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Surgical outcomes of laparoscopic distal pancreatectomy in elderly and octogenarian patients: a single-center, comparative study

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Abstract

Background Although recent reports have suggested the advantages of laparoscopic distal pancreatectomy (LDP), the potential benefits of this approach in elderly patients remain unclear. The aim of this study was to clarify the value of LDP in the elderly, in whom co-morbid diseases were generally more common.

Methods Seventy elderly patients (≥ 70 years) and 264 non-elderly patients (40–69 years) who underwent LDP, and 48 elderly patients (≥ 70 years) who underwent open distal pancreatectomy (ODP) between May 2005 and May 2018 were studied. Demographics, intraoperative, and postoperative outcomes were compared.

Results Comorbidity was more common in elderly patients than in non-elderly patients who underwent LDP (57.1 vs. 38.3%, $p < 0.01$). The intraoperative factors, postoperative complication rate, and length of hospital stay were comparable in these two groups. Elderly patients who underwent LDP had a significantly shorter operative time (185.5 vs. 208.0 min, $p = 0.02$), less blood loss (191.0 vs. 291.8 mL, $p < 0.01$), and reduced length of postoperative hospital stay (11.4 vs. 15.1 days, $p < 0.01$) than elderly patients who had ODP. The overall complication rate tended to be lower in LDP group than that in ODP group (20.0 vs. 33.3%, $p = 0.07$).

Conclusion LDP performed on the elderly is safe and feasible, leading to short-term outcomes similar to those of non-elderly patients. LDP could be an alternative to ODP in elderly patients, providing a lower rate of morbidity and favorable postoperative recovery and outcomes.

Keywords Laparoscopy · Pancreatectomy · Elderly · Adenocarcinoma · Morbidity

Abbreviations

DP	Distal pancreatectomy
LDP	Laparoscopic distal pancreatectomy
ODP	Open distal pancreatectomy
POPF	Postoperative pancreatic fistula
ISGPF	International Study Group on Pancreatic Fistula
PDAC	Pancreatic duct adenocarcinoma
RLN	Retrieved lymph nodes
SD	Standard deviation
BMI	Body mass index
ASA	American society of anesthesiologists
SCA	Serous cystadenoma
MCA	Mucinous cystadenoma
IPMN	Intraductal papillary mucinous neoplasm
SPT	Solid pseudopapillary tumor
NEN	Neuroendocrine neoplasm
CD	Clavien–Dindo classification

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One of the society's greatest successes during the last decades is the remarkable increase in the average life expectancy. The accompanying is that the number of elderly patients with preexisting diseases such as cardiovascular diseases and diabetes mellitus are also increasing significantly. Approximately 50% of cancer incidence and 80% of cancer-related mortality occur in individuals aged ≥ 65 years [1]. Distal pancreatectomy (DP) has been widely used for benign and malignant diseases located on pancreatic body and tail. Previous studies have revealed conflicting results that whether DP can be safely used for the elderly [2, 3]. Minimally invasive intervention, characterized by laparoscopic surgery, is one of the main directions of surgical development in the twenty-first century [4]. Laparoscopic pancreatic resections without reconstruction, mostly laparoscopic DP (LDP), are frequently performed in low- and high-volume centers [5, 6]. Results of several retrospective comparative studies and meta-analyses have shown favorable outcomes of LDP for benign diseases and adenocarcinomas [6–9]. However, whether the minimally invasive advantage of LDP would sequentially bring benefits to elderly patients was not established [10, 11]. In this setting, we evaluated the safety and efficacy of LDP in elderly patients compared to younger counterparts based on our high-volume. Furthermore, we also compared the short-term outcomes of LDP and open distal pancreatectomy (ODP) in elderly patients.

Materials and methods

Patients

In this intention-to-treat analysis study, the prospectively collected data for 384 consecutive LDPs performed at Sir Run Run Shaw Hospital during May 2005 to May 2018 were retrospectively reviewed. Our criteria for LDP have been gradually extended from those for benign diseases to malignancies. We routinely conducted multi-disciplinary team treatment model for every major abdominal surgery since January 2013, during which the decision to perform laparoscopic or open approach would be discussed. Now almost all benign or low-grade tumors are received LDP, but pancreatic duct adenocarcinoma (PDAC) with evidence of portal vein involvement were considered as contraindications to LDP. Details regarding patient demographics, comorbidities, operative details, pathology reports, and postoperative outcomes were extracted by chart review of medical records. The study protocol was approved by the Institutional Review Board of Zhejiang University. Elderly patients were defined as patients aged ≥ 70 years. This age cutoff was consistent with previous minimally invasive or open pancreatic surgical literature [2, 3, 11–15]. Thus, these 384 patients were divided into three age groups: ≥ 70 years (Group A: LDP, elderly group, $n = 70$), 40–69 years (Group B: LDP, non-elderly group, $n = 264$), and < 40 years ($n = 50$). Patients aged < 40 years were excluded from this study to eliminate the interference of particular young patients. Patients' demographics, intraoperative details (operative time, estimated blood loss, and transfusion requirements), short-term outcomes (morbidity, mortality, and postoperative hospital stay) were compared between Group A and Group B. Postoperative pancreatic fistula (POPF) was classified in accordance with the 2016 update International Study Group on Pancreatic Fistula (ISGPF) definition and grading [16]. The severity of postoperative complications was based on the Clavien–Dindo classification [17]. At the same study period, patients aged 70 years and older at the time of surgery who undergoing conventional ODP were identified at our center as well. Perioperative outcomes of these patients (Group C: ODP elderly group, $n = 48$) were also compared with Group A patients. Subgroup analysis was performed by dividing the Group A into two subgroups based on age (Group D: LDP, 70–79-year-old group, $n = 55$; Group E: LDP, ≥ 80-year-old group, $n = 15$) and then compared. In this study, PDAC was the most common tumor and surgical outcomes of this aggressive malignancy could be different from other benign or low-grade malignancies. Therefore, another subgroup analysis, in which only PDAC was included, between three groups was conducted. Oncological outcomes of retrieved lymph nodes (RLNs), and margin status were evaluated. Resection margins were considered negative (R0) when no tumor was evident along the transection surface [18]. A flow chart of patient selection is shown in Fig. 1.

Operating procedures

The standardized technique for LDP at our institution has been previously described [19, 20]. Briefly, patients were placed in the supine position with head slightly elevated. Five trocars (three 5-mm trocars and two 12-mm trocars) are used, and the five trocars were arranged in a V shape. Pneumoperitoneum was established at a pressure of 13–15 mmHg. Dissection was mainly performed from right to left. With or without splenectomy mainly depends on tumor malignancy, size, pattern, and location. Benign or low-grade malignant, single, less than 5-cm lesion without involving splenic vessels and hilus tended to spleen preservation. For malignancy, mainly PDAC, DP with splenectomy was used and en bloc resection was performed. Frozen section biopsy was routinely applied to ascertain the resection margin. The resected specimen was removed using an endoscopic bag by enlarging the incision at the periumbilical port. ODP was performed in a traditional manner or same method as LDP.

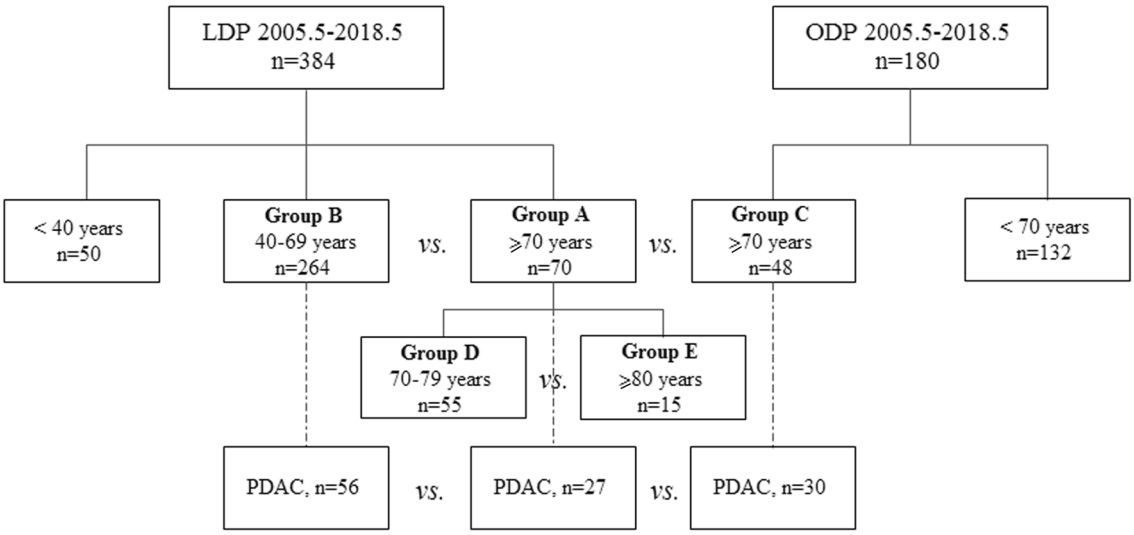

Fig. 1 Flow chart of patient selection

Statistical analysis

All statistical analyses were performed using SPSS version 23.0 (IBM Corp., Armonk, NY). Continuous variables are reported as mean ± standard deviation (SD). Differences in the quantitative variables were compared by the Student's *t* test, and comparisons of categorical variables were tested by the χ^2 test or Fisher exact probability test. All statistical tests were two-sided, and differences were considered significant when $p < 0.05$.

Results

Short-term outcomes of elderly versus non-elderly patients who underwent LDP

Demographic and clinicopathological features of the patients are summarized in Table 1. There was a 19.3-year difference in mean age between the elderly and non-elderly LDP groups (75.3 vs. 56.0 years, $p < 0.01$). Elderly group had higher proportion of male patients (57.1 vs. 37.1%, $p < 0.01$). Comorbidity was more common in elderly patients than in non-elderly patients (57.1 vs. 38.3%, $p < 0.01$). Elderly group presented with statistically higher preoperative ASA scores, with 94.3% of these patients within II/III classes compared to 40.9% in the non-elderly group ($p < 0.01$). Elderly group had higher proportion of PDACs (38.6 vs. 21.2%, $p < 0.01$), whereas benign or low-grade malignancies like cystadenoma, solid pseudopapillary tumor, and neuroendocrine neoplasm were more commonly in non-elderly patients.

Operative factors and postoperative recovery are summarized in Table 2. The proportion of spleen-preserving tended to be higher in non-elderly group (25.7 vs. 37.5%, $p = 0.07$). There were no significant differences in operative time, blood loss, transfusion required, and conversion between elderly and non-elderly groups. No patient died within 90 days after surgery. Postoperative morbidity occurred in 20.0% of elderly patients and in 17.4% of the non-elderly patients ($p = 0.82$). According to Dindo–Clavien classification, the severity of postoperative complications was comparable ($p = 0.84$). The mean length of postoperative hospital stay was also comparable between the two groups (11.4 vs. 10.1 days, $p = 0.12$).

Short-term outcomes of LDP versus ODP among elderly patients

The demographic and tumor characteristics are summarized in Table 1. There was no significant difference between the two groups with respect to age, body mass index (BMI), gender, comorbidity, and ASA score. However, the proportion of PDACs was higher in ODP group than that in LDP group (38.6 vs. 62.5%, $p < 0.01$).

The operative and postoperative characteristics are summarized in Table 2. There was no patient received spleen-preserving procedure in open group (25.7 vs. 0.0%, $p < 0.01$). Patients undergoing laparoscopic resections had a shorter operative time (185.5 vs. 208.0 min, $p = 0.02$), a lesser blood loss (191.0 vs. 291.8 mL, $p < 0.01$), and a lower transfusion requirement (5.7 vs. 22.9%, $p < 0.01$). The overall complication rate was lower in LDP group than that in ODP group with a marginal difference (20.0 vs. 33.3%, $p = 0.07$). Moreover, LDP group had a tendency of less cardiopulmonary complications than ODP group (4.3 vs. 14.6%, $p = 0.05$). However, there was no

Table 1 Clinicopathological characteristics

Variable	Group A ($n=70$)	Group B ($n=264$)	Group C ($n=48$)	p Value[a]	p Value[b]
Age (years)	75.3 ± 4.4	56.0 ± 7.6	74.5 ± 3.5	< 0.01	0.32
Sex (Male, %)	40 (57.1%)	98 (37.1%)	27 (56.3%)	< 0.01	0.92
BMI (kg/m^2)	22.8 ± 2.6	22.3 ± 3.0	22.1 ± 2.4	0.18	0.13
Comorbidity (yes, %)	40 (57.1%)	101 (38.3%)	25 (52.1%)	< 0.01	0.59
Hypertension	35	68	16		
Diabetes mellitus	8	35	8		
Cardiovascular	10	8	3		
Respiratory	2	8	0		
Liver	2	8	1		
Others	1	3	2		
ASA score (I/II/III)	4/53/13	156/106/2	4/37/7	< 0.01	0.80
Pathological diagnosis					
PDAC	27	56	30		
Pancreatic SCA	5	38	0		
Pancreatic MCA	12	45	3		
Pancreatic IPMN	5	18	8		
Pancreatic SPT	1	23	1		
Pancreatic NEN	12	42	3		
Pancreatic cyst	7	30	0		
Pancreatitis	0	8	3		
Others	1	4	0		
Tumor size	3.7 ± 2.1	4.2 ± 2.1	3.9 ± 2.2	0.07	0.68

Group A: LDP for elderly patients (≥ 70 years), Group B: LDP for non-elderly patients (40–69 years), Group C: ODP for elderly patients (≥ 70 years)

ASA American society of anesthesiologists, *BMI* body mass index, *PDAC* pancreatic duct adenocarcinomas, *SCA* serous cystadenoma, *MCA* mucinous cystadenoma, *IPMN* intraductal papillary mucinous neoplasm, *SPT* solid pseudopapillary tumor, *NEN* neuroendocrine neoplasm

[a]Compared between Group A and B

[b]Compared between Group A and C

significant difference in morbidity severity ($p=0.15$). In addition, LDP for elderly patients was associated with a significant reduction in the length of postoperative hospital stay (11.4 vs. 15.1 days, $p<0.01$).

Subgroup analysis of LDP for 70–79- versus ≥ 80-year-old patients

Perioperative outcomes of LDP for 70–79- versus ≥ 80-year-old patients are listed in Table 3. Octogenarian patients had a tendency of higher proportion of PDAC (34.5 vs. 53.3%, $p=0.19$). 70–79-old-year patients tended to undergo spleen-preserving procedures (30.9 vs. 6.7%, $p=0.06$). Operative time, intraoperative blood loss, morbidity, and length of postoperative hospital stay all tended to be superior in 70–79-year-old patients than those in ≥ 80-year-old patients. However, none of these differences reach statistical significance.

Subgroup analysis of pancreatic duct adenocarcinoma

Pathological and surgical outcomes of PDAC subgroup are described in Table 4. For elderly versus non-elderly patients who underwent LDP, the two groups had a similar sex ratio in contrast to the whole cohort, in which the elderly group had higher proportion of male patients (Table 1). A significantly higher proportion of elderly patients had ASA score of II/III. Operative time and blood loss were comparable in the two groups. Overall morbidity and postoperative hospital stay were slightly superior in elderly group without statistical significance. For LDP versus ODP among elderly patients, operative time was similar in the two groups. The mean blood loss and transfusion required rate were low in LDP group, and these differences were not statistically significant. Overall morbidity was less in LDP group with a marginal difference (22.2 vs.

Table 2 Operative factors and postoperative recovery

Variable	Group A ($n=70$)	Group B ($n=264$)	Group C ($n=48$)	p Value[a]	p Value[b]
Conversion (n, %)	2 (2.9%)	4 (1.5%)	–	0.37	–
Spleen-preserving (n, %)	18 (25.7%)	99 (37.5%)	0 (0%)	0.07	< 0.01
Operative time (min)	185.5 ± 53.9	175.1 ± 52.6	208.0 ± 41.2	0.14	0.02
Blood loss (mL)	191.0 ± 113.2	193.8 ± 107.8	291.8 ± 172.1	0.85	< 0.01
Transfusion required (n, %)	4 (5.7%)	6 (2.3%)	11 (22.9%)	0.14	< 0.01
Overall morbidity (n, %)	13 (20.0%)	46 (17.4%)	16 (33.3%)	0.82	0.07
Pancreatic fistula	10	34	9	0.76	0.52
Grade A	3	17	4		
Grade B	6	14	3		
Grade C	1	3	2		
Delayed gastric emptying	1	2	3		
Hemorrhage	0	3	1		
Abdominal abscess	2	2	1		
Wound infection	0	1	1		
Lymphorrhea	0	2	1		
Portal thrombosis	1	0	0		
Respiratory complications	3	4	5		
Cardiovascular complications	0	2	2		
Dindo–Clavien classification				0.84	0.15
I–II	6	25	9		
III–IV	7	21	7		
Postoperative hospital stay (days)	11.4 ± 5.8	10.1 ± 5.9	15.1 ± 6.7	0.12	< 0.01

Group A: LDP for elderly patients (≥ 70 years), Group B: LDP for non-elderly patients (40–69 years), Group C: ODP for elderly patients (≥ 70 years)

[a]Compared between Group A and B

[b]Compared between Group A and C

43.3%, $p=0.09$). The length of postoperative hospital stay was shorter in LDP group (11.1 vs. 16.6 days, $p<0.01$).

Discussion

Although the safety and feasibility of ODP in old patients had long been evaluated, the value of the laparoscopic surgery in this setting remained unclear. The results of the present series clearly suggest that LDP in elderly patients (≥ 70 years) is safe and does not contribute to higher rates of postoperative morbidity and mortality when compared to non-elderly patients (40–69 years) who undergoing LDP. The present study also suggests that LDP can provide short-term surgical benefits among elderly patients with less postoperative morbidity when compared to open surgery. However, this benefit may decrease with aging, becoming particularly uncertain after 80 years. Because as to laparoscopic cohort of geriatric (≥ 70 years), octogenarian patients (≥ 80 years) had a tendency of prolonged hospital stay and more cardiopulmonary complications in comparison to patients aged 70–79 years.

There is no general agreement on the definition of the elderly. In this study, we defined the age of 70 years as a relevant cutoff of elderly patients as several pancreatic and other abdominal surgical literature studies [2, 3, 11–15, 21, 22]. The elderly group had worse ASA scores ($p<0.01$), and they were more likely to have multiple comorbidities than their younger counterparts. In addition, the elderly presented higher rates of invasive malignant pathologies, mainly PDAC.

Elderly patients are more likely to have decreased life expectancy with comorbidities, so the decision to perform major pancreatectomy must be carefully balanced against potential benefits before surgery. Whether pancreatectomy is safely among elderly patients remains controversial. In the study of Adham et al., 116 elderly patients (≥ 70 years) and 228 non-elderly patients (< 70 years) who underwent pancreatectomy were compared. Elderly patients had high risk of POPFs (19 vs. 9%, $p=0.009$) and higher postoperative mortality rates (12.9 vs. 3.9%, $p=0.04$) [2], whereas Oliveira-Cunha et al. reported that pancreatectomy for the elderly (≥ 70 years) could be performed safely with comparable surgical results to those of non-elderly patients [3].

Table 3 Subgroup analysis of LDP for 70–79- versus ≥ 80-year-old patients

Variable	Group D ($n=55$)	Group E ($n=15$)	p Value
Age (years)	73.3 ± 2.3	82.5 ± 2.7	< 0.01
Sex (Male, %)	30 (54.5%)	10 (66.6%)	0.40
BMI (kg/m^2)	22.6 ± 2.5	23.6 ± 3.0	0.21
Comorbidity (Yes, %)*	31 (56.4%)	9 (60.0%)	0.80
ASA score (I/II/III)	4/42/9	0/11/4	0.49
PDAC proportion (n, %)	19 (34.5%)	8 (53.3%)	0.19
Spleen-preserving (n, %)	17 (30.9%)	1 (6.7%)	0.06
Operative time (min)	181.5 ± 49.3	200.3 ± 45.5	0.19
Blood loss (mL)	182.9 ± 87.2	210.7 ± 120.9	0.32
Overall morbidity (n, %)	9 (16.4%)	4 (26.7%)	
Pancreatic fistula	7	3	
Grade A	2	1	
Grade B	4	2	
Grade C	1	0	
Delayed gastric emptying	1	0	
Abdominal abscess	2	0	
Portal thrombosis	0	1	
Respiratory complications	1	2	
Dindo–Clavien classification			0.63
I–II	4	2	
III–IV	5	2	
Postoperative hospital stay (days)	10.9 ± 6.1	13.1 ± 3.5	0.08

Group D: LDP for 70–79-year-old patients, Group E: LDP for ≥ 80-year-old patients

ASA American society of anesthesiologists, *BMI* body mass index, *PDAC* pancreatic duct adenocarcinomas

However, these studies included various surgical extensions with pancreaticoduodenectomy (PD) the highest proportion. Moreover, these studies combined laparoscopic and open approaches together, which would weaken the efficacy of their studies. Recently, a French multicentric study compared 44 LDP cases with 56 ODP cases among the elderly (≥ 70 years) [11]. Although the overall postoperative complication rates were comparable (45.4 vs. 51.7%, $p=0.534$), the major complication rate (Clavien–Dindo ≥ 3) (18.2 vs. 12.5%, $p=0.431$) and overall POPF rate (27.7 vs. 17.8%, $p=0.259$) in LDP group were somewhat higher than those in ODP group [11]. Therefore, more researches are needed for the safety and effectiveness of LDP in the elderly.

In our study, the overall complication rate in LDP for elderly patients was comparable to non-elderly patients ($p=0.82$), but tended to be lower than that in ODP for the elderly ($p=0.07$). This potential advantage may mainly thanks to a reduced cardiopulmonary complications in LDP. The rate of POPFs after LDP was reported ranging from 11 to 40% [5, 23–26]. In the current study, it occurred in 10 Group A patients (14.3%), 34 Group B patients (12.9%), and 9 Group C patients (18.8%), respectively. These differences were not statistically significant. It was conceivable that POPF rates were comparable between groups because various procedures result in the same organ, lymphatic resection, and closure technique (both stapler and suture closure of pancreatic remnant can be finished under laparoscopic or open surgery). The true risk factors of POPFs had been recognized as soft pancreatic parenchyma, high-risk disease pathology, small pancreatic duct size, etc. instead of surgical procedures [27]. LDP has the advantage of requiring smaller incisions and less bowel manipulation, thereby reducing pain and wound complications [8]. Severe pain caused by large incisions could be associated with up to a 30% reduction in respiratory functional residual capacity and 60% reduction in vital capacity [28]. A recent study has reported lower postoperative pulmonary complications in patients undergoing LDP for PDAC [29]. Our study confirms this finding when comparing LDP with ODP among elderly patients. Moreover, age did not significantly increase the risk of pulmonary complications when comparing elderly versus non-elderly patients who underwent LDP. In addition, no mortality in the present study could be considered as an indicator of safety of laparoscopic technique for the elderly.

A recent research from the American College of Surgeons NSQIP demonstrated that longer operative times were independently associated with worse perioperative outcomes after pancreatic resection [30]. We not only found no significant differences in operative time of elderly versus non-elderly patients who under LDP, but the operative time of

Table 4 Subgroup analysis for pancreatic duct adenocarcinomas

Variable	Group A ($n=27$)	Group B ($n=56$)	Group C ($n=30$)	p Value[a]	p Value[b]
Age (years)	76.3 ± 5.0	58.5 ± 5.8	74.7 ± 3.5	< 0.01	0.19
Sex (Male, %)	20 (74.1%)	35 (62.5%)	20 (66.7%)	0.30	0.54
BMI (kg/m^2)	22.5 ± 2.9	22.1 ± 2.7	21.8 ± 2.2	0.54	0.26
Comorbidity (Yes, %)*	20 (74.1%)	32 (57.1%)	20 (66.7%)	0.14	0.54
ASA score (I/II/III)	0/25/2	24/30/2	1/24/5	< 0.01	0.43
Tumor size	4.0 ± 1.7	4.4 ± 1.7	3.4 ± 1.8	0.31	0.26
Retrieved lymph nodes	13.9 ± 5.9	14.1 ± 6.1	14.5 ± 6.0	0.89	0.70
R0 rate (*n*, %)	25 (92.6%)	54 (96.4%)	26 (86.7%)	0.39	0.39
Operative time (min)	207.2 ± 46.5	200.1 ± 55.8	210.2 ± 45.6	0.57	0.81
Blood loss (mL)	242.2 ± 137.9	227.7 ± 100.5	289.7 ± 160.7	0.63	0.24
Transfusion required (*n*, %)	3 (11.1%)	3 (5.4%)	9 (30.0%)	0.30	0.08
Overall morbidity (*n*, %)	6 (22.2%)	18 (32.1%)	13 (43.3%)	0.35	0.09
Pancreatic fistula	3	14	7	0.14	0.20
Grade A	0	7	3		
Grade B	3	6	3		
Grade C	0	1	1		
Delayed gastric emptying	0	0	3		
Hemorrhage	0	1	1		
Abdominal abscess	0	1	1		
Wound infection	0	0	1		
Lymphorrhea	0	2	1		
Portal thrombosis	1	0	0		
Respiratory complications	2	2	4		
Cardiovascular complications	0	1	1		
Dindo–Clavien classification				0.71	0.28
I–II	3	9	7		
III–IV	3	9	6		
Postoperative hospital stay (days)	11.1 ± 4.2	12.9 ± 6.6	16.6 ± 6.5	0.13	< 0.01

Group A: LDP for elderly patients (≥ 70 years), Group B: LDP for non-elderly patients (≥ 40, < 70 years), Group C: ODP for elderly patients (≥ 70 years)

ASA American society of anesthesiologists, *BMI* body mass index

[a]Compared between Groups A and B

[b]Compared between Groups A and C

LDP was significant shorter than that in ODP among elderly patients. This is because of the relatively simple steps of DP and advance in devices. Besides, the quick management of trocar incision could offset the duration of laparoscopic resection contrasting to sew up the long incision and skin in open surgery, which would take about 30 min.

One would expect the advantages of laparoscopic approach to be still exist in very elderly patients with lower physiological reserves. However, when the subgroup analysis was performed, an ambiguous loss of these advantages was noted in octogenarian patients (≥ 80 years). There was a trend toward more respiratory and cardiovascular complications and prolonged hospital stay. Although none of these were statistically significant due to limited sample size, we thought the physiological insult to these very elderly patients could partially cancel out the advantages of laparoscopic surgery. Thus, pancreatic surgeons should take attention to conduct LDP for octogenarian and nonagenarian patients. However, the moderate comparability due to high PDAC proportion and low spleen-preserving rate in octogenarian patients could influence the results against octogenarian group. Case-matched studies or randomized controlled trials (RCTs) are needed to confirm our findings.

The low comparability between groups inevitably undermined the reliability of our study, which was also the main limitation of this study. As shown in Table 1, male proportion was higher in Group A than that in Group B, and PDAC proportion and spleen-preserving rates were hardly balanced between groups. The reasons are as follows: (1) the incidence of PDAC increased with age, and the incidence in

men was higher than that in women [31]. (2) Benign and low-grade malignant neoplasms like cystadenoma and solid pseudopapillary tumor are more common in young or middle-aged women [32]. (3) In our center, with or without splenectomy should comprehensive consider factors like tumor malignancy, size, pattern, location, patients' age. We do not preserve the spleen in any pancreatic malignancy (mostly PDAC), and the younger a patient was, the more likely he/she will receive a spleen-preserving procedure. On the contrary, elderly patients undergoing division of the splenic artery and vein may be at higher risk for splenic infarct [33]. Based on the above facts, elderly group had more male, PDAC patients, and underwent DP without spleen-preserving. Although there was no intended bias in the selection of patients for LDP, these variables were known to affect outcomes. To strengthen the comparability, a subgroup analysis, in which only PDAC patients were included, was performed. We found LDP for PDAC in elderly patients is also feasible and results in acceptable perioperative complications that are similar to those in non-elderly patient. In addition, LDP for PDAC allows tendencies of less blood loss and morbidity as well as shorter hospitalization comparing with conventional ODP. In our LDP cohort for elderly PDAC patients, the mean operative duration was 207.2 ± 46.5 min, mean blood loss was 242.2 ± 137.9 mL, and three patients (11.1%) received transfusions. Morbidity occurred in 6 (22.2%) patients. Common complications were POPF ($n = 3$, 11.1%), and respiratory complications ($n = 2$, 7.4%). Our results were comparable to main published series of LDP for PDAC patients (Table 5) [8, 25, 34–41].

Other limitations of this study should be recognized. First, the retrospective nature of the study and the relatively small number of events, especially in subgroup analysis, might have led to insufficient statistical power. Second, the subgroup results of LDP for 70–79- versus ≥ 80-year-old patients was underpowered to detect statistically significant differences mainly due to scarcity of very old patients, and a direct comparison of LDP versus ODP among octogenarian patients cannot be done by the same token. Third, this study represents the experience of a single specialized Asian center. Therefore, our results may not be directly applicable to Western populations. But we believe that this study could serve as a useful background research for future multi-center RCTs that aim to investigate LDP in elderly and octogenarian patients.

Conclusions

According to our data, LDP is a safe and effective technique for aging patients, and therefore should be considered as a valid option. The short-term outcomes in elderly patients of LDP compared to open surgery result in several benefits including less blood loss, lower morbidity, and shorter hospitalization. We believe that age is not a contraindication for LDP. Nevertheless, larger prospective comparative studies

Table 5 Perioperative outcomes of published series with more than 20 cases of LDP for pancreatic duct adenocarcinomas (not only the elderly)

Authors	Sample size	Operative time (min)	Blood loss (mL)	Conversion (%)	POPF (%/)	Significant POPF (%)	Morbidity (%)	Hospital stay (days)	Mortality (%)
Kooby et al. [34]	23	238.4 ± 68.1	422 ± 473	17.4	–	–	–	7.4 ± 3.4	0% 30 days
Shin et al. [35]	80	239 (125–397)	–	–	18.6	11.5	25.7%	9 (5–29)	0%
Sulpice et al. [8]	347	–	–	–	–	–	33.7%	14.9 ± 8.9	2.6% 90 days
Sun et al. [36]	23	203 ± 54	208 ± 264	4.3	39	17	48%	17 ± 8	0% 30 days
Kawaguchi et al. [37]	23	203 ± 54	208 ± 264	4	39	17	47%	17 ± 8	0% 30 days
Stauffer et al. [38]	44	254 (99–521)	332 (10–2650)	11.4	13.6	11.4	13.6% CD > 2	5.1 (2–17)	2.3% 90 days
Shin et al. [39]	152	234 (121–475)	–	2.6	31.6	9.2	40.1%	8 (5–31)	0% 30 days
Sahakyan et al. [25]	196	220 ± 66	250 (0–3040)	2.6	25.1	15.7	31.9%	8 (2–63)	5.2% 30 days
Hilal et al. [40]	25	240 (120–390)	340 (50–1000)	0	–	28	12% CD > 2	5 (2–57)	0% 90 days
Zhang et al. [41]	22	188 ± 39	210 ± 130	–	36.4	9.1	–	–	0%

POPF postoperative pancreatic fistula, *CD* Clavien–Dindo classification

are required to confirm the efficacy and to show the superiority of LDP in elderly patients.

Compliance with ethical standards

Disclosures Ke Chen, Yu Pan, Yi-ping Mou, Jia-fei Yan, Ren-chao Zhang, Miao-zun Zhang, Jia-yu Zhou, Xian-fa Wang, Hendi Maher, and Qi-long Chen have no conflicts of interest or financial ties to disclose.

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