ORIGINAL ARTICLE

Laparoscopic posterior pelvic exenteration is safe and feasible for locally advanced primary rectal cancer in female patients: a comparative study from China PelvEx collaborative

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Abstract

Purpose Posterior pelvic exenteration (PPE) for locally advanced rectal cancer is a technical and challenging procedure. The safety and feasibility of laparoscopic PPE remain to be determined. This study aims to compare short-term and survival outcomes of laparoscopic PPE (LPPE) with open PPE (OPPE) in female patients.

Method From January 2015 to December 2020, data from 105 female patients who underwent PPE at three institutions were retrospectively analyzed. The short-term and oncological outcomes between LPPE and OPPE were compared.

Results A total of 54 cases with LPPE and 51 cases with OPPE were enrolled. The operative time (240 vs. 295 min, $p = 0.009$), blood loss (100 vs. 300 ml, $p < 0.001$), surgical site infection (SSI) rate (20.4% vs. 58.8%, $p = 0.003$), urinary retention rate (3.7% vs. 17.6%, $p = 0.020$), and postoperative hospital stay (10 vs. 13 days, $p = 0.009$) were significantly lower in the LPPE group. The two groups showed no significant differences in the local recurrence rate ($p = 0.296$), 3-year overall survival ($p = 0.129$), or 3-year disease-free survival ($p = 0.082$). A higher CEA level (HR 1.02, $p = 0.002$), poor tumor differentiation (HR 3.05, $p = 0.004$), and (y)pT4b stage (HR 2.35, $p = 0.035$) were independent risk factors for disease-free survival.

Conclusion LPPE is safe and feasible for locally advanced rectal cancers and shows lower operative time and blood loss, fewer SSI complications, and better preservation of bladder function without compromising oncological outcomes.

Keywords Posterior pelvic exenteration · Laparoscopic · Open surgery · Oncological outcome

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Introduction

Posterior pelvic exenteration (PPE) is more frequently reported in gynecological tumors [1–3], and PPE for rectal cancers has received less attention in terms of both surgical techniques and oncological outcomes. With the popularization of and advancements in early diagnosis and neoadjuvant therapy, the incidence of locally advanced rectal cancer (LARC) has decreased. Because of the unique anatomical characteristics of female patients, the possibility of total pelvic exenteration (TPE) is relatively rare, while combined resection of the uterus and vagina is more common. Therefore, a study focusing on PPE for female patients with LARC is essential.

The short-term advantages of laparoscopic rectal cancer resection and long-term oncological outcomes that are not compromised have been confirmed in multiple prospective multicenter controlled studies [4–7]. However, all studies excluded patients with clinical stage T4 (cT4) tumors. Recently, with advancements in laparoscopic technology and

application of high-definition laparoscopy and high-energy devices, an increasing number of laparoscopic posterior pelvic exenteration (LPPE) procedures have been reported in the field of gynecological tumors [8], but only a few reports with small sample sizes or just case reports have described the use of LPPE procedures in rectal cancers [9–11]. Moreover, the long-term oncological outcomes of LPPE remain unclear, and PPE is more challenging than TPE for R_0 resection because of organ preservation.

In this cohort study from China PelvEx collaborative, we conducted a comparative study of the surgical results and oncological outcomes between LPPE and OPPE for female patients with LARC. We also evaluated prognostic factors for PPE.

Patients and methods

Study design and participants

This was a multicenter, retrospective study from a prospectively collected institutional database and tumor registry for female patients with LARC at three institutions of the China PelvEx collaborative between January 2015 to December 2020. Consecutive female patients with LARC undergoing PPE were identified. The inclusion criteria were as follows: (1) radical resection; (2) female patients with LARC (cT4b); (3) histologically proven adenocarcinoma. The exclusion criteria were as follows: (1) total pelvic exenteration (TPE); (2) patients with simultaneous distant metastasis; (3) patients with recurrent rectal cancer; (4) proctectomy with oophorectomy; (5) PPE with sacrectomy. Preoperative multidisciplinary consultations were performed for all patients. Multidisciplinary consultations included colorectal surgery, medical oncology, radiotherapy, gynecology, urology, and plastic surgery. Treatment strategies for each patient such as the choice of surgical approach (open or laparoscopic) and whether preoperative chemoradiotherapy was performed were determined by multidisciplinary team meetings (MDT). We determined the surgical procedure also on the basis of the laparoscopic exploration. All patients provided written informed consent, and the study was approved by the Ethics Committee of Cancer Hospital, Chinese Academy of Medical Sciences, Peking University First Hospital, and Gansu Provincial Hospital (ethical approval number 22/442-3644).

Preoperative management

Preoperative multidisciplinary consultation was performed for all patients. Neoadjuvant chemoradiotherapy (nCRT) was suggested for patients with clinical stage T4b disease. We used a standard, long course regimen of 5-fluorouracil (5-FU)-based chemotherapy with a total dose of 45–54 Gy of external beam radiation. After nCRT, patients were reassessed using pelvic MRI. Surgery was performed approximately 6–12 weeks after nCRT.

Definitions

To date, there is no definition of PPE that is universally agreed upon. Some scholars still propose the definition in gynecological tumors for rectal cancer surgery [12–14], while others use the definite invasion of coccyx, presacral fascia, retrosacral space, and sacrum as PPE [15, 16]. In this study, the following definitions were used:

LARC: Those that are predicted by MRI to require an extended surgical resection beyond the total mesorectal plane to achieve an R_0 resection.

PPE: Defined as the removal of the reproductive organs and rectum, sparing the bladder.

Pathological resection margin status: R_0, microscopically clear resection margins of at least 1 mm; R_1, microscopically involved resection margin with tumor within 1 mm of the resection margin; R_2, macroscopically involved resection margin.

Overall survival (OS): The time from the date of surgery to the date of death from any cause.

Disease free survival (DFS): The time from the date of surgery to the date of pelvic recurrence and/or distant disease or death due to pelvic recurrence and/or distant disease.

Local recurrence (LR): Defined as tumor regrowth within the pelvis, perineum, or a para-anastomosis location, while any other recurrence was defined as distant metastasis.

Surgical procedure

All surgical procedures were performed by three surgeons (XW, BD, and JT) with more than 10 years of experience in performing OPPE and LPPE and at least 1000 cases of rectal cancer resection. After induction of general anesthesia, the patient was placed in a modified lithotomy, 30° Trendelenburg position, and five ports were placed according to routine practice for laparoscopic proctectomy. The surgeon stood on the patient's right, the first assistant on the left, and the second assistant on the cranial side. A monitor was placed next to the patient's left foot. A pneumoperitoneum was created at a pressure of 14 mmHg. The surgical procedure was generally similar in the three institutions and open or laparoscopic PPE was performed in line with previously reported methods [17, 18].

The procedure began with medial-to-lateral dissection of the rectosigmoid to the lateral abdominal wall, followed by mesorectal excision, paying attention to protect the hypogastric nerves and pelvic plexus. The retrorectal space was dissected 5 cm beyond the edge of the tumor or until the levator ani muscle was exposed. The pararectal spaces were dissected on both sides after dissection of the lateral and middle rectal arteries. The infundibulopelvic ligament with the ovarian vascular pedicle and round ligament were identified and cut. The anterior perineal and vesicovaginal spaces were dissected to expose the anterior vaginal walls. The parametrial tissue and paracolpium were excised without damaging the inferior hypogastric plexus after sealing the uterine vessels adjacent to the cervix using a bipolar coagulation system. The removal of vaginal wall depends on the extent of invasion, and the vaginal stump was sutured with V-Loc absorbable suture or reconstructed with V–Y plasty [19]. The decision whether to complete anterior resection or abdominal perineal resection depends on the tumor site and length of the residual rectum.

Follow-up

Data for various clinicopathological parameters, including age, body mass index (BMI), American Society of Anesthesiologists (ASA) score, neoadjuvant treatment, tumor size, pathologic stage, serum hemoglobin (Hb), albumin (Alb), carcinoembryonic antigen (CEA), and carbohydrate antigen 19-9 (CA19-9) levels as well as perioperative results, including operative time, conversion to open surgery, blood loss, and postoperative complications were collected. Complications were assessed according to the Clavien–Dindo classification [20]. Minor surgical morbidity was defined as grade I or II, and major morbidity was defined as grade III, IV, or V. Patients were followed up regularly. All patients were followed up by phone or at the outpatient department every 3 months in the first year after the operation, every 6 months in the second year, and at least once a year thereafter. Follow-up was till patient's death or December 1, 2022. The primary endpoint was 3-year DFS. The secondary endpoints were surgical complications.

Statistical analysis

IBM SPSS Statistics 25 (IBM, Inc., Armonk, NY, USA) was used for statistical analyses. Pearson's Chi-square and Fisher's exact tests were used to compare categorical variables. The Mann–Whitney U test or Student's t test was used for continuous variables. The probabilities of local recurrence rate (LRR), OS, and DFS were assessed using the Kaplan–Meier method, and differences were compared using the log-rank test for statistical significance. Statistically significant variables in the univariate analysis were subsequently tested by multivariable analysis using a Cox regression model. Statistical significance was set at $p < 0.05$.

Results

Patient characteristics

A total of 157 consecutive female patients who underwent pelvic exenteration (PE) were identified. Thirteen cases who underwent total pelvic exenteration (TPE), 15 with Krukenberg tumor invading the rectum, and 10 with other metastasis were excluded. Finally, 105 patients (54 with LPPE and 51 with OPPE) were enrolled in study. A flowchart of the study is shown in Fig. 1. The baseline patient characteristics are summarized in Table 1. nCRT was performed in 31 out of 105 patients, of which only 1 patient had pathological complete response. The LPPE and OPPE groups showed no significant differences in age, BMI, ASA score, comorbidities, neoadjuvant therapy, tumor size, tumor differentiation, (y)pT4b stage, (y)pN+ stage, history of abdominal surgery, and laboratory test results. In the entire cohort, the proportion of cases showing (y)pT4b stage was 63.8% (67/105).
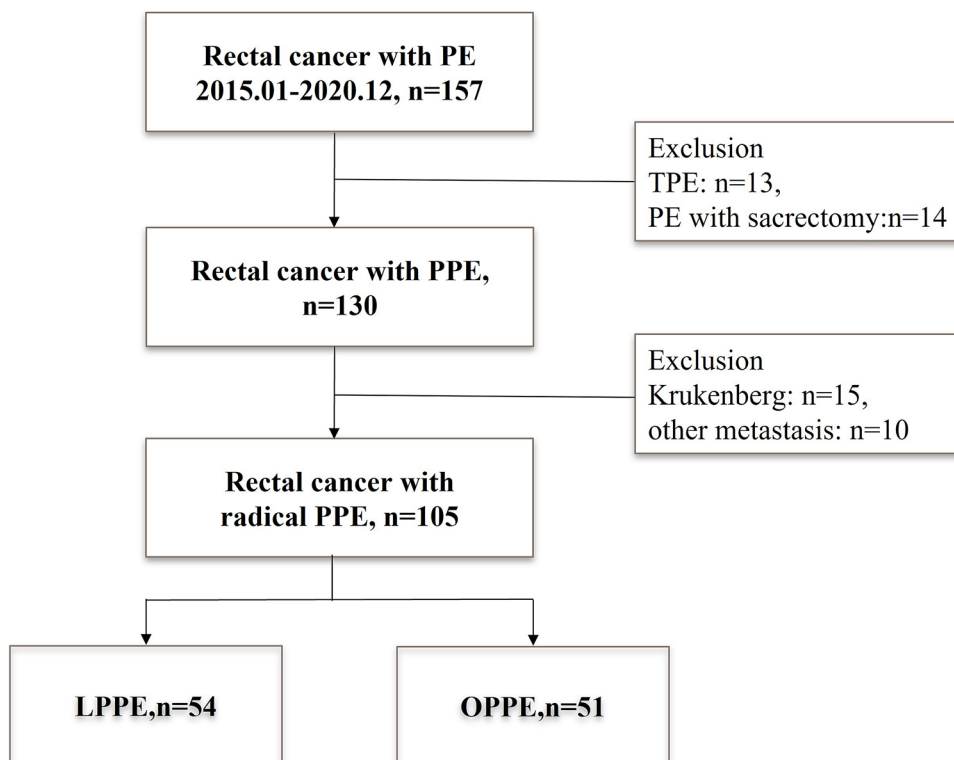
Perioperative and pathological results

The intraoperative data and pathologic results are shown in Table 2. None of the patients in the LPPE group required conversion to open surgery. The median operative time in the LPPE group was significantly shorter (240 vs. 295 min, $p = 0.009$). The median intraoperative blood loss in the LPPE group was significantly less (100 vs. 300 ml, $p < 0.001$). The two groups showed no significant differences in the number of retrieved lymph nodes, positive lymph nodes, colorectal reconstruction, and vaginal reconstruction. The negative rate of circumferential resection margin (CRM) in the LPPE group was 94.4%, more than 84.3% in the OPPE group, while the difference was not statistically significant ($p = 0.090$).

Postoperative recovery and complications

Data for postoperative convalescence and complications are shown in Table 3. No mortality occurred in either of the groups. The total in-hospital complication rate was 39.0% (41/105). The total surgical site infection (SSI) rate was 13.3% (14/105). The two groups showed no significant differences in the major complication rate (3/54 vs. 4/51, $p = 0.938$) or reoperation rate (2/54 vs. 3/51, $p = 0.672$). The overall postoperative complication rate (11/54 vs. 30/51, $p < 0.001$) and SSI complication rate (including abdominal incision, perineal incision, and pelvic and urinary infection, 2/54 vs. 12/51, $p = 0.003$) were both significantly lower in

Fig. 1 Flowchart of patient selection


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┌─────────────────────────────┐
│   Rectal cancer with PE     │
│  2015.01-2020.12, n=157     │
└─────────────────────────────┘
              │                      ┌──────────────────────────┐
              │──────────────────────│ Exclusion                │
              │                      │ TPE: n=13,               │
              │                      │ PE with sacrectomy:n=14  │
              ▼                      └──────────────────────────┘
┌─────────────────────────────┐
│   Rectal cancer with PPE,   │
│           n=130             │
└─────────────────────────────┘
              │                      ┌──────────────────────────┐
              │──────────────────────│ Exclusion                │
              │                      │ Krukenberg: n=15,        │
              │                      │ other metastasis: n=10   │
              ▼                      └──────────────────────────┘
┌─────────────────────────────┐
│     Rectal cancer with      │
│    radical PPE, n=105       │
└─────────────────────────────┘
       │                    │
       ▼                    ▼
┌───────────────┐    ┌───────────────┐
│  LPPE,n=54    │    │  OPPE,n=51    │
└───────────────┘    └───────────────┘
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the LPPE group. The total colorectal anastomotic leakage rate was 10.5% (6/57). Both LPPE and OPPE groups had three cases of colorectal anastomotic leakage (3/27 vs. 3/30, $p = 1.000$). The rate of urinary retention was significantly lower in the LPPE group (2/54 vs. 9/51, $p = 0.020$). The time to first flatus (2 vs. 3 days, $p = 0.001$), time to first liquid diet intake (3 vs. 4 days, $p = 0.001$), and postoperative hospital stay (10 vs. 13 days, $p = 0.009$) were significantly shorter in the LPPE group.

Oncological outcomes

The median follow-up period was 41 months (interquartile range 19–63 months) in the entire cohort, 38 months (interquartile range 15–52 months) in the LPPE group, and 46 months (interquartile range 20–94 months) in the OPPE group. The two groups showed no significant differences in the rate of LRR, OS, and DFS (Fig. 2a–c). The 3-year LRR in the LPPE and OPPE groups were 19.2% and 26.9%, respectively. The 3-year OS were 76.3% and 64.4% and 3-year DFS were 63.8% and 48.3% in the LPPE and OPPE groups, respectively.

Univariate and multivariable analyses of the prognostic factors influencing OS and DFS are presented in Table 4. In the univariate analysis, higher CEA level and CA19-9 level, poor differentiation, (y)pT4b and N1–2 significantly affected both OS and DFS ($p < 0.05$). Positive CRM also significantly affected OS ($p < 0.05$). Multivariable analysis revealed that

higher CEA levels (HR 1.02, 95% CI 1.01–1.03; $p = 0.002$) and poor differentiation (HR 3.05, 95% CI 1.43–6.52; $p = 0.004$) were independent risk factors for OS. For DFS, higher CEA level (HR 1.02, 95% CI 1.01–1.03; $p < 0.001$), poor differentiation (HR 2.96, 95% CI 1.41–6.18; $p = 0.004$), and (y)pT4b stage 0 (HR 2.35, 95% CI 1.06–5.19; $p = 0.035$) were independent risk factors.

Discussion

PPE has been reported more frequently in cases of advanced gynecological tumors such as ovarian cancer, cervical cancer, and vaginal tumors [8, 21–25]. For rectal cancers, it is not common to focus only on PPE, which is usually analyzed and discussed together with TPE [26–28], and the understanding of PPE is usually insufficient among colorectal surgeons. As a result of the specific anatomy of the female pelvis, the indications of TPE for LARC invading the bladder are less common. In this series, TPE represented only 3.4% of PE cases. Therefore, it is necessary to further elaborate the surgical techniques, postoperative complications, and survival outcomes of PPE in female patients. In recent years, the popularity of laparoscopic techniques and technological advances in instrumentation, such as higher-resolution magnified views, the da Vinci surgical system, and energy platforms, have broadened its use and made more complex and extensive surgeries possible [1, 29–33]. Most reports

Table 1 Characteristics of patients in LPPE group and OPPE group

Variables	LPPE group ($n = 54$)	OPPE group ($n = 51$)	p
Age (years)	59.6 ± 12.1	59.6 ± 12.2	0.999
BMI (kg/m^2)	23.8 ± 4	23.2 ± 3.5	0.383
ASA score			0.242
I–II	47 (87.0)	40 (78.4)	
III	7 (13.0)	11 (21.6)	
nCRT	18 (33.3)	13 (25.5)	0.379
Comorbidity	25 (46.3)	31 (60.8)	0.137
History of abdominal surgery	15 (27.8)	13 (25.5)	0.791
Diameter in long axis (cm)	5.0 (4.0–6.6)	5.0 (4.0–7.5)	0.219
Differentiation			0.541
Well/moderate	34 (63.0)	35 (68.6)	
Poor/signet-ring	20 (37.0)	16 (31.4)	
(y)pT stage			0.626
(y)pT4b	32 (59.3)	35 (68.6)	
(y)pT4a	6 (11.1)	4 (7.8)	
(y)pT3	14 (25.9)	12 (23.5)	
(y)pT2	1 (1.9)	0	
(y)pT1–0	1 (1.9)	0	
(y) pN+	30 (55.6)	27 (52.9)	0.788
Vascular invasion	15 (27.8)	13 (25.5)	0.791
Perineural invasion	18 (33.3)	10 (19.6)	0.112
Laboratory data			
CEA level (ng/ml)	3.9 (2.4–14.6)	5.0 (2.8–11.9)	0.248
CA19-9 (U/ml)	19.6 (10–41.3)	19.0 (10.5–64.8)	0.969
Hemoglobin (g/L)	114.7 ± 25.3	111.4 ± 22.4	0.478
Albumin (g/L)	39 ± 4.4	38.7 ± 4.4	0.692
Enrolled centers			0.896
PKUFM	23 (42.6)	24 (47.1)	
NCC	21 (38.9)	18 (35.3)	
GSH	10 (18.5)	9 (17.6)	

BMI body mass index, *ASA* American Society of Anesthesiologists, *nCRT* neoadjuvant chemotherapy, *PPE* posterior pelvic exenteration, *(y)pT4b/N+* pathologic T4b stage or having positive lymph nodes retrieved with or without neoadjuvant therapy, *CEA* carcinoembryonic antigen, *CA19-9* carbohydrate antigen 19-9, *PKUFM* Peking University First Hospital, *NCC* National Cancer Center, *GSH* Gansu Provincial Hospital

about LPPE involve gynecologic surgery. Some colorectal surgeons have shown that LPPE for LARC is feasible with less morbidity and acceptable short-term outcomes; however, the sample size was small (less than 10 cases) [11]. To date, there is still a lack of surgical and oncological evidence for LPPE in comparison with traditional OPPE. In this comparative study from China PelvEx collaborative, 54 cases of LPPE and 51 cases of OPPE were enrolled, which, to the best of our knowledge, makes it the first and largest comparative study between LPPE and OPPE. Our study showed that LPPE can be selectively implemented by experienced surgeons with lower operative time, blood loss, and SSI, better preservation of bladder function, and quicker postoperative convalescence without compromising oncological outcomes.

An important indicator for evaluating the quality of surgery is the R$_0$ resection rate [34]. Unlike TPE, PPE can be performed as an organ-sparing surgery that preserves the integrity of the bladder and its innervating nerves. Therefore, in some respects, R$_0$ resection in PPE is more difficult than in TPE. In PPE, to preserve the bladder and pelvic plexus nerves, the dissecting plane may be closer to the parametrial tissue and paracolpium, thus affecting R$_0$ resection. Although the difference in positive CRM rates between LPPE and OPPE was not significant (3/54 vs. 8/51, $p = 0.090$), as the number of cases increased, it may be practicable for the laparoscopic group to obtain a safer CRM. Therefore, patients in the LPPE group are likely to have better survival expectations. The experience of the laparoscopic technique in lateral lymph node dissection (LLND) made us more familiar with the anatomic structure in the lateral pelvic compartment and the lateral dissecting line shifting from the total mesorectal excision (TME) plane to the parietal

Table 2 Intraoperative and pathologic characteristics in LPPE group and OPPE group

Variables	LPPE group ($n=54$)	OPPE group ($n=51$)	p
Operative time (min)	240 (200–338)	295 (250–359)	0.009
Conversion to open surgery	0 (0)	–	–
Intraoperative blood loss (ml)	100 (50–300)	300 (100–600)	<0.001
Colorectal reconstruction			0.159
Colorectal anastomosis	27 (50.0)	30 (58.8)	
Hartmann	8 (14.8)	2 (3.9)	
APR	19 (35.2)	19 (37.3)	
Vagina reconstruction			0.111
Suture	50 (92.6)	42 (82.4)	
Plasty	4 (7.4)	9 (17.6)	
No. of retrieved lymph nodes	18 (12–25)	22 (17–26)	0.056
No. of positive lymph nodes	1 (0–2)	1 (0–4)	0.365
CRM status			0.090
CRM > 1 mm	51 (94.4)	43 (84.3)	
CRM ≤ 1 mm	3 (5.6)	8 (15.7)	

APR abdominal perineal resection, *CRM* circumferential resection margin

Table 3 Postoperative parameters between LPPE group and OPPE group

Variables	LPPE group ($n=54$)	OPPE group ($n=51$)	p
Mortality	0 (0.00)	0 (0.00)	1.000
Clavien–Dindo grade			**<0.001**
0	43 (79.6)	21 (41.2)	
I–II	8 (14.8)	26 (51.0)	
III–V	3 (5.6)	4 (7.8)	
Surgical reintervention	2 (3.7)	3 (5.9)	0.672
Radiological reintervention	1 (1.9)	1 (2.0)	1.000
Surgical site infection	2 (3.7)	12 (23.5)	**0.003**
Abdominal incision	0 (0)	6 (11.8)	**0.030**
Perineal incision[a]	1 (5.3)	2 (10.5)	1.000
Pelvic infection	1 (1.9)	3 (5.9)	0.354
Urinary infection	0 (0)	2 (3.9)	0.243
Rectal anastomotic leakage[b]	3 (11.1)	3 (10.0)	1.000
Intestinal leakage/fistula	0 (0)	1 (2.0)	0.486
Urinary leakage	1 (1.9)	0 (0)	1.000
Ileus	3 (5.6)	4 (7.8)	0.938
Pulmonary embolism	0 (0)	1 (2.0)	0.486
Urinary retention	2 (3.7)	9 (17.6)	**0.020**
Time to first flatus (day)	2 (2–3)	3 (2–4)	**0.001**
Time to first liquid diet (day)	3 (2–4)	4 (3–4)	**0.001**
Length of stay (days)	10 (8–14)	13 (11–17)	**0.009**

[a]For patients receiving abdominal perineal resection only (19 cases in each group)

[b]For patients receiving colorectal anastomosis only (27 cases in the LPPE group and 30 cases in OPPE group)

Bold values indicate $P<0.05$

pelvic fascia plane. The uterine vessels were dissected at the root of the inner iliac artery, and more lymph adipose tissue around the paracolpium was cleared. Moreover, meticulous dissection in the narrow pelvis under laparoscopy also helped determination of the invaded boundary and facilitated proper decision-making.

In comparison with other studies on the short-term advantages of laparoscopy, the time to first flatus, time to first
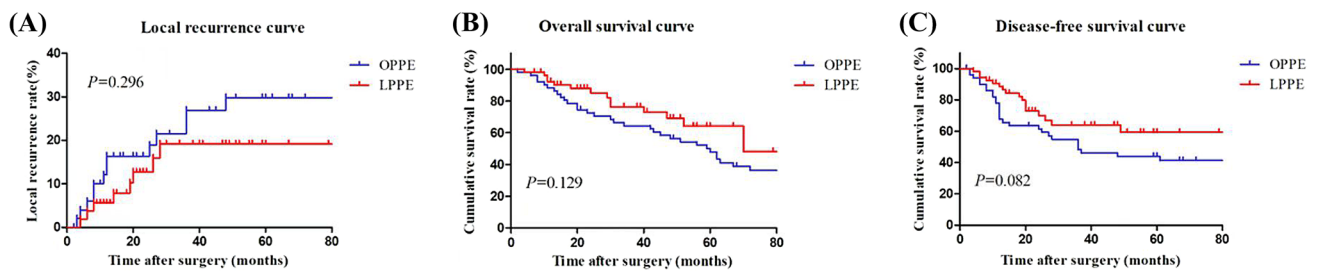
Fig. 2 Kaplan–Meier survival curves comparing local recurrence (**a**), overall survival (**b**), and disease-free survival (**c**) in the OPPE and LPPE groups

Table 4 Univariate and multivariate analysis for overall survival and disease-free survival in 105 patients receiving PPE

Variables	Overall survival				Diseases-free survival			
	Univariate analysis		Multivariate analysis		Univariate analysis		Multivariate analysis	
	HR (95% CI)	p	HR (95% CI)	p	HR (95% CI)	p	HR (95% CI)	p
Age at operation	1.01 (0.99–1.04)	0.298			1.02 (0.99–1.04)	0.169		
Distance from anal verge	0.92 (0.84–1.02)	0.092			0.93 (0.86–1.01)	0.098		
nCRT (yes/no)	1.56 (0.89–2.73)	0.120			1.53 (0.83–2.82)	0.174		
CEA level	1.01 (1.01–1.022)	**0.001**	1.02 (1.01–1.03)	**0.002**	1.01 (1.00–1.02)	**0.002**	1.02 (1.01–1.03)	**< 0.001**
CA19-9 level	1.002 (1.000–1.004)	**0.024**	1.00 (1.00–1.00)	0.767	1.002 (1.000–1.004)	**0.031**	1.000 (0.998–1.003)	0.699
Surgical approach (laparoscopic/open)	1.63 (0.86–3.10)	0.134			1.69 (0.92–3.09)	0.089		
Differentiation (poor/well, moderate)	2.20 (1.20–4.04)	**0.011**	3.05 (1.43–6.52)	**0.004**	2.23 (1.22–4.07)	**0.010**	2.96 (1.41–6.18)	**0.004**
Vascular invasion (yes/no)	1.37 (0.70–2.65)	0.356			1.50 (0.79–2.86)	0.219		
Perineural invasion (yes/no)	1.79 (0.95–3.38)	0.072			1.73 (0.92–3.26)	0.088		
(y)pT stage (T4b/non-T4b)	2.63 (1.30–5.32)	**0.007**	1.95 (0.9–4.25)	0.091	3.21 (1.54–6.68)	**0.002**	2.35 (1.06–5.19)	**0.035**
(y)pN stage (N1–2/N0)	1.87 (1.01–3.45)	**0.045**	0.96 (0.49–1.89)	0.909	2.13 (1.16–3.93)	**0.015**	1.33 (0.69–2.57)	0.391
CRM status (positive/negative)	3.10 (1.53–6.31)	**0.020**	1.53 (0.63–3.74)	0.348				
Postoperative complications (yes/no)	1.23 (0.57–2.65)	0.589			1.00 (0.43–2.37)	0.992		

CEA carcinoembryonic antigen, *PPE* posterior pelvic exenteration, *CRM* circumferential resection margin

Bold values indicate $P < 0.05$

liquid diet, and intraoperative blood loss in the LPPE group were significantly lower than those in the OPPE group. Although the two groups showed no significant differences in the overall and major complications, the rates of postoperative infectious complications (2/54 vs. 12/51, $p = 0.003$) and urinary retention (2/54 vs. 9/51, $p = 0.020$) were lower in the LPPE group. These results were consistent with those of other studies on LLND in laparoscopic or robotic surgery. The concerns regarding techniques for LPPE can be summarized as follows: First, the bilateral hypogastric nerve and neurovascular bundle should be carefully preserved when dissecting the retrorectal and pararectal space according to the principle of TME. Second, the inferior hypogastric

plexus should be isolated from the lateral vaginal wall and the branches to the vagina should be dissected while preserving the vesical branches. Third, meticulous dissection and a magnified view of the narrow pelvis under laparoscopy are more favorable for plexus preservation.

The LPPE and OPPE groups showed no significant differences in oncological outcomes, including the LRR, OS, and DFS. The DFS in the LPPE group was higher than that in the OPPE group, although the difference was not statistically significant ($p = 0.082$). On the one hand, the lower positive CRM rate in LPPE may be favorable for better LRR and DFS. More precise dissection under laparoscopy might facilitate more thorough radical resection of the tumor. Thus,

more cases, a longer follow-up period, and a case-matched comparison are needed in further studies to confirm the oncological outcomes of LPPE.

The limitations of this study are related to the retrospective study design, patient selection bias, and the relatively shorter follow-up duration in the LPPE group. Second, with the improvement of surgical technology, the update of laparoscopic equipment, the proportion of laparoscopic surgery has gradually increased, and the enrollment of cases cannot be completely consistent in time. Third, the limited data on the evaluation of bladder function may have affected the results, and whether the results apply to male patients will be clarified through further research. Lastly, less than a third of LARC received nCRT, which may introduce bias into the neoadjuvant role on survival analysis. Nevertheless, this study introduced the largest series of LPPE to date, and is the first to evaluate the surgical results and oncological outcomes between LPPE and OPPE.

Conclusion

Our results showed that LPPE is safe and feasible for selected LARC cases in female patients when performed by highly skilled surgeons, presenting a shorter operative time, less blood loss, lower surgical site infection, better preservation of bladder function, and quicker postoperative recovery without compromising the oncological outcomes. Further studies with a larger sample size and a longer follow-up period are needed to corroborate our findings.

Declarations

Conflict of interest The authors declare that they have no conflicts of interest.

Ethical approval All work was carried out in compliance with the Ethical Principles for Medical Research Involving Human Subjects outlined in the Helsinki Declaration in 1975 (revised in 2000). The study was approved by the Ethics Committee of Cancer Hospital, Chinese Acad-

emy of Medical Sciences, Peking University First Hospital, and Gansu Provincial Hospital (ethical approval number 22/442-3644).

Informed consent All patients provided written informed consent.

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