |
| Abdominal wound infection | 3 |  | 5 |  | 0.721 |
| Perineal wound reintervention | 1 |  | 2 |  | 1.000 |
| Bowel obstruction | 1 |  | 2 |  | 1.000 |
| Urinary retention | 2 |  | 3 |  | 1.000 |
| Ureter damage | 1 |  | 1 |  | 1.000 |
| Urethra damage | 1 |  | 0 |  | 1.000 |
| Parastomal hernia | 1 |  | 0 |  | 1.000 |
| Total | 9 |  | 13 |  | 0.500 |

LAPR: Laparoscopic abdominoperineal resection; OAPR: Open abdominoperineal resection.

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Table 4 Summarized clinicopathological features according to neoadjuvant therapy** | | | | | | | | | | | | |
|  | | **No neoCRT** | | | | |  | **neoCRT** | | | | |
| LAPR | | OAPR | |  |  | LAPR | | OAPR | |  |
| mean, *n* | SD (%) | mean, *n* | SD (%) | *P* value |  | mean, *n* | SD (%) | mean, *n* | SD (%) | *P* value |
| Age (yr) |  | 58.41 | 11.98 | 57.44 | 12.86 | 0.623 |  | 56.81 | 10.64 | 54.77 | 10.23 | 0.483 |
| BMI |  | 23.21 | 3.00 | 22.84 | 2.89 | 0.431 |  | 22.90 | 3.08 | 23.37 | 2.74 | 0.561 |
| Gender |  |  |  |  |  | 0.113 |  |  |  |  |  | 0.087 |
|  | Male | 42 | 52.5% | 32 | 40.0% |  |  | 13 | 50.0% | 19 | 73.1% |  |
| Female | 38 | 47.5% | 48 | 60.0% |  |  | 13 | 50.0% | 7 | 26.9% |  |
| ASA score |  |  |  |  |  | 0.429 |  |  |  |  |  | 0.696 |
|  | Ⅰ | 42 | 52.5% | 37 | 46.3% |  |  | 12 | 46.2% | 15 | 57.7% |  |
| Ⅱ | 38 | 47.5% | 43 | 53.8% |  |  | 13 | 50.0% | 10 | 38.5% |  |
|  | Ⅲ | 0 | 0.0% | 0 | 0.0% |  |  | 1 | 3.8% | 1 | 3.8% |  |
| Histology |  |  |  |  |  | 1.000 |  |  |  |  |  | 1.000 |
|  | Adenocarcinoma | 57 | 80.3% | 56 | 73.7% |  |  | 5 | 50.0% | 9 | 75.0% |  |
| Mucinous adenocarcinoma | 6 | 7.5% | 6 | 7.5% |  |  | 3 | 11.5% | 2 | 7.7% |  |
| Pathological stage |  |  |  |  |  | 0.884 |  |  |  |  |  | 0.970 |
|  | pCR | NA |  | NA |  |  |  | 2 | 7.7% | 3 | 11.5% |  |
| Ⅰ | 33 | 41.3% | 33 | 41.3% |  |  | 10 | 38.5% | 8 | 30.8% |  |
| Ⅱ | 20 | 25.0% | 20 | 25.0% |  |  | 4 | 15.4% | 4 | 15.4% |  |
| Ⅲ | 19 | 23.8% | 19 | 23.8% |  |  | 6 | 23.1% | 6 | 23.1% |  |
| Ⅳ | 8 | 10.0% | 8 | 10.0% |  |  | 4 | 15.4% | 5 | 19.2% |  |
| Lymphovascular invasion |  |  |  |  |  | 0.685 |  |  |  |  |  | 1.000 |
|  | No | 66 | 82.5% | 64 | 80.0% |  |  | 25 | 96.2% | 26 | 100.0% |  |
| Yes | 14 | 17.5% | 16 | 20.0% |  |  | 1 | 3.8% | 0 | 0.0% |  |
| Perineural invasion |  |  |  |  |  | 0.151 |  |  |  |  |  | 0.701 |
|  | No | 62 | 77.5% | 69 | 86.3% |  |  | 23 | 88.5% | 21 | 80.8% |  |
| Yes | 18 | 22.5% | 11 | 13.8% |  |  | 3 | 11.5% | 5 | 19.2% |  |
| Grade |  |  |  |  |  | 0.224 |  |  |  |  |  | 0.411 |
|  | NA | 9 | 11.2% | 4 |  |  |  | 16 | 61.5% | 14 | 53.8% |  |
|  | Ⅲ/Ⅳ | 14 | 17.5% | 20 | 25.0% |  |  | 5 | 19.2% | 3 | 11.5% |  |
| Ⅰ/Ⅱ | 57 | 71.2% | 56 | 70.0% |  |  | 5 | 19.2% | 9 | 34.6% |  |
| pT category |  |  |  |  |  | 0.816 |  |  |  |  |  | 0.196 |
|  | pT0 | 0 | 0.0% | 0 | .0% |  |  | 4 | 15.4% | 4 | 15.4% |  |
|  | pT1 | 11 | 13.8% | 5 | 12.5% |  |  | 1 | 3.8% | 5 | 19.2% |  |
|  | pT2 | 27 | 33.8% | 7 | 30.0% |  |  | 13 | 50.0% | 7 | 26.9% |  |
|  | pT3 | 42 | 52.5% | 10 | 57.7% |  |  | 8 | 30.8% | 10 | 38.5% |  |
| pN category |  |  |  |  |  | 0.337 |  |  |  |  |  | 0.723 |
|  | pN0 | 56 | 70.0% | 53 | 66.3% |  |  | 18 | 69.2% | 17 | 65.4% |  |
|  | pN1 | 17 | 21.3% | 14 | 17.5% |  |  | 6 | 23.1% | 8 | 30.8% |  |
|  | pN2 | 7 | 8.8% | 13 | 16.3% |  |  | 2 | 7.7% | 1 | 3.8% |  |
| Total retrieved nodes |  | 14.58 | 6.70 | 14.11 | 5.35 | 0.630 |  | 7.65 | 4.73 | 9.19 | 3.59 | 0.193 |
| Distance (cm) |  | 3.73 | 1.25 | 3.55 | 1.26 | 0.380 |  | 4.33 | 1.50 | 3.65 | 1.35 | 0.095 |

LAPR: Laparoscopic abdominoperineal resection; OAPR: Open abdominoperineal resection; BMI: Body mass index; ASA: American society of anesthesiologists; pCR: Pathological complete remission; neoCRT: Neoadjuvant chemoradiation therapy.

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Table 5 Postoperative recovery according to neoadjuvant therapy** | | | | | | | | | | | |
|  | **No neoCRT** | | | | |  | **neoCRT** | | | | |
| LAPR | | OAPR | |  |  | LAPR | | OAPR | |  |
| mean | SD | mean | SD | *P* value |  | mean | SD | mean | SD | *P* value |
| Intraoperative blood loss (mL) | 91.88 | 63.87 | 87.94 | 57.55 | 0.683 |  | 100.00 | 46.90 | 90.00 | 48.00 | 0.451 |
| Operation time (min) | 176.48 | 48.47 | 170.25 | 41.73 | 0.385 |  | 194.23 | 44.00 | 177.65 | 67.85 | 0.301 |
| Time to first pass of flatus (h) | 57.55 | 7.56 | 62.93 | 9.33 | 0.000 |  | 56.58 | 9.03 | 65.31 | 8.68 | 0.001 |
| Postoperative analgesia (d) | 2.39 | 0.63 | 2.70 | 0.64 | 0.001 |  | 2.23 | 0.71 | 2.54 | 0.58 | 0.094 |
| Urinary drainage (d) | 6.63 | 3.75 | 7.70 | 1.07 | 0.016 |  | 5.92 | 1.96 | 7.88 | 1.86 | 0.001 |
| Postoperative hospital stay (d) | 11.41 | 5.24 | 12.80 | 3.94 | 0.060 |  | 10.35 | 2.48 | 12.12 | 4.07 | 0.064 |

LAPR: Laparoscopic abdominoperineal resection; OAPR: Open abdominoperineal resection; neoCRT: Neoadjuvant chemoradiation therapy.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Table 6 Summary of complications according to neoadjuvant therapy** | | | | | | | |
|  | **No neoCRT** | | |  | **neoCRT** | | |
| LAPR | OAPR |  |  | LAPR | OAPR |  |
| *n* | *n* | *P* value |  | *n* | *n* | *P* value |
| Abdominal wound infection | 3 | 3 | 1.000 |  | 0 | 2 | 0.497 |
| Perineal wound reintervention | 0 | 1 |  |  | 1 | 1 |  |
| Bowel obstruction | 1 | 1 |  |  | 0 | 1 |  |
| Urinary retention | 1 | 3 |  |  | 1 | 0 |  |
| Ureter damage | 1 | 0 |  |  | 0 | 1 |  |
| Urethra damage | 1 | 0 |  |  | 0 | 0 |  |
| Parastomal hernia | 1 | 0 |  |  | 0 | 0 |  |
| Total | 7 | 8 | 1.000 |  | 2 | 5 | 0.191 |

LAPR: Laparoscopic abdominoperineal resection; OAPR: Open abdominoperineal resection; neoCRT: Neoadjuvant chemoradiation therapy.