

# Laparoscopic surgery for pancreatic lesions: current status and future

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**Abstract** Laparoscopic pancreatic surgery has been gaining increasing recognition in recent years, and its practice has increased despite its highly complex procedure and longer learning curve compared with surgeries for other abdominal organs. Laparoscopic distal pancreatectomy and tumor enucleation are two of the fastest-growing techniques and are currently in wide use because of their comparable technical simplicity. Literature review showed that laparoscopic distal pancreatectomy and enucleation are safe and efficient approaches for benign and low-degree malignant tumors; however, the indication for malignant tumors remains controversial. Laparoscopic pancreaticoduodenectomy is practiced in a limited number of surgical centers and presented as case reports or in small series. Although its feasibility was demonstrated by many surgeons, whether the laparoscopic procedure can achieve benefits comparable to or even more prominent than those of an open procedure has not been clinically proven. Prospective, randomized, controlled trials of laparoscopic operation versus open pancreatic surgery are necessary to justify the wide application and routine practice of the laparoscopic procedure for pancreatic lesions.

**Keywords** minimally invasive surgery; pancreatic surgery; pancreatic neoplasm; distal pancreatic lesions; pancreatic fistula

## Introduction

The laparoscopic technique is one of the most advanced surgical approaches in the modern medicine world. It creates smaller incision sites, which leads to decreased healing time and surgical wounds, faster recovery, and reduced pain. Laparoscopic surgery is becoming a routine method for the treatment of many diseases, including cholecystolithiasis, hepatic cysts, and, more recently, colorectal and gastric cancer. However, the use of minimally invasive techniques for the pancreas remains uncommon. Given the location of the retroperitoneum, the special physiology of the endocrine and exocrine of the pancreas, close relation with major vessels, and long learning curve, laparoscopic pancreatic surgery (LPS) is more difficult to perform than surgeries for other abdominal organs. With the development in surgical technology and accumulation of advanced laparoscopic skills in recent years, pancreatic laparoscopic surgery is gaining

increasing recognition and has become increasingly common practice [1–3]. This article reviews the development of LPS and presents its current status and related issues to provide extensive and up-to-date information on this minimally invasive technique.

## History

The initial idea for the laparoscopic exploration of the pancreas was described by Bernheim in 1911 [3], but it was not until 1994 that Soper *et al.* [4] performed a laparoscopic distal pancreatectomy (Lap DP) on a porcine model to document its safety and feasibility. Gagner [5] first reported five cases of spleen-preserving laparoscopic distal pancreatectomy for human insulinoma in 1996, which is noted as a landmark in this field. Subsequently, Cuschieri [6] and Park *et al.* [7] reported their experience and further support for this technique. Since that time, case reports and small series have accumulated in literature. Until 2009, more than 146 laparoscopic pancreaticoduodenectomies (Lap PD) [8], 800 Lap DPs [2], and 101 tumor enucleations (Lap EN) [9] were performed worldwide. Moreover, laparoscopic

approaches were also applied in many other aspects, including explorative laparoscopy for cancer staging [10], diagnostic laparoscopic biopsy, external and internal pancreatic drainage [11, 12], and laparoscopic necrosectomy [13–15]. Of these applications, Lap DP was initially the fastest developed because of its relative technical simplicity.

## Indication

The indications for laparoscopic surgery of the pancreas are generally benign or low-degree malignant tumors detected via preoperative identification, and chronic pancreatitis with symptoms. CT or MRI scans and endoscopic ultrasound can greatly assist in the differential diagnosis. However, many high-degree malignant cases, such as pancreatic ductal adenocarcinoma, were also reported in Lap PD. Lap EN is mostly applied to insulinoma and some rare cases, such as nonfunctioning neuroendocrine tumors [16–18]. Mabrut [19] reviewed 127 laparoscopic pancreatic operations in 25 European medical centers and found that 87% of the cases were benign tumors. In Lap DP and Lap EN, the malignant cases were all limited to the unexpected postoperative pathologic diagnosis in literature reports. If this situation occurred in Lap EN, conversion or reoperation should undoubtedly be performed. For Lap DP, whether a second open operation should be performed remains controversial. The main debates are whether this minimally invasive procedure can radically resect the tumor and local lymph nodes, and on the possibility of implantation metastasis in the abdomen and trocar sites. In a recent prospective comparison between Lap DP and Open DP, Lap DP failed to provide a comparable lymphadenectomy, indicating the risks in performing laparoscopy for pancreatic adenocarcinoma [20]. Therefore, performing laparoscopic surgery for the preoperative suspicion of malignancy is still not advisable.

## Surgical approach

### Lap PD

The first pylorus-preserving Lap PD was successfully performed in 1992 [21]. The operation took more than 10 h and the hospitalization day lasted for 30 days because of postoperative delayed gastric emptying. Thus, no clinical advantage was observed over the conventional open procedure. Subsequent attempts by Alfred Cuschieri still obtained disappointing results [22]. However, case reports or small cohorts are still continuously presented by skilled endoscopic surgeons, especially in the recent decade. Staudacher *et al.* shared their experiences of four patients who underwent Lap PD: the mean blood loss was 325 ml, operative time was 416 min, hospital stay was 12 days, and no postoperative

complications occurred [23]. Another series was described by Palanivelu [24]. He reported on 35 patients who underwent Lap PD (19 men and 16 women; mean age at 48.7 years): 23 cases had ampullary neoplasms, 3 with lower bile duct neoplasms, 7 had carcinoma of the pancreatic head, and 2 cases had duodenal carcinoma. Reconstruction was performed laparoscopically, with pancreatojejunostomy in 25 patients and pancreatogastrostomy in 10. The mean operative time was 6.6 h (range, 5.5–11 h), mean blood loss was 295 ml (range, 85–600 ml), and mean hospital stay was 9.2 days. In a recent report of 7 cohort cases from the UK, the mean operating time, blood loss, and hospital stay were 628 min, 350 ml, and 11.1 days, respectively. The conversion, morbidity, pancreatic fistula, readmission, reoperation, and mortality rates were 0%, 28.6%, 14.3%, 28.6, 0%, and 0% respectively [25].

When the feasibility of the technique was illustrated by many surgeons, the main concern was whether the laparoscopic procedure can achieve comparable or even more prominent advantages over open procedure. Diener *et al.* [26] compared laparoscopic with open pancreaticoduodenectomy via a meta-analysis of literature review and found that the operating time (493.28 vs. 401 min), hospital stay (18.7 vs. 20.9 days), mortality rate (1.3% vs. 1.54%), and complications were similar between the two procedures. Blood loss was higher in the open technique (819.6 ml in open vs. 142.8 ml in laparoscopic). Recently, the largest review included 146 cases, with the mean age at 59 years (range: 43–71 years), mean operating time of 439.28 min (range: 284–660 min), and blood loss of 142.8 ml (range: 50–770 ml) [8]. The average hospital stay was 18 days (range: 7–39 days), and the average conversion rate was 46% (range: 12%–100%). The mean number of lymph nodes in the pathology was 19 (range: 13–26). The complication rates were 16% and mortality was recorded in only 2 (1.3%) patients during the perioperative period. From the literature review, the operative variables, specifically the duration of surgery and lymph node yield in the laparoscopic procedure, appear comparable to those of the published open series. However, the major disadvantage of the laparoscopic approach is the difficulty and long learning curve required. Moreover, the patients involved in the reports were all highly selected, and this technique is still limited to a few laparoscopic surgeons in different centers worldwide. Therefore, whether this technique can be applied in more patients and become a general practice is still unknown.

### Lap DP

In contrast to the extremely complex and difficult procedure of Lap PD, Lap DP is preferred because no anastomosis is required, and the size of the incisions can be greatly reduced compared with the conventional open approach. Nowadays, Lap DP is gaining more popularity worldwide, and has accumulated more than 800 cases based on the literature

review [2]. Many pancreatic surgery centers have reported their experience on Lap DP and made comparisons between Lap and the open procedure. Finan *et al.* [27] analyzed 38 Lap DP and 98 Open DP cases, and a decreased operative time (156 vs. 200 min,  $P < 0.01$ ), blood loss (157 vs. 719 ml,  $P < 0.01$ ), and length of stay (5.9 vs. 8.6 days,  $P < 0.01$ ) were observed in the former procedure. No significant difference in the rate of pancreatic fistula formation or clinically significant leaks between the two groups was determined. In addition, no significant difference in the incidence of postoperative morbidity or mortality was observed between the different surgical approaches. A 2:1 matching case control (Open DP vs. Lap DP) design showed that no significant differences in the operation time as well as in the rates of intraoperative transfusions, complications, recurrence, or mortality between the two groups were observed [28]. The Lap DP group had a statistically significant shorter hospital stay despite the higher cost. A recent meta-analysis of the comparison showed that the patients in the Lap DP groups had significantly less blood loss, shorter time for oral intake, and shorter postoperative hospital stay [29]. Meanwhile, the Lap DP approach had fewer overall complications, fewer major complications, lower surgical-site infections, and less pancreatic fistulas despite similar mortality and reoperation rates between the two groups. These reports indicate that Lap DP for benign and low-degree malignant tumors is superior to the open procedure in many aspects.

Two major methods of Lap DP are the laparoscopic splenopancreatectomy with splenectomy and laparoscopic spleen-preserving distal pancreatectomy. Currently, spleen-preserving is desirable for both patients and surgeons, considering the immunological functions of the spleen and the long-term quality of life of the patients. A systematic review of 806 Lap DP procedures showed that spleen preservation was performed in 400 patients (49.6%), whereas the en bloc distal pancreatectomy with splenectomy was performed in 402 patients (49.8%) [2]. Two techniques have been described in the spleen-preserving procedure. The first is to preserve the splenic artery and vein by careful separation of the pancreas and splenic vessels near the splenic pedicle. This is possible in the absence of an infiltration of the splenic pedicle and with the advanced skill of the surgeon. An alternative technique was described by Warshaw in 1988 [30]. The main splenic vessels are divided at the pancreatic neck and near the splenic pedicle. The distal pancreas associated with the splenic vessels is transected, leaving the short gastric vessels and the left gastroepiploic vessels to feed the spleen. The latter method is easy to perform and may avoid conversion to open surgery because of an unexpected injury of the splenic vessels [31]. However, the possibilities of splenic infarction and abscess make surgeons uneasy to perform this procedure. Serious complications, such as entire splenic necrosis or abscess, which needed reoperation for splenectomy, have been reported [32–34]. Since then, doctors

have paid an increased attention to preserving the short gastric vessels when using Warshaw's technique. Unfortunately, the incidence rate of the complications has not decreased in the past three years [35,36]. Therefore, surgeons should be cautious when applying this technique.

The average conversion rate from Lap DP to open surgery is 9.2%. The major reasons for conversion are bleeding, obesity, dense adhesion, and presence of malignancy [2,37,38]. Intraoperative bleeding is the most common cause of conversion, especially for the spleen-preserving procedure. Our unit performed Lap DP and Lap EN in 2002, and have accumulated more than 70 successful cases. Based on our experience, important points must be considered to prevent conversion: (1) The correct selection of cases. The operative method should be chosen cautiously based on the preoperative radiologic examinations. The splenic vessels can more likely be spared when a thin fat plane can be seen between the splenic vessels and the pancreas, and the border of the tumor is clear, with no surrounding adhesions in the enhanced CT. (2) Mastery of surgical skill. Using the suction apparatus as a blunt dissection instrument separates the pancreas from the splenic vessels. Dissection accompanying aspiration can provide a clear view at the anatomical level. (3) Comprehension of anatomy. In normal conditions, a thin, loose, connective tissue is present between the pancreas and the splenic vessels. Dissection along this level can minimize intra-operative bleeding.

### Lap EN

Lap EN was first designed by Ernesto Tricomi in 1898 [39], and today it has become a widely-accepted choice of treatment for insulinomas. Compared with other procedures, EN can preserve the normal parenchyma and maintain pancreatic functions. Other lesions were also treated by this procedure in previous reports, including non-functioning pancreatic endocrine tumors [40,41], serous and mucinous cystadenomas [42–44], solid pseudopapillary tumors, small branch-duct intraductal papillary mucinous cystic neoplasms, and other rare conditions such as cystic lymphangioma [45,46]. Although experience has been gradually gained, the application of Lap EN is still limited to selected patients. To perform EN safely, the lesion should be benign or no invasive behavior is observed; it should be on the anterior surface of the pancreas, with a diameter less than 4 cm, and is at least 2–3 mm away from the main pancreatic duct.

In contrast to open surgery, the laparoscopic procedure lacks manual palpation. Preoperative localization becomes a key factor in choosing suitable surgical methods. Spiral CT based on a pancreatic protocol should be sufficient for most cases. However, a negative visual finding can still be encountered in a small series of patients during the operation. Intraoperative ultrasound is useful in clearly identifying the morphology, site, and proximity of the lesions to the main pancreatic duct. Moreover, this examination can help rule out

the possibility of multiple tumors existing in the pancreatic parenchyma.

A series of Lap ENs has been presented in literature. Karaliotas *et al.* [1] compared 5 Lap EN with 7 Open EN, with a mean operation time of 121 versus 92 min, and mean hospital stay of 11 versus 14 days ( $P < 0.05$  in both). The pancreatic fistula rates were 20% and 28.57%, respectively ( $P = 0.65$ ). Mortality was nil. Sweet *et al.* [17] reported success in 7 patients from 9 cases scheduled to accept Lap EN. The main reason for laparotomy (22%) is the inability to identify the lesion seen during preoperative imaging. Pancreatic fistula occurred in 2 patients (29%). Remarkably, in this series, hospitalization was only 1 day in 5 of 7 patients, and the author reported that most patients tolerated closed-suction drainage as an outpatient treatment without difficulty. A recent large cohort of 23 consecutive patients who underwent Lap EN was analyzed [47]. Lap EN was successfully achieved for 21 patients (91.3%), and postoperative pancreatic fistula was observed in 3 cases (13%). One death (4%) occurred. EN was performed for endocrine neoplasm in 15 patients (65%) and for cystic neoplasm in 8 patients (35%). Therefore, Lap EN seems associated with a decrease in the operative time, hospital stay, and pancreatic fistula compared with the conventional open approach.

### Pancreatic fistula in the Lap procedure

As in open surgery, pancreatic fistula is also a major postoperative complication in LPS. Mabrut *et al.* [19] reviewed 897 patients who underwent Open DP and reported the incidence of pancreatic fistula in 3.5% to 26% of the patients, with an average of 13%. Meanwhile, comparable rates in Lap DP and Lap EN ranged from 10% to 33% [28] and 18% to 33% [17], respectively. An important issue is that the diagnostic criteria for pancreatic fistula varied among different medical centers in literature reports. The pancreatic fistula is associated with the pancreatic texture and the management of the pancreatic stump. The risk increases if the pancreatic tissue is soft or brittle. Fistula formations are directly correlated with the management of the pancreatic stump. Various methods of transecting the pancreas have been reported, whereas the Endo GIA linear stapler is the most popular instrument for surgeons. Edwin *et al.* [48] and Palanivelu *et al.* [31] used the Endo GIA with 4.8 mm staples and reported that pancreatic fistulas occurred in none of 17 and 1 of 22 Lap DP patients. Other techniques, such as ultrasonic scalpel and absorbable, synthetic staple-line reinforcement material, have been used with good results [3,49,50]. Hilal *et al.* [38] reported that suturing the pancreatic remnant with PDS 3.0 interrupted stitches rather than the staple line obtained an encouraging result, reducing the pancreatic fistula rate from 50% to 9%. Additional measures, such as applying a fibrin sealant to the pancreatic stump or use of postoperative somatostatin, are of no benefit to patients [19].

## Conclusions

Although LPS developed late and slowly compared with other minimally invasive techniques, it still gained huge success and brought clinical benefits to patients, especially in distal pancreatectomy and EN. However, the operative outcomes are not always favorable even when Lap PD is performed in selected patients by skilled surgeons. The technique for the reconstruction stage, including pancreaticojejunostomy and pancreaticogastrostomy, has not yet been established. Therefore, Lap DP and EN are further advanced and more beneficial than Lap PD. In addition, the suitability of LPS for malignant tumors remains controversial. Prospective, randomized, controlled trials of laparoscopic versus open pancreatic surgery are needed to prove the advantages of LPS in both clinical and oncologic aspects. However, with the advancement in laparoscopic instruments and accumulation of surgical experience, the application of LPS may become common practice in the future.

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