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Laparoscopic central pancreatectomy for benign or low-grade malignant lesions in the pancreatic neck and proximal body

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Abstract
Introduction Laparoscopic central pancreatectomy (LCP) is a parenchyma-sparing minimally invasive surgical technique for removal of benign or low-grade malignant lesions from the neck and proximal body of the pancreas. The aim of this study was to compare the short- and long-term clinical outcomes of LCP with those of other pancreatectomies.
Methods During the study period, January 2007 to December 2010 (median follow-up 40.6 months), 287 pancreatectomies were performed for lesions in the neck and proximal body of the pancreas. To compare the clinical outcomes of LCP and other pancreatectomies, 26 cases of LCP, 14 cases of open central pancreatectomy (OCP), and 96 cases of extended laparoscopic distal pancreatectomy (E-LDP) were selected.
Results Tumor sizes in the LCP (2.2 cm) and OCP (2.9 cm) groups were smaller than in the E-LDP (4.0 cm) group. Mean operation time in the LCP group (350.2 min) was longer than in the OCP (270.3 min) and E-LDP groups (210.6 min). There were more surgical complications in the LCP (38.5 %) and OCP groups (50 %) than in the E-LDP group (14.6 %). Mean duration of postoperative hospital stay was 13.8 days for the LCP group, which was significantly shorter than for the OCP group (22.4 days). New-onset diabetes was less frequent after LCP than after E-LDP (11.5 vs. 30.8 %).
Conclusions In selected patients with small and benign tumors in the pancreatic neck and proximal body LCP leads to increased postoperative morbidity but earlier postoperative recovery than OCP, and excellent postoperative pancreatic function (compared with E-LDP). LCP should, therefore, be considered a valid therapeutic option for selected patients.

Keywords Laparoscopic central pancreatectomy · Pancreatic fistula · Parenchymal preserving

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The use of laparoscopic distal pancreatectomy (LDP) for lesions in the tail of the pancreas has increased rapidly in recent years, because the technique is associated with more favorable outcomes than traditional open distal pancreatectomy (ODP) [1–3], and there has been a paradigm shift from ODP to LDP for left-side pancreatic neoplasms [4]. LDP is considered as the standard operation for benign or borderline pancreatic tail lesions by most surgeons. However, it presents more difficult in the case of benign lesions of the neck or proximal body of the pancreas, and extended distal pancreatectomy (E-DP) is the traditional treatment for these tumors. However, E-DP results in significant waste of normal pancreatic tissue, with the consequent risk of diabetes and exocrine insufficiency. There have been several studies of central pancreatectomy (CP), and this has proved a useful treatment for benign or borderline lesions in the neck of the pancreas. CP preserves a greater proportion of the normal pancreatic parenchyma and decreases the incidence of diabetes and exocrine insufficiency of the pancreas [5–8]. However, CP may cause more complications, especially pancreatic fistula, as it generates two cut surfaces following segmental resection [6, 9–11]. The incidence of benign and borderline malignant pancreatic

tumors is increasing as a result of increased concern about personal health and advances in imaging [12, 13]. These patients are expected to survive longer after successful pancreatectomy than patients treated for pancreatic ductal adenocarcinoma. Hence surgeons must consider not only the safety of the surgery but also the patients' quality of life, including cosmetic effects and endocrine and exocrine pancreatic function, and CP for benign tumors of the pancreatic neck can prevent such dysfunction in the long term. Furthermore, laparoscopic surgery has the advantage of being minimally invasive, with less perioperative bleeding, earlier recovery and discharge after surgery, and superior cosmetic effects. Laparoscopic central pancreatectomy (LCP) may, therefore, contribute to improved quality of life and is considered the best approach for benign and borderline malignant tumors in the pancreatic neck and proximal body.

This study retrospectively evaluated patients who had undergone LCP in our hospital and compared them with patients who had received E-LDP or OCP for benign or low-grade malignant lesions in the pancreatic neck and proximal body.

Methods

The study was performed at the Asan Medical Center (AMC), a 2,700-bed tertiary care teaching hospital in Seoul, Korea. A total of 287 patients who had undergone pancreatectomy for lesions in the neck and proximal body of the pancreas from January 2007 to December 2010 were studied retrospectively. Of the included patients, 38 had undergone LCP, 14 had undergone OCP, 227 had undergone E-DP, and 8 had undergone enucleation.

Inclusion and exclusion criteria

In this study, we analyzed patients with LCP and those with E-LDP and OCP to compare short-term clinical outcomes and long-term exocrine and endocrine function. The inclusion and exclusion criteria used to define each group are described below. At our institution, the indication for OCP was a localized lesion in the neck or proximal body of the pancreas with no evidence of high-grade malignancy. All reconstruction of the distal pancreatic remnant after OCP was performed by end-to-side pancreaticojejunostomy (PJ) and side-to-side jejunojejunostomy (JJ). The inclusion criterion for the LCP group was: those patients who had undergone total LCP with Roux-en-Y PJ. Exclusion criteria were: patients who had undergone LCP with pancreaticogastrostomy (PG), LCP without PJ, or LCP with extracorporeal PJ. Of the 38 patients who had undergone LCP, 26 had undergone total LCP with PJ. Twelve patients were excluded from comparative study: of these eight had undergone total LCP without PJ, one had undergone total LCP with PG, and three had undergone LCP with extracorporeal PJ by mini-laparotomy (6 cm transverse incision of the left upper quadrant). Among the 227 patients with E-DP, those who had malignant pancreatic lesions, such as intraductal pseudopapillary mucinous carcinoma and pancreatic ductal adenocarcinoma, and had undergone open E-DP were also excluded. Finally, patients who had undergone enucleation were excluded. For the present analysis, 96 patients with E-LDP and 14 with OCP were included and compared with 26 patients with LCP (Fig. 1).

For comparative analysis, demographic characteristics, including age, gender, body mass index (BMI, kg/m^2), medical history, and previous abdominal operations, were evaluated. Final pathologic diagnoses, size of lesion, and length of resected pancreas were determined from final pathologic reports. To compare perioperative results, the operation time, calculated actual blood loss, length of postoperative hospital stay, date of starting oral intake, date of hospital discharge, new-onset diabetes, and postoperative complications, including pancreatic fistulas, were evaluated.

Operation time was defined as the time from the start of skin incision to completion of skin closure. Actual blood loss (ABL) was calculated with the following formula:

$$\text{Actual blood loss} = \frac{(\text{EBV} \times (Hi - Hf))}{\left(\frac{Hi+Hf}{2}\right)} + (500 \times Tu).$$

(EBV: estimated blood volume, 70 cm^3/kg, H*i*: initial Hgb, H*f*: immediate postoperative Hgb, T*u*: the sum of transfusion of packed red blood cells) Negative values of this equation were treated as 0 in the statistical analysis.

Resumption of a normal diet was defined as starting to take sips. Length of postoperative hospital stay was calculated from the day after the operation to the date of hospital discharge. Drainage removal time was defined as removal of the final drainage tube, regardless of type or number of drainage tubes used.

New-onset diabetes was defined as diabetes with a requirement for medical treatment including hypoglycemic medication and insulin.

Postoperative surgical complications were described according to the classification proposed by Clavien et al. [14], as follows: grade I and grade II complications include only minor deteriorations from the normal postoperative course, which can be treated with drugs, blood transfusion, physiotherapy, and nutritional supply. Grade III complications require interventional treatment. Grade IV

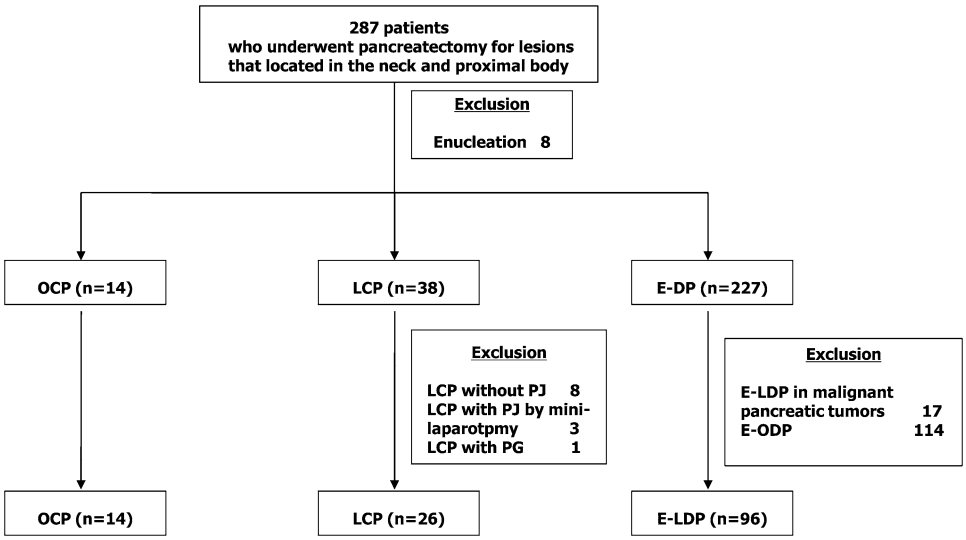

Fig. 1 Study flow diagram. Retrospective review of 287 patients who had undergone pancreatectomy for lesions in the neck and proximal body of the pancreas from January 2007 to December 2010. A final total of 26 patients with laparoscopic central pancreatectomy (LCP), 14 with open central pancreatectomy (OCP) and 96 with extended laparoscopic distal pancreatectomy (E-LDP) were enrolled in the study. *E-DP* extended distal pancreatectomy, *E-ODP* extended open distal pancreatectomy, *PJ* pancreaticojejunostomy, *PG* pancreaticogastrostomy

complications are life-threatening complications requiring management in the intensive care unit (ICU). Grade V is death of the patient.

Pancreatic fistulas, which are an important postoperative complication of pancreatic surgery, were classified according to the system of the International Study Group of Pancreatic Fistula (ISGPF) [15]. Grades B and C fistulas require specific treatment and, in this study, clinically significant pancreatic fistulas were defined as grade B or C.

Postoperative bleeding was defined as a decrease in hemoglobin level with objective evidence of bleeding (changes in drain characteristics, evidence of bleeding in radiologic study) or cases requiring surgical bleeding control.

Mortality was defined as any death within 30 days after the operation, in or out of hospital. Reoperation was defined as operation related to postoperative surgical complications within the same admission period as the central pancreatectomy. Readmission was defined as readmission within 30 days after hospital discharge due to postoperative complications or pancreatic disease.

Follow-up was based on clinical and laboratory assessments for detection of recurrence, and screening of endocrine and exocrine function. Patients were supposed to undergo clinical and laboratory evaluation every 3 or 6 months. The follow-up period was calculated from the date of discharge to the final outpatient department visit. If the patient undertook subsequent additional outpatient department visits, the final outpatient department visit was taken as December 2013.

The results are presented as means ± standard deviations (SD). Patients who underwent LCP were compared with those who underwent OCP, using the χ^2 test and Fisher's exact test for categorical variables, and Student's *t* test and the Mann–Whitney *U* test for continuous variables. Differences were considered significant if the *p*-value was less than 0.05. All analyses were performed using SPSS 21.0 statistical software (SPSS Inc., Chicago, IL, USA).

The laparoscopic central pancreatectomy procedure

The patient was placed in the supine position, or a reverse Trendelenberg (10–30°) position if necessary. A nasogastric tube and bladder catheter were inserted. All patients wore antithrombotic stockings during surgery and received prophylactic low-molecular weight heparin until they could walk freely. The operator and the second assistant who held the laparoscope stood to the right of the patient, and the first assistant and scrub nurse were positioned to the left. An open technique was used in all patients to establish the pneumoperitoneum under direct vision through a periumbilical 12-mm trocar. Abdominal pressure was maintained at 12 mmHg by insufflation of carbon dioxide. During most operations, four trocars were placed under direct scope vision. Two 5-mm trocars (one on the right flank for the left hand of the operator and one on the left flank for surgical assistance) and two 12-mm trocars (one on the umbilicus for the right hand of the operator and one on the right lower quadrant of the abdomen for the laparoscope) were used (Fig. 2). After establishing abdominal access, a 30° telescope was inserted and the entire peritoneal cavity was examined for abnormalities. The gastrocolic omentum was divided for entrance to the lesser sac, avoiding injury to the colon by the monopolar electrocautery device or ultrasonic

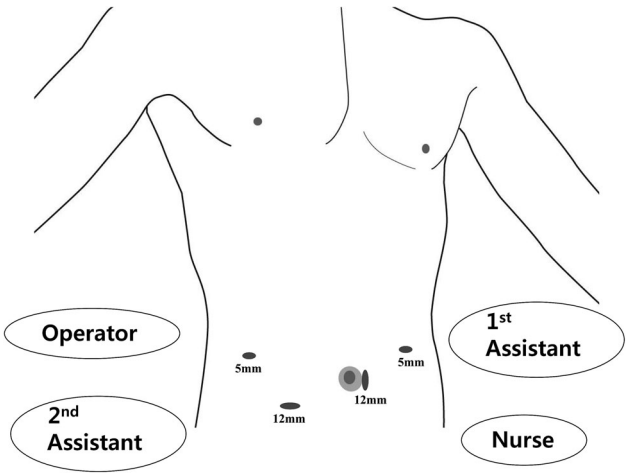

Fig. 2 Placement of trocars for laparoscopic central pancreatectomy. Two 5-mm trocars (one on the *right* flank for the *left* hand of the operator and one on the *left* flank for surgical assistance) and two 12-mm trocars (one on the umbilicus for the *right* hand of the operator and one on the *right* lower quadrant of abdomen for the laparoscope) were used

coagulating shears. The posterior gastric wall was lifted and retracted cranially using a vicryl 2-0 traction suture, exposing the tumor within the neck of the pancreas. If the pancreatic lesion could not be identified easily or further localization was necessary, a laparoscopic intraoperative ultrasound probe was inserted into the 12-mm trocar, and intraoperative ultrasonography was performed, providing excellent results in identifying the location of the lesion.

The superior mesenteric vein (SMV) and retropancreatic portal vein were identified at the inferior border of the pancreatic neck and dissected over the retropancreatic portal vein. A tunnel was created in front of the SMV under the pancreatic neck. On completion of the tunnel, a tape was passed through to provide traction on the pancreas. By pulling the tape upwards, the pancreatic neck was dissected proximally and distally for approximately 2 cm, easing insertion of an endostapler to perform the proximal pancreatic transection.

For transaction of the proximal pancreas with a safe resection margin, roticular endoscopic linear staplers of various sizes were used (staple height 3.5–4.2 mm), depending on the thickness or hardness of the pancreas. After completing the proximal pancreatic resection, seven or eight small titanium clips were applied along the stapling line of the proximal pancreatic stump to prevent pancreatic fistula and bleeding from the resected proximal stump of the pancreas. In most cases, fibrin glue also was applied to the pancreatic stump or a small bleeding site using the specific delivery device.

Distal pancreatic transection was then performed with a harmonic scalpel or linear stapler. The pancreatic duct was isolated and transected. Once the duct was identified, a 2-mm silastic stent was inserted. The duct and stent were sutured together using PDS 5-0 (Ethicon Inc., Somerville, NJ, USA). To release the distal stump of the pancreas from the splenic artery and vein, small connecting vessels were sectioned between clips. This dissection extended up to 2 cm away from the distal section line. In order to provide a relatively tension-free anastomosis, sufficient dissection of the pancreatic distal stump from the splenic vessels must be achieved.

After completing the resection, the specimen was placed in an entrapment bag and removed through the 12-mm umbilical port with minimal extension. Negative resection margins of proximal and distal portions of the tumors were confirmed by frozen sectional biopsy. Intracorporeal PJ reconstruction was then performed using a 50-cm retrocolic Roux-en-Y jejunal loop. The most common anastomosis is end-to-side invaginated PJ with a double-layer suture. A 2-layer end-to-side PJ with prolene 5-0 interrupted suture was used for the external seromuscular layer of the jejunum, and a prolene 4-0 continuous suture was used for the full-layer jejunal anastomosis with the pancreas. Fibrin glue was placed around the PJ to protect the anastomosis. Finally, mechanical side-to-side JJ was performed with a stapler (EndoGIA II 60-2.5) and the mesenteric defect closed with vicryl 4-0 and black 4-0 sutures. Routine Jackson-Pratt (JP) drainage was inserted at the proximal stump of the pancreas and distal PJ site in all cases.

Open central pancreatectomy procedure

For OCP a long midline incision was used to access the peritoneal cavity. The gastrocolic ligament was then divided to expose the whole pancreas. The tumor was identified by sight or palpation in most cases and, occasionally by intraoperative ultrasonography. The SMV was identified beneath the neck of the pancreas. The posterior aspect of the pancreas was freed from the trunk of the mesenteric-portal vein. The pancreatic segment harboring the lesion was then mobilized. In OCP, the proximal pancreatic resection was performed with a stapler, electrocautery or knife, depending on the surgeon's preference, leaving at least a 1 cm margin around the tumor. If the pancreas was sectioned with a knife, hemostasis of the stumps of the pancreas dealt with by interrupted sutures. On the cephalic stump, the pancreatic duct was individually ligated. The dissection was continued toward the splenic vein and artery. The excised pancreatic specimen was then sent to check whether the resection margins were adequate and to obtain a diagnosis from frozen sections. A temporal silastic catheter was inserted into the main pancreatic duct on the distal stump. A Roux-en-Y jejunal loop was isolated and an end-to-side invaginated PJ was carried out with a double-layer suture. The last step was the construction of a side-to-side JJ with a double layer approximately 50 cm away from the pancreatic anastomosis. To prevent pancreatic leak, a JP drain was routinely left near the anastomosis.

Table 1 Demographic characteristics of the patients who underwent LCP, OCP and E-LDP

	p value[a]	OCP	LCP	E-LDP	*p* value[b]
Number		14	26	96	
Age (years)	0.569	49 ± 14	46.8 ± 9.6	49.8 ± 15.1	0.236
Sex (M:F)	0.06	8:6	7:19	27:69	0.903
BMI (kg/m^2)	0.650	24.3 ± 4.3	23.7 ± 3.6	23.6 ± 3.0	0.777
ASA score	0.06	1.57	1.19	1.38	0.064

LCP laparoscopic central pancreatectomy, *OCP* open central pancreatectomy, *E-LDP* extended laparoscopic distal pancreatectomy, *M* male, *F* female, *BMI* body mass index, *ASA score* American Society of Anesthesiologists

[a] LCP versus OCP

[b] LCP versus E-LDP

Table 2 Pathologic results for patients with benign or low-grade malignant tumors in the pancreatic neck and proximal body undergoing LCP, OCP and E-LDP

	OCP ($n = 14$)	LCP ($n = 26$)	E-LDP ($n = 96$)	*p* value
Pathology				
Serous cystadenoma	2 (14.3)	7 (26.9)	13 (13.5)	
Mucinous cystadenoma	1 (7.1)	1 (3.8)	23 (24)	
Pancreatic neuroendocrine tumor	4 (28.6)	4 (15.2)	9 (9.4)	
SPN	2 (14.3)	7 (26.9)	14 (14.6)	
IPMN	3 (21.4)	5 (19.2)	28 (29.2)	
Pancreatitis	2 (14.3)	1 (3.8)	8 (8.3)	
Benign cyst	0	1 (3.8)	1 (1)	
Tumor size (cm)	2.9 ± 1.3	2.2 ± 1.1	4.0 ± 2.4	<0.001
Mean length of resected pancreas (cm)	4.7 ± 1.6	4.6 ± 0.9	12.0 ± 2.1	<0.001

p value: LCP versus E-LDP

LCP laparoscopic central pancreatectomy, *OCP* open central pancreatectomy, *E-LDP* extended laparoscopic distal pancreatectomy, *SPN* solid pseudopapillary neoplasm, *IPMN* intraductal papillary mucinous neoplasm

Table 3 Comparison of operative and postoperative outcomes between LCP and OCP

	LCP	OCP	*p* value
Operation time (min)	350.2 ± 63.4	270.3 ± 68.8	0.001
Actual blood loss (ml)	477.1 ± 388.2	555.5 ± 298.8	0.516
Diet start (postoperative days)			
Sips of water	4.0 ± 2.1	4.6 ± 1.7	0.421
Postoperative hospital stay (days)	13.8 ± 7.3	22.4 ± 12.1	0.008
Follow-up (months, mean ± SD)	38.5 ± 12.5	47.1 ± 17.8	0.08
Overall complications (*n* (%))	10 (38.5)	7 (50)	0.48
Early complications	8 (30.8)	6 (42.9)	0.445
Long-term complications	2 (7.7)	1 (7.1)	0.95
Severe complications (≥grade 3)	4 (15.3)	1 (7.1)	0.458
Clinically relevant pancreatic fistula	5 (19.2)	5 (35.7)	0.251
New-onset diabetes (*n* (%))	2/26 (8)	0/14	
Weight loss[a] (*n* (%))	10 (38.5)	7 (50)	0.481
Mortality (*n*)	0	0	

A Clavien-Dindo classification greater than 3 was defined as a major complication

Grading of pancreatic fistula followed the definition of the International Study Group of Pancreatic Fistula

Grades B or C: clinically relevant pancreatic fistula

LCP laparoscopic central pancreatectomy, *OCP* open central pancreatectomy, *SD* standard deviation

[a] Weight loss greater than 3 % of initial weight during follow-up

Extended laparoscopic distal pancreatectomy procedure

We have described our LDP procedure previously [16]. We define E-LDP as a pancreatic resection performed at the portal vein-SMV axis. The length of resected pancreas was more than 10 cm in all patients undergoing E-LDP.

Results

Between January 2007 and December 2010, 287 pancreatectomies were performed at the AMC on patients with lesions in the neck and proximal body of the pancreas. During that period, 38 patients underwent LCP, 14 underwent OCP, 227 underwent E-DP, and 8 underwent enucleation. After applying the inclusion and exclusion criteria, 96 patients with E-LDP and 14 with OCP were included in the analysis together with 26 patients with LCP.

Table 4 Comparison of operative and postoperative outcomes in LCP and E-LDP

	LCP	E-LDP	*p* value
Operation time (min)	350.2 ± 63.4	210.6 ± 64.3	<0.001
Actual blood loss (ml)	477.1 ± 388.2	494.4 ± 400.5	0.845
Diet start (postoperative days)			
Sips of water	4.0 ± 2.1	2.1 ± 1.4	<0.001
Postoperative hospital stay (days)	13.8 ± 7.3	9.3 ± 5.0	0.006
Follow-up (months, mean ± SD)	38.5 ± 12.5	38.5 ± 15.7	0.99
Overall complications (*n* (%))	10 (38.5)	14 (14.6)	0.002
Early complications	8 (30.8)	5 (5.2)	<0.001
Long-term complications	2 (7.7)	9 (9.4)	0.787
Severe complications (≥ grade 3) (*n* (%))	4 (15.3)	5 (5.2)	0.1
Clinically relevant pancreatic fistula (*n* (%))	5 (19.2)	8 (8.3)	0.11
New-onset diabetes (*n* (%))	2/26 (8)	24/78 (30.8)	0.037
Weight loss[a] (*n* (%))	10 (38.5)	52 (54.2)	0.155
Mortality (*n*)	0	0	

A Clavien–Dindo classification greater than three was defined as a major complication

Grading of pancreatic fistula followed the definition of the International Study Group of Pancreatic Fistula

Grades B or C: clinically relevant pancreatic fistula

LCP laparoscopic central pancreatectomy, *E-LDP* extended laparoscopic distal pancreatectomy, *SD* standard deviation

[a] Weight loss greater than 3 % of initial weight during follow-up

A comparative analysis of the demographic and pathologic characteristics, perioperative clinical outcomes, and complications of the three groups of patients is presented in Tables 1, 2, 3, 4.

Comparative analysis of LCP and OCP

Demographic characteristics

The mean age was 46.9 ± 9.6 years for the LCP group (7 men and 19 women) and 19 ± 14 years (8 men and 6 women) for the OCP group. Mean BMI was 23.7 ± 3.6 kg/m^2 for the LCP group and 24.3 ± 4.3 kg/m^2 for the OCP group. There were no statistically significant differences in demographic findings, such as patient age, gender, BMI, or previous abdominal operations between the patients undergoing LCP and OCP (Table 1).

Pathologic results

The pathologic characteristics were similar in the two groups (Table 2). Final evaluation by a pathologist revealed that benign cystic neoplasms were most common in both groups. Pancreatic neuroendocrine tumors in the pancreatic neck were also a major indication for CP. Mean tumor size in the LCP group was 2.2 ± 1.1 cm and in the OCP group, 3.0 ± 2.6 cm. Mean length of resected pancreas in the LCP group was 4.6 ± 1.0 cm and in the OCP group, 4.7 ± 1.6 cm. Tumor size and mean length of resected pancreas were similar in the two groups ($p > 0.05$).

Perioperative results

Return to normal bowel movements and sipping water was achieved a mean of 4.0 ± 2.1 days after the operation in the LCP group and 4.6 ± 1.4 days in the OCP group ($p > 0.05$). However, LCP patients had a significantly shorter postoperative hospital stay than OCP patients (13.8 vs. 22.4 days, $p < 0.05$) (Table 3). Mean operation time also differed significantly between the two groups (350.2 vs. 270.3 min, $p < 0.05$) (Table 3). There was no significant difference in ABL between the two groups.

Postoperative complications

No operative deaths occurred in either group. Postoperative complications were classified and graded according to Clavien's classification. The overall complication rates in the LCP and OCP groups were 38.5 and 50 %, respectively. There was no significant difference in the incidence of major complications (grade 3–5) or major postoperative pancreatic fistulas (ISGPF grades B and C) between the two groups (Table 4). There were no reoperations in either group over 30 postoperative days, nor were there any immediate postoperative readmissions (within 1 month after discharge). However, there were 2 reoperations in the LCP group, after 34 months and 6 months, respectively, and two patients needed small bowel resection and anastomosis due to mechanical ileus.

Comparative analysis of LCP and E-LDP

Demographic characteristics

There were no significant differences in demographic findings, such as patient age, gender, and BMI. However, patients who had undergone E-LDP had fewer previous abdominal operations than those who had undergone LCP ($p < 0.05$) (Table 1).

Pathologic results

Pathologic characteristics were comparable in the two groups (Table 2). Final evaluation by a pathologist revealed that benign cystic neoplasms were most common in both groups. The mean size of the tumors in the E-LDP group was larger than in the LCP group (4.0 vs. 2.2 cm, $p < 0.05$), and the mean length of resected pancreas in the E-LDP group was greater (12 vs. 4.6 cm, $p < 0.05$).

Perioperative results

Return to normal bowel movement and sipping water was achieved a mean of 2.1 ± 1.4 days after the operation in the E-LDP group and 4.0 ± 2.1 days in the LCP group ($p < 0.05$). Postoperative hospital stay was shorter in the E-LDP patients than the LCP patients (9.3 vs. 13.8 days, $p < 0.05$), but mean operation time was longer (350.2 vs. 210.6 min, $p < 0.05$) (Table 3). There was no significant difference in ABL between the two groups.

Postoperative complications

No operative deaths occurred in either group. Postoperative complications were classified and graded according to Clavien's classification. The overall complication rate for the LCP group was higher than for the E-LDP group (38.5 vs. 14.6 %, $p < 0.05$), but there was no significant difference in major complications (grade 3–5). ($p > 0.05$), nor was there a difference in major postoperative pancreatic fistula (ISGPF grades B and C) (Table 4). There were no reoperations in either group over 30 postoperative days, nor were there any immediate postoperative readmissions (within 1 month after discharge). There was a higher incidence of postoperative new-onset diabetes in the E-LDP group (30.8 % vs. 11.5 %, $p < 0.05$).

Discussion

The surgical techniques for major pancreatectomy have improved in recent years, patients with benign pancreatic tumors can expect a good quality of life after surgery, as well as safe operations. Under these circumstances, surgeons must consider quality of life when designing surgical approaches for patients with benign pancreatic tumors. Thus, function-preserving and minimally invasive pancreatectomies are the best surgical approach for these tumors.

Since 1994, when Gagner et al. [17, 18] reported the first use of laparoscopic surgery for pancreatectomy, a number of reports supporting its safety and feasibility have been published [1, 3, 4, 19, 20]. The LDP has become the standard technique for treating left-side pancreatic neoplasms [4]. Furthermore, laparoscopic pylorus-preserving pancreaticoduodenectomy (L-PPPD) has recently been widely accepted for benign tumors in the pancreatic head [20]. However, tumors in the neck of the pancreas are a particular challenge to surgeons. Traditionally E-DP was the treatment of choice for these tumors. However, this conventional procedure had some disadvantages in terms of long-term quality of life [21, 22]. As a result parenchyma-sparing pancreatectomy, CP is the preferred surgical procedure for such benign and low-malignancy pancreatic neck lesions. _ENREF_7There have been several studies of CP and it has proved a useful treatment for benign or borderline lesions in the neck of pancreas [5–8, 11, 23, 24]. In addition, a large CP series has suggested that the operative risk of CP is similar to that of conventional pancreatectomy, with good preservation of endocrine or exocrine pancreatic function [25].

It is widely accepted that advanced laparoscopic surgery can be performed safely and effectively by experienced surgeons and, in selected patients, has several advantages over conventional open techniques, such as early postoperative recovery and improved cosmetic effects [1, 3, 4, 26, 27]. A combination of laparoscopic surgery and parenchyma-sparing pancreatectomy (LCP) is, therefore, the best procedure for benign and low-grade malignant pancreatic neck lesions.

However, there have been few studies comparing the perioperative outcomes of patients undergoing LCP with those undergoing OCP or E-LDP. Our study is a large, single-institution retrospective series comparing short- and long-term clinical outcomes for patients undergoing LCP, OCP, and E-LDP.

Between January 1998 and December 2012, 109 consecutive CPs were performed in our institution. Over that time, 48 patients underwent LCP and 61 underwent OCP. We began performing laparoscopic pancreatectomy in March 2005 and, up to December 2012, more than 1,000 consecutive laparoscopic pancreatectomies, including L-PPPD, LDP, LCP and laparoscopic enucleation, have been performed in our center. The use of LCP has increased gradually over time. When we began using LCP in 2007, only 22.2 % (2/9) of patients undergoing total CP underwent LCP; this increased to 88 % (22/25) by 2010.

In our center, all of the surgical procedures were performed by expert pancreatic surgeons. The mean operation time for LCP was 350.2 min, which is comparable to other studies of LCP, which have reported operative times in the range 225–435 min [28–30]. Comparative analysis (Table 3) shows that the operation time for the LCP group was longer than for the OCP and E-LDP groups (350.2 vs. 270.3 and 210.6 min, respectively; $p < 0.05$). The longer operation time required for LCP can be attributed partly to surgeons' learning curves. Operation times also decrease as

the experience of the surgical team (composed of surgical-room staff and assistants) increases.

In the present study, final pathologic examination showed that over 70 % of patients had benign pancreatic cystic tumors, such as intraductal papillary mucinous neoplasms, mucinous cystic neoplasms, solid pseudopapillary tumors, and serous cystic neoplasms. In our institution, for all patients with CP, both cut ends were submitted for intraoperative frozen section analysis, which is essential for avoiding recurrence of tumors in the remnant pancreas. There was no recurrence of pancreatic tumors after CP during follow-up.

Laparoscopic surgery is associated with decreased postoperative pain, reduced trauma to the abdominal wall, smaller incisions, cosmetic advantage, and an earlier return to previous activity. Although the timing of the start of food intake may depend on the personal preference of the surgeon, LCP produced excellent results compared with OCP, in terms of postoperative recovery, represented by postoperative hospital stay. In agreement with several previous comparative studies of laparoscopic pancreatectomy, the current results showed a significantly shorter postoperative hospital stay for the LCP patients than the OCP patients (13.8 vs. 22.5 days, respectively; $p < 0.05$). In general, the hospital stay of the patients who underwent CP in our study was longer than in Western studies [6–8, 28–30]; however, this could be due to differences between health insurance systems. Although hospital stay was shorter in the LCP group, the mean hospital charge for in the laparoscopic group was higher than in the open group, though the difference was not statistically significant. The higher hospital charges in the LCP group are due to the use of laparoscopic instruments.

We reported total complication rates, according to the Clavien classification [14], of 38.5 and 14.6 % in the LCP and E-LDP groups, respectively ($p < 0.05$). However, most complications could be managed successfully by a conservative approach, including percutaneous drainage, antibiotics, etc. The perioperative complications following LCP in our series were all within the reference range suggested in other large series [29].

Pancreatic fistulas are an important complication following pancreatic surgery. There is controversy over whether CP results in higher levels of pancreatic fistula than distal pancreatectomy (DP). The exact incidence of pancreatic fistula in CP is not known due to relatively low patient numbers. In this study, 29 of 40 patients with CP (72.5 %) developed pancreatic fistulas, all of which healed with conservative management. The rates of clinically significant pancreatic fistulas (grades B and C) in our study did not differ significantly: 19.2 and 35.7 % in LCP and OCP, respectively. Although there are differences in the definitions used for pancreatic fistulas, postoperative pancreatic fistulas following CP in our series were within the reference ranges reported elsewhere [29, 30]. Fistula rates after DP and pancreaticoduodenectomy are well below that of CP [3, 4, 26, 27]. We have reported previously frequencies of pancreatic fistulas (grades B or C) resulting from LDP and L-PPPD of 7 and 6 %, respectively [1, 20]. In this study, the clinically relevant pancreatic fistula rate of E-LDP was 8.3 %. LCP had a higher rate (19.2 %) of pancreatic fistula than other laparoscopic pancreatectomies.

The main benefit of CP is that it preserves a greater proportion of healthy pancreatic tissue than E-LDP. Patients in this study who underwent CP had smaller lesions, which were resected with significantly shorter lengths of pancreas than patients who underwent E-LDP (Table 2). Since pancreatic islets are mostly located in the tail of the pancreas, DP may damage the endocrine function of the pancreas, which can result in diabetes [31]. It has been reported that the most important advantage of CP is the excellent endocrine pancreatic function after operation [32]. Hence it is to be expected that CP patients will experience less postoperative pancreatic dysfunction than DP patients. In our series, the incidence of new-onset diabetes in the E-LDP group was higher than in the LCP group. We did not investigate in detail the changes in pancreatic exocrine function after pancreatectomy, since this is difficult because there is no consistent objective measure. We used only one approach; checking patient's weight loss in order to evaluate exocrine insufficiency, and there was no difference between the LCP and E-LDP groups. In our study, only 2 of 40 patients with CP suffered new-onset diabetes during the follow-up period. This suggests that CP decreases the incidence of diabetes by preserving a greater proportion of the normal pancreatic parenchyma. Another advantage of CP compared with extended DP is that it preserves the spleen and avoids the risk of post-splenectomy sepsis and hematologic disorders.

Choice of the best technique for pancreatic-gastrointestinal anastomosis remains a challenge for the pancreatic surgeon. Several studies have compared the incidence of pancreatic fistula according to the type of pancreatico-enteric anastomosis (PG vs. PJ), and no differences have been reported [32–35]. In our institution, partial reconstruction of the distal pancreatic remnant was performed after CP with an end-to-side PJ (double layer). This is the standard procedure for expert pancreatic surgeons who carry out pancreatico-enteric anastomosis in our center. PG has the advantage of being technically easier and faster than PJ, since only one anastomosis is needed. However, the most important factor in minimizing postoperative complications is the involvement of highly experienced surgeons working in specialized centers.

CP without pancreatico-enteric anastomosis for lesions in the neck and proximal pancreas is a safe and effective

procedure [36]. However, 6 of a total of 8 patients in our center had LCP without PJ (75 %), and they had clinically significant pancreatic fistulas. Grade B fistulas occurred in 2 cases, and grade C fistulas in 4 cases; all required re-intervention with endoscopic ultrasono-guided gastrocystostomy. Even if these patients maintained long-term endocrine function, they needed a very long recovery time. It was also reported that deaths due to pancreatic fistulas as a result of ligation of the distal stump were not significantly different, but that morbidity was greater in the group without anastomosis [37]. Therefore, it would be better to limit the indication of occlusion of the distal pancreatic stump after CP to specific operative circumstances, such as situations in which difficult pancreatico-enteric anastomosis is expected, such as presentation with near atrophy of the distal pancreas or fatty changes in the distal pancreas.

This study has several limitations. First, there was no defined algorithm for selecting patients for LCP. Since the development of the application of laparoscopic surgery in pancreatic surgery, we have tried to perform LCP with those patients with tumors in the pancreatic neck who might otherwise have undergone E-DP or OCP. There were no differences in demographic findings, including medical history and pathologic results, between the two groups, and this may be due to selection bias. Secondly, the study population was limited by the demographics that present at a single institution, and, since our series is selected from a high-volume academic institution employing experienced pancreatic surgeons, the results may not be universally applicable. However, in our experience, longer operative times and poor surgical technique can be overcome by greater experience of surgeons, surgical-room staff and assistants. LCP could therefore be performed safely by most pancreatic surgeons with several years experience of open pancreatic surgery.

We hypothesized that LCP may have the general advantages of laparoscopic access, including improved cosmetic results, reduced postoperative pain, early mobilization, rapid return to normal activity, and early discharge from hospital, in addition to the advantages of OCP. LCP also has many advantages over E-LDP. The operation retains a greater proportion of normal pancreatic tissue, especially in the body-tail, thus avoiding long-term exocrine and endocrine insufficiency. LCP also spares the spleen, thus avoiding problems of severe infection, thrombosis, and immunodeficiency. However, until now there had been no comparative study of the three groups (LCP vs E-LDP and OCP). The aim of this study was to compare short- and long-term clinical outcomes in patients undergoing LCP, OCP, and E-LDP. LCP is feasible and safe procedure for small pancreatic tumors which located around pancreatic neck considering advantage of LCP such as preserving endocrine and exocrine function of pancreas and minimal invasive surgery.

Conclusions

Our large, single-center experience has shown that LCP is a feasible and safe procedure for treatment of small pancreatic tumors in the pancreatic neck, with the advantages of preserving endocrine and exocrine function of the pancreas and involving minimally invasive surgery. LCP is associated with earlier postoperative recovery than OCP, and excellent postoperative pancreatic function compared with E-LDP. We conclude that LCP is a valid therapeutic option for selected patients with small and benign tumors in the pancreatic neck and proximal body.

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