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**Laparoscopic pancreatectomy: Indications and outcomes**

Liang S *et al.* Laparoscopic pancreatectomy: Indications and outcomes

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**Abstract**

The application of minimally invasive approaches to pancreatic resection for benign and malignant diseases has been growing in the last two decades. Studies have demonstrated that laparoscopic distal pancreatectomy (LDP) is feasible and safe, and many of them show that compared to open distal pancreatectomy, LDP has decreased blood loss and length of hospital stay, and equivalent post-operative complication rates and short-term oncologic outcomes. LDP is becoming the procedure of choice for benign or small low-grade malignant lesions in the distal pancreas. Minimally invasive pancreaticoduodenectomy (MIPD) has not yet been widely adopted. There is no clear evidence in favor of MIPD over open pancreaticoduodenectomy in operative time, blood loss, length of stay or rate of complications. Robotic surgery has recently been applied to pancreatectomy, and many of the advantages of laparoscopy over open surgery have been observed in robotic surgery. Laparoscopic enucleation is considered safe for patients with small, benign or low-grade malignant lesions of the pancreas that is amenable to parenchyma-preserving procedure. As surgeons’ experience with advanced laparoscopic and robotic skills has been growing around the world, new innovations and breakthrough in minimally invasive pancreatic procedures will evolve.

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**Key words:** Laparoscopy; Distal pancreatectomy; Pancreaticoduodenectomy; Robotic pancreatectomy; Enucleation

**Core tip:** This review discusses recent advances in laparoscopic distal pancreatectomy (LDP), minimally invasive pancreaticoduodenectomy (MIPD), and enucleation. Recent studies show that LDP have improved perioperative recovery and equivalent oncologic outcomes. Studies on MIPD demonstrate that it is safe in terms of intra-operative outcomes, post-operative recovery and early oncologic outcomes; however, it requires advanced laparoscopic skills. Laparoscopic enucleation has become the operation of choice for small benign tumours that are away from the main pancreatic duct, especially insulinomas. We also summarize key results in pre-operative, perioperative and post-operative outcomes from contemporary series comparing open and laparoscopic pancreatic resections in the tables.

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**INTRODUCTION**

Pancreatic resection is technically challenging due to anatomic factors such as retroperitoneal location, close proximity to the duodenum and major vasculature. As a result, the application of laparoscopy to pancreatectomy has been slower compared to other abdominal procedures. As surgeons become more adept at advanced laparoscopy, there is increasing evidence demonstrating not only the safety and feasibility of laparoscopic pancreatic resection, but also potential advantages in postoperative recovery and equivalent oncological outcome. Here, we review recent advances in laparoscopic distal pancreatectomy, pancreaticoduodenectomy, and enucleation, with emphasis on patient selection, surgical technique, perioperative outcomes, oncologic outcomes, and the emerging role of robotics.

**LAPAROSCOPIC DISTAL PANCREATECTOMY**

Laparoscopic distal pancreatectomy (LDP) is the most commonly performed pancreatic resection using minimally invasive techniques. The main advantages of LDP over open distal pancreatectomy (ODP) are the potential for improved surgical exposure and visualization, and enhanced post-operative recovery and morbidity[[1](#_ENREF_1)]. A summary of series that compare the pre-operative, intra-operative and post-operative factors and outcomes in LDP and OPD at their institutions is shown in Tables 1 and 2[[2-25](#_ENREF_2)].

**PATIENT SELECTION**

Appropriate patient selection is essential for any surgical procedure attempted with a laparoscopic approach. Patient factors, such as body habitus, cardiopulmonary comorbidity, and a history of previous laparotomy are typical factors that may make laparoscopic surgery more challenging. High BMI is not a contraindication for LDP, nor is the size of the tumour being resected[[8](#_ENREF_8),[11](#_ENREF_11),[12](#_ENREF_12),[26](#_ENREF_26)]. The laparoscopic approach may be even more beneficial in patients with higher BMI because of better access into the deep abdomen, less post-operative incisional pain and faster postoperative recovery.

Tumor factors may also affect a patient’s suitability for a laparoscopic resection. Malignant potential should not necessarily be a limiting factor for laparoscopic resection. However, large, locally advanced malignancies may not be technically feasible laparoscopically due to concerns with tumor handling, seeding, and risk of positive margins. Likewise, cancerous lesions located near the neck of the pancreas or close to the celiac trunk and its branches should be approached with caution[[11](#_ENREF_11)]. In the absence of randomized controlled trials, most series suggest that patients with isolated benign, pre-malignant or small low-grade malignant lesions in the distal pancreas should be considered for undergoing LDP [[1](#_ENREF_1)]. In experienced centres, LDPs can be safely performed in patients with high BMI, large tumour size and malignant diseases.

**SURGICAL TECHNIQUE AND INTRA-OPERATIVE CONSIDERATIONS**

In the early 1990s the first reports of laparoscopic pancreatic resection were published[[27](#_ENREF_27)]. Since then, this technique has gained widespread adoption. Distal pancreatectomy in many respects is an ideal minimally invasive approach since it involves resection without reconstruction.

To help ascend the learning curve for a novel approach, some authors advocate the use of hand-access ports in the midline and right lower quadrant[[28](#_ENREF_28)]. The main advantages of hand-access ports are allowing direct palpation of the tumour, and control of hemorrhage by manual pressure[[1](#_ENREF_1)]. The need for these ancillary access devices has been mitigated by advances in surgical technique, vascular sealing devices and endomechanical staplers which allow for safe performance of pancreatic resections fully laparoscopically.

LDP may be performed with or without splenic preservation. The main advantage to splenic preservation is to avoid the risk of overwhelming post-splenectomy infection (OPSI), which has an annual incidence of 0.23%-0.42% per year and a lifetime risk of 5%[[29](#_ENREF_29)]. LDP with preservation of the spleen is preferred for benign diagnoses as the need for lymph node retrieval is not as crucial[[1](#_ENREF_1),[30](#_ENREF_30)]. Likewise, the splenic vasculature should be taken in malignant cases to facilitate total extirpation and negative margins. Distal pancreatectomy with splenic preservation has similar rates of post-operative morbidity and pancreatic fistulas as distal pancreatectomy with splenectomy[[10](#_ENREF_10)]. Although long-term prospective studies are lacking, we advocate preservation of the spleen in LDP performed for benign diseases whenever possible in order to minimize the effect on the immune system against encapsulated organisms.

Spleen-preserving distal pancreatectomy may also be performed using the Warshaw technique, which divides the splenic artery and vein while preserving the blood supply to the spleen from the short gastric vessels[[31](#_ENREF_31)].

Intraoperative variables include operating time, blood loss, and conversion, and selected studies comparing LDP and ODP at the same institutions are shown in Table 1. Some series report a shorter operating time for LDPs compared to ODP[[10](#_ENREF_10),[15](#_ENREF_15),[23](#_ENREF_23)], but some of the studies’ calculation of the average LDP operating time does not include the converted cases, which are much longer[[10](#_ENREF_10),[15](#_ENREF_15)]. Other series reported equivalent or longer operating time with LDP compared to ODP[[9](#_ENREF_9),[11](#_ENREF_11),[12](#_ENREF_12)]. One may note that the operating time is variable even though the surgical techniques are similar. This may be explained by the difference in the surgeons’ learning curve[[26](#_ENREF_26)].

A LDP that is not converted to open is associated significantly less intra-operative blood loss compared to ODP in many series[[2](#_ENREF_2),[4-6](#_ENREF_4),[10-12](#_ENREF_10),[14](#_ENREF_14),[16](#_ENREF_16),[21](#_ENREF_21),[23](#_ENREF_23)]. The usual rate of conversion to ODP is about 10%-20% (Table 1), but can be over 25% in series with less selected patients[[11](#_ENREF_11),[32](#_ENREF_32)]. Reasons for conversion include high BMI, adhesions, difficulty localizing the lesion, large and proximal tumours, hemorrhage, and concern for margin adequacy. Conversion to open surgery may also be associated with a greater risk of postoperative complications[[11](#_ENREF_11)].

**POST-OPERATIVE OUTCOMES**

Patients with cardiac and pulmonary comorbidities risk prolonged postoperative recovery and comorbidity after undergoing a midline laparotomy or subcostal incision due to postoperative pain, atelectasis, pneumonia, and ileus. Some argue that these patients are ideal candidates for laparoscopic resection due a potential greater benefit of an enhanced postoperative recovery. Although there is a lack of randomized trials comparing LDP and ODP, there have been many retrospective series in the past decade studying the post-operative outcomes of LDP. The main advantages of LDP include shorter hospital stay (difference of 2 days or more)[[2-6](#_ENREF_2),[9](#_ENREF_9),[11-16](#_ENREF_11),[19-21](#_ENREF_19),[23](#_ENREF_23),[24](#_ENREF_24)], decreased requirement for pain medications, and swifter return to regular diet (difference of 1.7 days)[[19](#_ENREF_19)]. The overall morbidity is approximately 26%-40%[[2](#_ENREF_2),[10](#_ENREF_10),[11](#_ENREF_11),[13](#_ENREF_13)], which is similar to ODP from contemporary series (29%-57%). Most published series suggest mortality is rare with the laparoscopic technique and that it can be done reliably and safely in most cases[[10-12](#_ENREF_10),[15](#_ENREF_15)].

The rate of pancreatic fistula is similar between LDP and ODP, with most studies reporting it to be in the acceptable ranges for both approaches[[10](#_ENREF_10),[11](#_ENREF_11),[13](#_ENREF_13),[15](#_ENREF_15)]. There is a wide range of reported rates of pancreatic fistulas, as shown in Table 2. The large difference in rates of pancreatic fistulas may be explained by the different reporting strategies. For example, some studies report an overall rate, whereas others report only the pancreatic fistulas that require interventions. In addition, this difference may also be due to differences in intra-operative technique and equipment.

In summary, LDPs demonstrate significantly faster post-operative recovery and shortened length of stay, and similar safety compared to ODP.

**ONCOLOGIC OUTCOMES**

Oncologic outcomes can be categorized into intra-operative and long-term. Comparisons between LDP and ODP in pathologic considerations, such as tumour size, specimen length, proportion of malignant histology, margin positivity and lymph node harvest have been described in various case series comparing their LDP with ODP experience (Table 1). In Kneuertz *et al*[[26](#_ENREF_26)] there is no difference in tumour size, proportion of malignant histology, and margin positivity between early and recent experiences.

Patients undergoing LDP tend to have smaller size lesions (2.5-3.3 cm in LDP *vs* 3-7.7 cm in ODP)[[10](#_ENREF_10),[11](#_ENREF_11),[13](#_ENREF_13),[15](#_ENREF_15)]. The range for specimen length in LDP is 7.7-9.4 cm[[10](#_ENREF_10),[12](#_ENREF_12),[13](#_ENREF_13)], which is slightly smaller than in ODP (9.4-10cm). In most series, patients with malignancy tend to undergo open resections. Therefore, the margin positivity from the LDP group in these series should be interpreted with caution, because of pre-existing selection bias. However, in Kooby’s matched analysis of patients undergoing LDP and ODP for malignant diseases only, they reported similar rates of margin positivity (26% in LDP and 34% in ODP), lymph node retrieval (14 *vs* 12.3), and specimen length (9.4 cm *vs* 9.6 cm)[[12](#_ENREF_12)].

There is little data on long term oncologic outcomes after LDP. Marangos et al found that the 3-year survival rate in a cohort of 30-patient with 93% margin negativity for exocrine carcinoma is 36%, and the median survival time was 23 months (range 0.5-108 months)[[33](#_ENREF_33)].

In conclusion, LDP is safe, effective, and has become the operation of choice for lesions involving the distal pancreas. It should be considered a standard approach for most indications for distal pancreatectomy except in large cancers or large, centrally located lesions near the pancreatic neck or major vessels. Its application has been broadened to include patients with higher BMIs and comorbidity scores. LDP’s main advantages are shorter length of stay, faster post-operative recovery, and decreased requirement for pain medications with no difference in post-operative morbidity, mortality and short-term oncologic outcome. Further studies are needed to evaluate the long-term oncologic outcomes of LDP.

**MINIMALLY INVASIVE PANCREATICODUODENECTOMY**

Since the first laparoscopic pancreaticoduodenectomy in 1994[[34](#_ENREF_34)], the experience with minimally invasive pancreaticoduodenectomy (MIPD) has increased. Despite the known benefits of laparoscopy, the anatomic challenges and inherent technical complexity of this operation and the difficulty of performing three major anastomoses have limited the widespread use of minimally invasive pancreaticoduodenectomy. A summary of series that compare the pre-operative, intra-operative and post-operative factors and outcomes in MIPD and OPD at their institutions is shown in Tables 3 and 4[[35-38](#_ENREF_35)].

**PATIENT SELECTION**

In adopting laparoscopic approaches, or in the infancy of novel techniques, the traditional indications for open surgery include patients with morbid obesity[[39](#_ENREF_39), [40](#_ENREF_40)], and severe cardiac or pulmonary comorbidity[[39](#_ENREF_39)]. However, these patients may benefit the most from the minimally invasive approaches if they can be done safely. The earliest series of MIPD involved patients with small[[39-41](#_ENREF_39)], benign or low grade[[38](#_ENREF_38),[41](#_ENREF_41),[42](#_ENREF_42)] tumours of the pancreatic head, duodenal ampulla, and distal common bile duct, in the absence vascular or extrabiliary involvement[[39](#_ENREF_39),[40](#_ENREF_40),[42](#_ENREF_42),[43](#_ENREF_43)]. Patients with ampullary lesions, mucinous cystic neoplasms and Intrapapillary Mucinous Neoplasms (IPMNs) are ideal surgical candidates for MIPD due to the tendency for them to be non-adherent to the major arterial and venous structures near the pancreatic neck and uncinate process.

**SURGICAL TECHNIQUE & INTRA-OPERATIVE CONSIDERATIONS**

MIPD has been slow to adopt because of the anatomical and reconstructive challenges previously mentioned. There are two general approaches to MIPD: a total laparoscopic approach (TLPD) where the anastomoses (pancreaticojejunostomy, hepaticojejunostomy, gastrojejunostomy) along with the resection are done intracorporeally; and the laparoscopic-assisted, or hybrid approach where the reconstruction is done through a small incision which is also used for specimen extraction[[38](#_ENREF_38), [40](#_ENREF_40), [42](#_ENREF_42), [44-46](#_ENREF_44)].

TLPD and the hybrid approach have similar mean operative time (268 *vs* 286 min), blood loss (75 *vs* 83cc), complication rate (33 *vs* 25%), and length of stay (13.4 *vs* 14 d)[[45](#_ENREF_45)]. Several retrospective series demonstrate that MIPD can be safely performed in experienced hands. The average operating time and blood loss for three large MIPD series are 368-541 min, and 65-240 cc, respectively[[35](#_ENREF_35),[41](#_ENREF_41),[43](#_ENREF_43)]. In comparison, a contemporary OPD series by Cho *et al*[[38](#_ENREF_38)] shows that the average operating time is shorter (287 min), and blood loss is greater (552cc) in open cases. Asbun *et al*[[35](#_ENREF_35),[36](#_ENREF_36)] Kuroki *et al*[[35](#_ENREF_35),[36](#_ENREF_36)] compared their LPD and OPD cases and also found that LPD resulted in significantly less blood loss. The rate of converting MIPD to open ranges from 0-31.6%[[36](#_ENREF_36),[38](#_ENREF_38),[40](#_ENREF_40),[41](#_ENREF_41),[44](#_ENREF_44)]. Common reasons for conversion are hemorrhage, portal vein bleeding, difficult dissection, adhesions, and tumour involvement of major vascular structures[[1](#_ENREF_1),[47](#_ENREF_47)].

**POST-OPERATIVE RECOVERY**

It is unclear whether patients who undergo TLPD or hybrid have better post-operative outcomes than OPD. It is also difficult to compare the post-operative outcome measures across series because each hospital may have different practices and enhanced recovery programs in post-operative pain management, diet advancement, and criteria for discharge. In addition, the institutional and personal experience with the technical challenges of MIPD varies among the series, and the studies may take place in different stages of the institution and surgeon’s learning curves. Since many MIPD series are small in sample size and they often exclude patients with major vascular involvement, extensive adhesions, large tumours and morbid obesity, the post-operative outcomes may favor MIPD over OPD, because of the intrinsic differences in patient selection. As a result, it is very difficult to objectively compare and summarize the rate of major morbidity and mortality among the studies. Tables 3 and 4 lists studies that compared outcomes of LPDs and OPDs at their institutions.

Most MIPD series report low mortality rate[[38-46](#_ENREF_38)]; Gumbs et al. reviewed 285 cases and found the overall mortality was 2%[[48](#_ENREF_48)]. A more recent series reports a 100-d mortality rate of 5.7%, which is not significantly different than the mortality rate of 8.8% in the OPD group in the same series[[35](#_ENREF_35)]. Their reported mortality rate is higher than many other past studies because the authors extended the time range to 100 d. The majority of MIPD series have a 30-d mortality rate that is lower than that reported by the American College of Surgeons’ National Surgical Quality Improvement Program (ACS NSQIP) database of pancreaticoduodenectomy (mortality rate of 1.9%-2.8% in 6988 patients)[[49](#_ENREF_49)]. The MIPD’s rate of major morbidity in the series mentioned above ranges from 25%-48%., compared to 31% in OPD[[50](#_ENREF_50)]. The rate of pancreatic fistulas is an important post-operative outcome and is reported in majority of series. the rate of International Study Group of Pancreatic Fistula (ISGPF) grade B pancreatic fistula ranges from 2.4%-18%[[35](#_ENREF_35),[38](#_ENREF_38),[40](#_ENREF_40),[41](#_ENREF_41),[43](#_ENREF_43)]. Cho *et al*[[35](#_ENREF_35),[38](#_ENREF_38)] and Asbun and Stauffer compared their MIPD to contemporary OPD, and found that the OPD group have similar rate of pancreatic fistula (3%-13%). Other complications reported include biliary leak (2.4-7%)[[38](#_ENREF_38),[40](#_ENREF_40),[41](#_ENREF_41)], delayed gastric emptying (7%-9.1%)[[38](#_ENREF_38),[44](#_ENREF_44)], small bowel obstruction 6.2%[[45](#_ENREF_45)], intra-abdominal hemorrhage (5.3%)[[40](#_ENREF_40)], intra-abdominal abscess (2.4%-19.9%)[[35](#_ENREF_35),[40](#_ENREF_40)], wound infection (11.3%)[[35](#_ENREF_35)], pulmonary complications and DVT (2.4%-14.3%)[[39](#_ENREF_39),[41](#_ENREF_41)].

The average length of stay for MIPD varies between 8 and 18[[35](#_ENREF_35),[38-41](#_ENREF_38),[44](#_ENREF_44),[45](#_ENREF_45)]. Asbun *et al*[[35](#_ENREF_35)]found that the length of stay is significantly shorter in MIPD group compared to OPD group (8 *vs* 12.4 d), whereas Cho *et al*[[38](#_ENREF_38),[40](#_ENREF_40),[46](#_ENREF_46)] did not (16.4 *vs* 15.6 d)[[38](#_ENREF_38)]. Diet advancement usually occurs around 7 d[[38](#_ENREF_38),[40](#_ENREF_40),[46](#_ENREF_46)], which is similar to OPD in Cho *et al*[[38](#_ENREF_38),[40](#_ENREF_40),[46](#_ENREF_46)] series. In summary, there is no clear evidence that MIPD results in significant improvement in post-operative mortality, morbidity and recovery (Tables 3 and 4). Tremendous patient selection and institutional bias undoubtedly influences the published literature.

**ONCOLOGIC OUTCOMES**

The short-term oncologic outcomes of MIPD appear similar to OPD. Once again, published series have highly selected patients without major vascular involvement and relatively small tumour sizes of 2.1-3 cm[[40](#_ENREF_40),[41](#_ENREF_41),[43-45](#_ENREF_43)]. Negative margins are achieved in 100% cases in these series which is far different from the typical R0 margin rate of 70%-80% in large trials of OPD[[50](#_ENREF_50)]. We believe this is a reflection of patient selection in that patients with smaller, lower grade lesions are likely selected for MIPD. The rate of lymph node retrieval in published reports of MIPD seems adequate[[35](#_ENREF_35),[38](#_ENREF_38)].

There are few long-term oncologic outcome studies in MIPD. Palanivelu *et al*[[41](#_ENREF_41)] found that the median survival for 42 patients undergoing MIPD is 46 months; their five-year survival rates for pancreatic head adenocarcinoma is 19.1%, and for ampullary adenocarcinoma is 30.7%. The authors did comment on the biased patient selection based on non-obese patients with small, early lesions. Therefore, it is difficult to make conclusions of oncologic outcomes in the absence of randomized studies or studies with large sample size and long-term follow-up.

In conclusion, MIPD has not yet been wide adopted for lesions involving the ampulla and pancreatic head. MIPD is safe in experienced hands, but there is no clear evidence in favor of MIPD in post-operative major morbidity, mortality, recovery, and oncologic outcomes compared to OPD. TLPD and LAPD do not seem to differ in operative time, blood loss, length of stay, or rate of complications. A plausible explanation is that both TLPD and hybrid require a mini-laparotomy of similar length, so the degree of surgical trauma and the resulting post-operative morbidity should be similar as well. Given that OPD done in high-volume centres has excellent perioperative outcomes, it may be hard to justify the increased operative time and resource utilization in MIPD. However, the traditional advantages of minimally invasive procedures may also hold true, such as decreased blood loss and less post-operative pain. Future studies may consider standardizing institutional or personal experience with MIPD, include larger sample size, and include better separation of outcomes by TLPD vs. hybrid, Greater follow-up is required and a better understanding of the learning curve for this approach is needed.

**ROBOTIC PANCREATECTOMY**

Robotic surgery has recently been applied to pancreatectomy. Its main advantages are three-dimensional binocular vision and higher degree of freedom of the instruments than laparoscopy[[1](#_ENREF_1)]. The main disadvantages are increased operative time and cost. There is different extent of robotic involvement, such as totally robotic technique of resection and reconstruction, laparoscopic resection and robotic reconstruction, and various hybrid techniques. Many of the advantages of conventional laparoscopy over open surgery have been observed in the robotic experience[[51](#_ENREF_51)]. No clear benefit or advantage over laparoscopy has been established with the application of robotics[[51-54](#_ENREF_51)]. It may be reasonable to postulate that the added dexterity of the robotic system may facilitate intracorporeal reconstruction[[51-53](#_ENREF_51), [55-59](#_ENREF_55)].

The surgical technique of robotic pancreatectomy has not been standardized, and there is varying extent of the robotic involvement. Recent studies suggest that robotic pancreatectomy has longer operative time and cost, lower conversion rate, and similar post-operative recovery and length of stay as MIPD. In addition, some studies report higher re-operation rate after RPD[[53](#_ENREF_53)].

**LAPAROSCOPIC ENUCLEATION**

Laparoscopic enucleation has gained great popularity compared to open enucleation in recent years in treating benign or low-grade malignant pancreatic tumours. It is a “parenchyma-sparing procedure”, and its main advantages are preservation of normal pancreatic endocrine and exocrine function, avoidance of dissection or reconstruction of pancreatic or biliary duct, less blood loss and less demand for advanced laparoscopic skills[[60](#_ENREF_60),[61](#_ENREF_61)]. Indication for laparoscopic enucleation is for benign or low-grade malignant tumours that can be safely removed without damaging the pancreatic or biliary duct. Examples include insulinomas, nonfunctional neuroendocrine tumours, cystic tumours, cystadenomas, IPMNs, and solitary metastasis from renal cell carcinoma[[60](#_ENREF_60), [62](#_ENREF_62)].

The main drawback to this technique is the risk of pancreatic fistula formation. A recent review summarizes that the rate of pancreatic fistula ranges from 13%-38%[[62](#_ENREF_62)]. Dedieu *et al*[[60](#_ENREF_60)] noted that their incidence of pancreatic fistula after laparoscopic enucleation in 21 patients was 13%, which is lower than that reported for open enucleation (38%-42%). Their rate of International Study Group for Pancreatic Fistula (ISGPF)[[63](#_ENREF_63)] grade B or C fistula was only 4.5%, compared to 21%-23% in open series[[60](#_ENREF_60), [64](#_ENREF_64), [65](#_ENREF_65)]. The length of stay is about 6-9 d[[60](#_ENREF_60), [61](#_ENREF_61), [66](#_ENREF_66)], which is shorter than 10-14 d in series with enucleation done with open technique in > 90% of the patients[[64](#_ENREF_64),[65](#_ENREF_65)].

Currently, laparoscopic enucleation is considered safe for patients with small benign or low-grade malignant lesions of the pancreas that is amenable to parenchyma-preserving procedure. Pre-operative imaging and intra-operative ultrasound assessment are crucial in ensuring that the tumour can be enucleated with negative margins and leaving the main pancreatic duct intact. In cases of non-functional neuroendocrine tumours, it is also advised to perform lymphadenectomy as these lesions can behave aggressively[[61](#_ENREF_61)].

**CONCLUSION**

Recent studies show that LDP is safe, and may result in improved perioperative recovery, and equivalent oncologic outcomes. LDP is increasingly applied to patients with high BMI, history of previous abdominal surgery, presence of comorbidities and large tumours. LDP has become the operation of choice for most lesions involving the distal pancreas. Studies on MIPD demonstrate that it is safe in terms of intra-operative outcomes, post-operative recovery and early oncologic outcomes; however, there is likely a degree of publication bias and little is known regarding the learning curve for this approach. Further studies with larger sample size and long-term follow up are needed. It has not been widely incorporated into surgeons’ practice due to the need for advanced laparoscopic skills. Laparoscopic enucleation has become the operation of choice for small benign tumours that are away from the main pancreatic duct, especially insulinomas. Its application has been expanded to non-functional neuroendocrine and low-grade malignant tumours. As surgeons’ experience with advanced laparoscopic and robotic skills has been growing around the world, new innovations and breakthrough in minimally invasive pancreatic procedures will evolve.

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**Table 1 Summary of laparoscopic distal pancreatectomy series comparing the pre-operative variables and intra-operative outcomes laparoscopic distal pancreatectomy and open distal pancreatectomy**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Study** | **LDP/ODP** | **BMI** | **Comorbidity** | **Splenic Preservation** | **OR Time (min)** | **Blood Loss (cc)** | **Conversion** |
| Abu Hilal *et al*[[2](#_ENREF_2)] 2012  | 35/16 | N/A | N/A | 40%/19% | 200/225 | 200/3941 | 0.0% |
| Fox *et al*[[3](#_ENREF_2)] 2012  | 42/76 | 27.3/26.5 | NS | 35.7%/22.4% | 304/281 | 375/375 | 11.9% |
| Mehta *et al*[[4](#_ENREF_2)]2012 | 30/30 | N/A | N/A | 70%/30%1 | 188/226 | 294/7291 | N/A |
| Limogelli *et al*[[5](#_ENREF_2)] 2012  | 16/29 | 26.4/27.1 | N/A | 31%/14% | 204/1601 | 160/3651 | 12.0% |
| Soh *et al*[[6](#_ENREF_2)] 2012  | 10/21 | 25/21 | NS | N/A | 383/330 | 275/6001 | N/A |
| Butturini *et al*[[7](#_ENREF_2)] 2011  | 43/73 | N/A | N/A | 44.2%/11%1 | 180/180 | N/A | 0.0% |
| Cho *et al*[[8](#_ENREF_2)] 2011 | 254/439 | NS | NS | 34%/10%1 | NS | NS | 9.4% |
| Aly *et al*[[9](#_ENREF_2)]2010  | 40/35 | 21/21 | N/A | 32%/8%1 | 342/2501 | 363/6061 | 10.0% |
| Dinorcia *et al*[[10](#_ENREF_2)] 2010  | 71/192 | N/A | NS | 15.5%/15.6% | 250/2701 | 150/900 1 | 25.3% |
| Jayaraman *et al*[[11](#_ENREF_2)] 2010  | 107/236 | 27/27 | N/A | 21%/14% | 194/1631 | 150/350 1 | 30.0% |
| Kooby *et al*[[12](#_ENREF_2)] 2010  | 231/189 | 28.5/26.2 | NS | N/A | 238/230 | 422/7901 | 17.0% |
| Vijan *et al*[[13](#_ENREF_2)] 2010 | 100/100 | 27.4/27.9 | NS | 25%/NR | 214/208 | 171/5191 | 4.0% |
| Baker *et al*[[14](#_ENREF_2)] 2009  | 27/85 | N/A | NS | N/A | 236/253 | 219.4/612.61 | 3.6% |
| Finan *et al*[[15](#_ENREF_2)] 2009 | 44/104 | 28.3/26.9 | NS | 2%/NR | 156/2001 | 157/7191 | 12.0% |
| Nakamura *et al*[[16](#_ENREF_2)] 2009  | 21/16 | 23.4/21.3 | NS | 35%/31% | 308/282 | 249/7141 | 4.8% |
| Bruzoni *et al*[[17](#_ENREF_2)] 2008  | 7/4 | 29.5/29 | N/A | 100%/100% | 182/152 | 214/362 | 0.0% |
| Eom *et al*[[18](#_ENREF_2)] 2008 | 31/62 | 22.2/23 | N/A | 42%/NR | 217.7/194.8 | N/A | N/A |
| Kim *et al*[[19](#_ENREF_2)] 2008 | 93/35 | 23.4/23.9 | NS | 40.9%/5.7%1 | 195/190 | NS | N/A |
| Matsumoto *et al*[[20](#_ENREF_2)] 2008  | 14/19 | N/A | NS | N/A | 290.7/213.81 | 247.1/400.3 | 7.0% |
| Misawa *et al*[[21](#_ENREF_2)] 2007  | 8/9 | N/A | N/A | 12.5%/0% | 255/205 | 14/3071 | 0.0% |
| Tang *et al*[[22](#_ENREF_2)] 2007  | 9/5 | N/A | NS | 55.6%/0% | 180/210 | 100/4501 | 0.0% |
| Teh *et al*[[23](#_ENREF_2)] 2007  | 12/16 | 26.4/27.5 | NS | 41.7%/6.3% | 212/2781 | 193/6091 | 16.0% |
| Velanovich *et al*[[24](#_ENREF_2)] 2006  | 15/15 | N/A | N/A | 0%/0% | N/A | N/A | 20.0% |
| Fernandez-Cruz *et al*[[25](#_ENREF_2)] 2002  | 5/41 | N/A | N/A | 100%/39.9% | N/A | N/A | N/A |

1The results are shown as “LDP/ODP”; an asterisk denotes a*P* < 0.05 *vs* control. NS: Statistically non-significant between the two groups; N/A: Data not available.

**Table 2 Summary of laparoscopic distal pancreatectomy series comparing the post-operative outcomes in laparoscopic distal pancreatectomy and open distal pancreatectomy**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Study** | **Hospital stay** | **Mortality** | **Morbidity** | **Re-operation** | **Pancreatic Fistula** | **Tumour Size** | **% Malignancy** | **Margin positivity** | Lymph node Harvest |
| Abu Hilal *et al*[[2](#_ENREF_2)] 2012  | 7/111 | 0%/6% | 40%/69% | N/A | 29%/44% | 3.4/3.3 | 25%/11% | 2.9%/6.2% | N/A |
| Fox *et al*[[3](#_ENREF_2)] 2012  | 5/71 | 0 | 24.2%/19.7% | 4.76%/2.63% | 28.57%/13.16%1 | 2.9/3.5 | 4.8%/2.6% | N/A | N/A |
| Mehta *et al*[[4](#_ENREF_2)] 2012  | 8.7/12.61 | 0%/3.3% | 50%/43.5% | 3.3%/6.7% | 16.7%/13.3% | 3.8/4.3 | 23.3%/23.3% | N/A | 8.4/13.8 |
| Limogelli *et al*[[5](#_ENREF_2)] 2012  | 6.4/8.81 | 0%/2% | 25%/41% | 0%/7% | 18%/20% | 3.2/4.31 | 37%/45% | 6%/7% | N/A |
| Soh *et al*[[6](#_ENREF_2)] 2012 | 5/81 | 0 | 70%/57.1% | N/A | 30%/9.6% | 2.45/51 | 10%/66.7%1 | N/A | 2/4 \* |
| Butturini *et al*[[7](#_ENREF_2)] 2011  | 8/9 | 0 | 41.9%/30.1% | 9.3%/9.6% | 29.7%/13.7% | 3.9/4.0 | 4.7%/2.7% | N/A | N/A |
| Cho *et al*[[8](#_ENREF_2)] 2011  | NS | 0.5%/1% | 12%/15% | 1%/3% | 23%/27% | S | N/A | N/A | N/A |
| Aly *et al*[[9](#_ENREF_2)] 2010  | 22/271 | 0 | 20%/31% | N/A | 12%/17% | 3/4 | N/A | N/A | N/A |
| Dinorcia *et al*[[10](#_ENREF_2)] 2010  | 5/61 | 0%/1% | 28.2%/43.8%1 | 5.6%/3.6% | 11.3%/14.1% | 2.5/3.61 | 12.7%/38.5%1 | 2.8%/13% \* | 6/8 |
| Jayaraman *et al*[[11](#_ENREF_2)] 2010  | 5/71 | 0%/0.8% | 27%/40%1 | 2%/2% | 15%/13% | 3/3 \* | 17%/47%1 | 3%/4% | 6/7 |
| Kooby *et al*[1[2](#_ENREF_2)] 2010  | 7.4/10.71 | N/A | N/A | N/A | N/A | 3.5/4.5 | 1 | 27%/26% | 13.8/12.5 |
| Vijan *et al*[[13](#_ENREF_2)] 2010  | 6.1/8.61 | 3%/1% | 34%/29% | N/A | 17%/17% | 3.3/4 \* | 23%/23% | 0 | NS |
| Baker *et al*[[14](#_ENREF_2)] 2009  | 4.0/8.61 | 0%/2% | 37%/35% | N/A | 14.6%/14% | 3.78/4.03 | 30.1%/29.1% | N/A | 4/10 \* |
| Finan *et al*[[15](#_ENREF_2)] 2009  | 5.9/8.61 | 0%/4.8% | NS | 0 | 18%/19% | 3.26/7.73 \* | 25%/42%1 | 0 | N/A |
| Nakamura *et al*[[16](#_ENREF_2)] 2009  | 10/25.81 | N/A | N/A | N/A | 0%/12.5% | 4.8/4.1 \* | 14.3%/6.25% | N/A | N/A |
| Bruzoni *et al*[[17](#_ENREF_2)] 2008  | 6.2/9 | N/A | N/A | N/A | N/A | 2.3/3.8 | 0%/0% | 0 | N/A |
| Eom *et al*[[18](#_ENREF_2)] 2008  | 11.5/13.51 | 0 | 35.5%/24.2% | N/A | 9.7%/6.5% | 3.95/6.15 \* | 9.7%/1.6% | N/A | N/A |
| Kim *et al*[[19](#_ENREF_2)] 2008  | 10/161 | 0 | 24.7%/29% | N/A | 8.6%/14.3% | N/A | 0 | N/A | N/A |
| Matsumoto *et al*[[20](#_ENREF_2)] 2008  | 12.9/23.81 | 0 | 7.1%/21.1% | N/A | 0%/10.5% | 3.0/3.4 | 0 | N/A | N/A |
| Misawa *et al*[[21](#_ENREF_2)] 2007  | 10/161 | N/A | N/A | N/A | 0%/22% | 2.0/7.5 | 0%/0% | N/A | N/A |
| Tang *et al*[[22](#_ENREF_2)] 2007  | 7/11 | 0 | 33.3%/0% | N/A | 22.2%/0% | N/A | 0%/0% | 0%/0% | N/A |
| Teh *et al*[[23](#_ENREF_2)] 2007  | 6.2/10.61 | 0 | 1.7%/5.6% | 0 | 8.3%/6.2% | 3.4/3.4 | 0%/0% | N/A | N/A |
| Velanovich *et al*[[24](#_ENREF_2)] 2006  | 5/81 | N/A | 20%/27% | N/A | 13%/13% | N/A | 20%/32% | N/A | N/A |
| Fernandez-Cruz *et al*[[25](#_ENREF_2)] 2002  | 6/12 | N/A | 20%/48% | 20%/0% | N/A | N/A | N/A | N/A | N/A |

1The results are shown as “LDP/ODP”; an asterisk denotes a*P* < 0.05 *vs* control. NS: Statistically non-significant between the two groups; N/A: Data not available.

**Table 3 Summary of minimally invasive pancreaticoduodenectomy series comparing the pre-operative variables and intra-operative outcomes minimally invasive pancreaticoduodenectomy and open pancreaticoduodenectomy**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Study** | **TLPD** | **LAPD** | **HAPD** | **OPD** | **BMI** | **Comorbidity** | **Indication** | **Pylorus preservation** | **OR Time (min)** | **Blood Loss (cc)** | **Conversion** |
| Asbun *et al*[[35](#_ENREF_35)] | 53 | N/A | N/A | 215 | 26.6/27.6 | NS | N/A | 73.6%/45.6%1 | 541/4011 | 195/10321 | 15% |
| Kuroki *et al*[[36](#_ENREF_35)] 2012  | N/A | 20 | N/A | 31 | 21.9/22.9 | NS | N/A | 80%/83.9% | 656.6/554.6 | 376.6/1509.5 1 | 0 |
| Zureikat *et al*[[37](#_ENREF_35)] 2011  | 14 | N/A | N/A | 14 | 28.5/30 | NS | N/A | 0/0 | 456/3721 | 300/400 | 14% |
| Cho *et al*[[38](#_ENREF_35)] 2009  | N/A | 15 | N/A | 15 | 23/25 | NS | N/A | 100%/100% | 338/287 | 445/532 | 0 |

1The results are shown as “MIPD/OPD”; an asterisk denotes a*P* < 0.05 *vs* control. TLPD: Total laparoscopic pancreaticoduodenectomy; LAPD: Laparoscopically assisted pancreaticoduodenectomy; HAPD: Hand-assisted pancreaticoduodenectomy; NS: Statistically non-significant between the two groups; N/A: Data not available.

**Table 4 Summary of minimally invasive pancreaticoduodenectomy series comparing the post-operative outcomes in minimally invasive pancreaticoduodenectomy and open pancreaticoduodenectomy**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Study** | **Hospital Stay** | **Mortality** | **Overall morbidity** | **Re-operation** | **Pancreatic Fistula** | **Tumour Size** | **PDAC** | **Margin positivity** | **Lymph node Harvest** |
| Asbun *et al*[[35](#_ENREF_35)] 2012  | 8/12.4 \* | 5.7%/8.8% | N/A | 3.8%/7% | 16.7%/17.3% | 2.74/3.14 | 41.5%/46.5% | 5.1%/17% | 23.44/16.841 |
| Kuroki *et al*[[36](#_ENREF_35)] 2012  | N/A | N/A | N/A | N/A | 45%/22.6% | N/A | 0/12.9% | N/A | N/A |
| Zureikat *et al*[[37](#_ENREF_35)] 2011  | 8/8.5 | 7%/0% | 20%/7.1% | 7%/7% | 36%/42.8% | 2.2/3.61 | 57%/57% | 0/8.3% | 18.5/19 |
| Cho *et al*[[38](#_ENREF_35)] 2009  | 16.4/15.6 | 0 | 27%/27% | N/A | 13%/13% | N/A | 40%/100% | 0 | 18.5/20 |

1The results are shown as “MIPD/OPD”; an asterisk denotes a*P* < 0.05 *vs* control. TLPD: Total laparoscopic pancreaticoduodenectomy. LAPD: Laparoscopically assisted pancreaticoduodenectomy; HAPD: Hand-assisted pancreaticoduodenectomy; NS: Statistically non-significant between the two groups; N/A: Data not available.