Chapter

Laparoscopic Pancreatoduodenectomy

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Abstract

In recent years, total laparoscopic pancreaticoduodenectomy (TLPD) has been introduced as a feasible alternative to open pancreaticoduodenectomy (OPD) when performed by experienced surgeons in laparoscopic and pancreatic surgery. Its application has been gradually increased, but its safety, reproducibility, and oncological outcomes are still debated due to its technical complexity and prolonged operating time. We performed a systematic analysis of the more relevant aspects of TLPD. In this chapter, we report a general overview of the different experiences present in the literature regarding indications, surgical techniques, postoperative outcomes, benefits and limitations of this approach, oncological results, learning curve, and costs. There is no standardized surgical technique for TLPD. Different techniques exist for both the demolitive stage and the reconstructive stage. We summarized the different aspects of the surgical technique based on the various experiences reported by different authors. Compared to OPD, TLPD provides the advantages of laparoscopy, i.e., reduced blood loss, decreased postoperative pain, and shorter length of hospital stay, without increasing the rate of postoperative complications or compromising oncological outcomes. An appropriate patient selection is crucial at the beginning of the learning curve. With increased experience, more challenging cases may also be approached with this technique, including those requiring major vascular resections or multi-visceral resections.

Keywords: mini-invasive pancreaticoduodenectomy, laparoscopic pancreaticoduodenectomy, advanced laparoscopic surgery, pancreatic surgery

1. Introduction

Minimally invasive techniques in pancreatic surgery were initially used only for diagnostic and stadiative purposes, palliative procedures, or the drainage of cysts and the enucleation of small solid lesions [1, 2]. In the last 10 years, with advances in technology and surgical techniques, there has been a growing application of minimally invasive surgery for the treatment of benign and malignant pancreatic neoplasms [3], and complex operations such as distal pancreatectomy (DP) and pancreaticoduodenectomy (PD) have started to be performed [2]. Laparoscopic distal pancreatectomy (LDP) does not require the execution of anastomosis, resulting in quite easy performance and achieving worldwide acceptance. On the other hand, the laparoscopic pancreaticoduodenectomy (LPD) has obtained a marginal acceptance until now, raising doubts about its safety and reproducibility, due to its technical complexity and prolonged operating time [3].

Although the first LPD was performed by Gagner and Pomp more than 20 years ago for the treatment of a chronic pancreatitis involving the pancreatic head [4], the procedure had a slow diffusion [5], especially in comparison to the other applications of minimally invasive surgery in the field of oncological treatment [3].

This slow diffusion can be explained by three main reasons.

The first one is the technical complexity of LPD, especially due to the retroperitoneal position of the pancreas and the proximity to the duodenum and surrounding vascular structures; the fashioning of the laparoscopic anastomoses; and the laparoscopic dissection of the uncinate process from the large vessels [6–8].

The second one is the high complication rate of PD, heavily affecting postoperative recovery; this represents a limit to the potential advantages of mini-invasiveness [9].

Finally, there is a lack of international consensus about the benefits regarding the feasibility and oncological efficacy of LPD [10].

However, in the last decade, the growing number of publications about laparoscopic pancreatic surgery seems to assess its feasibility and safety [3], especially if performed in highly experienced centers [11].

2. Indications

In all the cases where PD is indicated, laparoscopic approach can be theoretically applied:

- pancreatic adenocarcinoma
- symptomatic chronic pancreatitis
- neuroendocrine pancreatic tumors: functioning tumors, tumors with resectable metastases, tumors with diameters >2 cm, symptomatic nonfunctioning tumors, G3 with Ki67 > 20%, and neuroendocrine carcinoma
- cystic pancreatic tumors
- IPMN with high-risk stigmata (dilation of the Wirsung ≥10 mm, contrast-enhancing solid intracystic component ≥5 mm, causing obstructive jaundice, with positive cytology)
- malignant tumors of the distal common bile duct
- malignant tumors of the ampulla of Vater
- malignant tumors of the duodenum

Since the learning curve for LPD is long, patients should be adequately selected. As reported in the literature [12], it is preferable to start with patients with low BMI and small ampullary tumors, duodenal adenocarcinomas, or tumors of the distal biliary tract and avoid ductal pancreatic adenocarcinomas because of their infiltrative nature.

Accurate selection of patients is essential to decrease the rate of conversion and avoid unnecessary laparoscopic attempts, which would only increase the operative time and the risk of intraoperative complications.

Suggested contraindications to LPD are significant comorbidities [1, 2, 13–15], previous upper-mesocolic abdominal surgeries [1, 14, 16, 17], and high BMI [17, 18].

On the contrary, age does not seem to be a contraindication. A study by Buchs et al. [13] compared LPD in patients younger and older than 70 years: post-operative outcomes in the two groups were similar, showing that age alone may not be a selection criterion for LPD.

Current studies about LPD are subject to high selection bias, since most centers are still in the learning curve and selecting only ideal candidates for the procedures.

A recent review by Wang et al. [19] analyzed studies that evaluated inclusion and exclusion criteria for mini-invasive PD, reporting 14 studies that only mentioned inclusion criteria, 20 that only mentioned exclusion ones, and 13 that reported both. This review showed that patients selected for LPD had small periampullary tumors and low BMI. The most frequent contraindications were vascular invasion, previous upper-mesocolic procedures, and severe cardiovascular disease.

Indications and contraindications to LPD also depend on the experience of the surgical team [12]; with increased experience, it may also be performed for the treatment of tumors involving surrounding organs or vascular structures, and almost all contraindications to LPD may become relative. In this scenario, some pioneering groups have also started performing venous resections during LPDs [7, 8].

However, the majority of authors consider as exclusion criteria: large tumors [1, 16], chronic pancreatitis, tumors involving the superior mesenteric-portal vein confluence, the superior mesenteric artery or the hepatic artery [12, 13], and neoadjuvant radio-chemotherapy [20, 21], due to the local fibrosis caused by radiotherapy.

Many algorithms have been developed to help with LPD patient selection [22, 23].

3. Surgical technique

Currently, there is no consensus on the best surgical option for LPD, neither for the demolitive phase nor for the reconstructive one.

Differences in the surgical technique concern as follows:

- Preparatory phase: trocar placement, type of trocar used, access technique to peritoneum.
- Demolitive phase: surgical steps, devices and materials, pylorus preservation or not.
- Reconstructive phase: type of suture, anastomosis technique, surgical specimen extraction, drainages, stent placement in pancreatic duct to protect the pancreatico-jejunal anastomosis.

3.1 Preparatory phase

The number, type, and placement of trocars for LPD vary greatly throughout the literature. Most authors use 5 trocars (52.1%) [1, 24, 25]; some use 6 (30.4%) [26, 27]; more rarely, 4 [28, 29] or 7 [16] are used.

Pneumoperitoneum is usually induced using the "open" technique according to Hasson in periumbilical or supra-umbilical position [20, 24, 26, 28, 30], while rarely the "closed" technique with the Veress needle is used [1, 16, 27, 29].

Trocar placement varies between series, especially concerning the optic port and the port for the hepatic retractor. The optic port is more commonly placed in the umbilical region (41.7%). The port for the hepatic retractor is, in many cases, placed along the midline in the subxiphoid region, while in some cases, it is placed along the right anterior axillary line, just under the hepatic ridge.

3.2 Demolitive phase

Boggi et al. [31] published a systematic review that analyzed various aspects of the demolitive phase. Their results are summarized in this section.

Concerning materials, the majority of authors used energy devices (678 patients, 90.8% of cases). Some authors used a single energy device (in 10 cases ultrasonic shears, in 4 cases radiofrequency), while 8 used a dual energy device (6 ultrasound and radiofrequency, 1 ultrasound and bipolar, 1 ultrasound and monopolar).

The section of the pancreatic neck can be done using the ultrasonic shears, the electrocautery (104 patients, 15.9%), the stapler or ultrasonic shears (100 patients, 15.3%), electrocautery or ultrasonic shears (65 patients, 9.9%), only stapler (12 patients 1.8%), or only radiofrequency (6 patients, 0.9%) (**Figures 1**–**3**).

The method used to section the gastroduodenal artery is another relevant technical aspect, since the arterial stump is a frequent site of bleeding in case of pancreatic fistula.

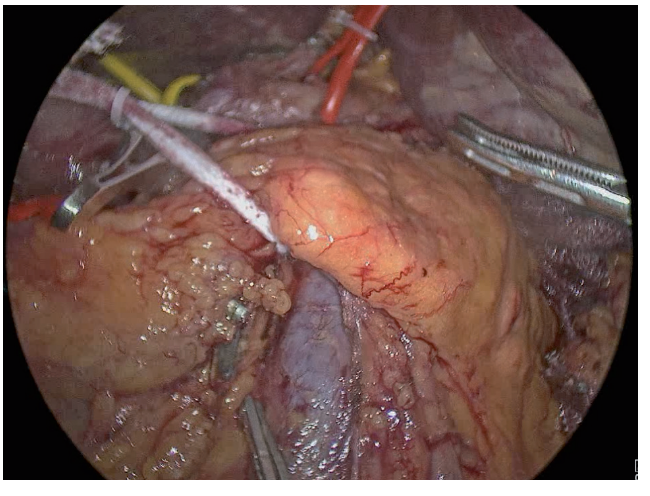

Figure 1.
Retropancreatic tunnel.

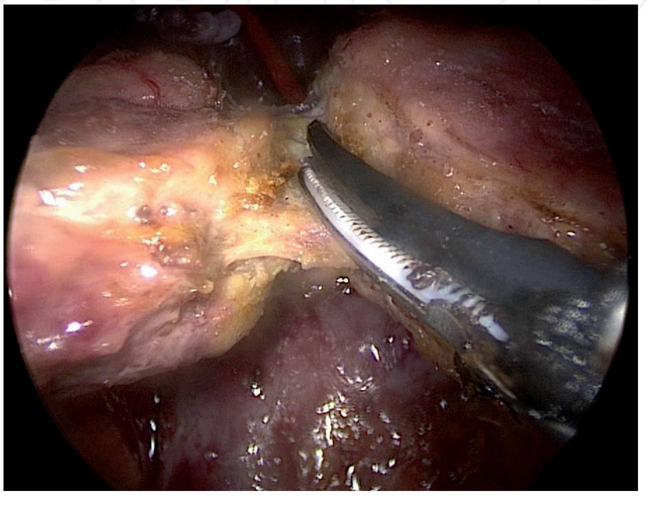

Figure 2.
Pancreatic neck section using ultrasonic shears.

In the majority of cases (274 patients, 54.5%), the use of clips was reported, while some authors (100 patients, 19.9%) reported only ligature. Other options are vascular stapler plus suture (1 article, 50 patients, 9.9%), clips plus suture (1 article, 35 patients, 6.9%), vascular stapler only (1 article, 24 patients, 2.7%), and radiofrequency only (1 article, 11 patients, 2.1%) (**Figures 4** and **5**).

The specimen is often extracted via an umbilical (42.2%), supra-pubic (15.7%), or subxiphoid (15%) mini-laparotomy; other sites for extraction are sub-umbilical (8.9%), the right inferior quadrant (8.8%), or supraumbilical (4.9%) one.

Finally, the surgeon must decide whether to preserve the pylorus (Traverso-Longmire intervention) or resect the gastric antrum (classic Whipple procedure).

Pylorus-preserving surgery is more commonly performed (55%) than gastric antrum resection among 21 authors (636 patients), 6 always preserve the pylorus (262 patients, 41.1%), 8 always section the gastric antrum (13 patients, 17.7%), while 7 used both techniques (261 patients, 41%).

Pylorus preservation in oncological cases is a controversial topic; it was compared with the Whipple technique without significant differences between the two techniques in terms of overall survival ($p = 0.11$), in-hospital mortality ($p = 0.18$) and morbidity ($p = 0.69$), incidence of postoperative pancreatic fistula (POPF; $p = 0.63$), biliary leakage (BL; $p = 0.82$), post-pancreatectomy hemorrage (PPH; $p = 0.53$), or delayed gastric emptying (DGE; $p = 0.16$) [32]. Pylorus-preservation

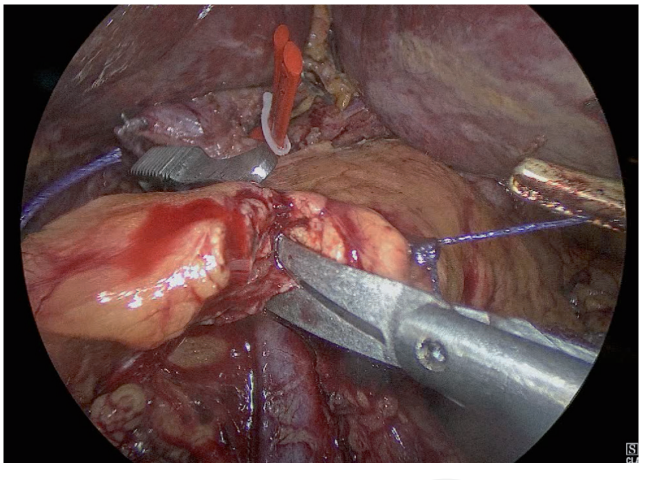

Figure 3.
Pancreatic neck section using ultrasonic scissors.

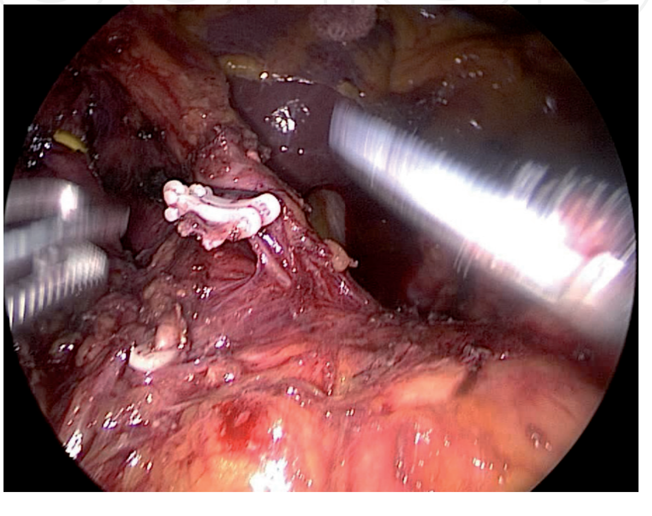

Figure 4.
Gastroduodenal artery closure using clips.

was associated with a shorter operative time (p = 0.0004) and a reduced intraoperative blood loss (p = 0.00001).

There is a lack of data about laparoscopic "artery first approach" to PD and total mesopancreas excision (TMpE), because no details about this important topics were reported in the literature.

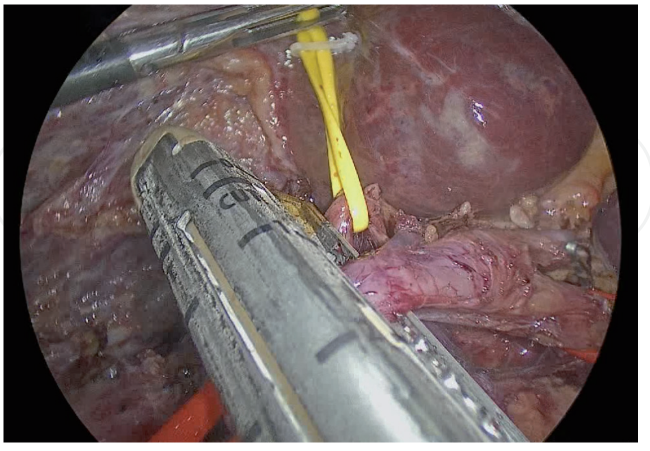

Figure 5.
Gastroduodenal artery closure using vascular stapler.

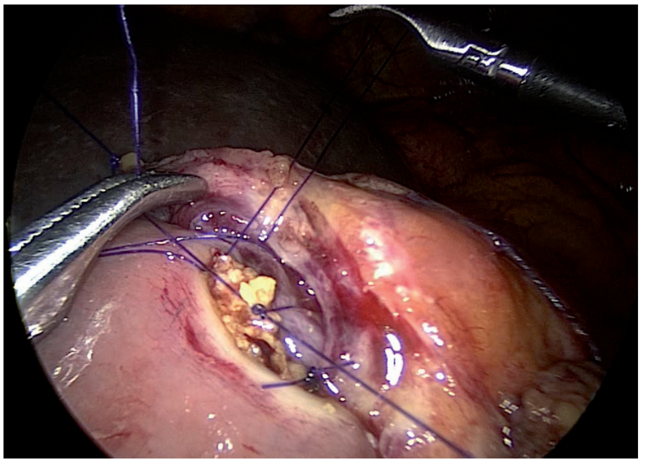

Figure 6.
Duct-to-mucosa anastomosis.

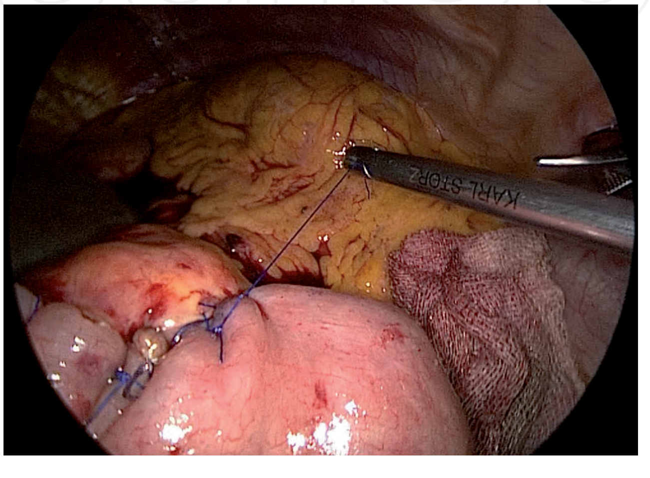

Figure 7.
Pancreato-jejunal anastomosis.

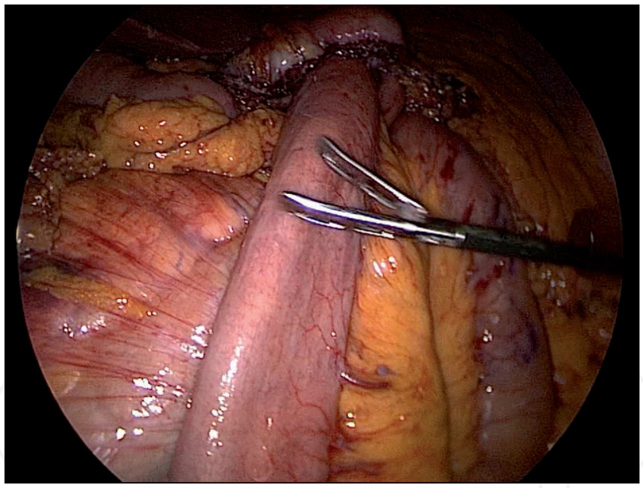

Figure 8.
Antecolic gastro-jejunal anastomosis.

3.3 Reconstructive phase

Great variability in the reconstructive phase is reported in the literature, both in materials (type of suture) and in fashioning anastomoses.

The management of the pancreatic stump represents one of the most important steps of the entire procedure [33, 34], especially when dealing with a soft gland, as it is one of the main risk factors for the development of a POPF [35, 36].

Pancreaticojejunostomy (PJ; 84% of cases; **Figures 6** and 7) and pancreaticogastrostomy (PG; 9.8% of cases) are the most commonly performed anastomoses; on the other hand, the duct occlusion has mostly been abandoned (6.8% of cases) [31].

In order to reduce the risk of POPF, the majority of the authors (72.8%) positioned a stent in the Wirsung, either routinely or selectively; the pancreatic anastomosis was in most cases performed with a double layer (90.6%) and interrupted sutures (74.6%).

The gastro/duodenal-jejunal (GJ/DJ) anastomosis was antecolic in 76.3% of cases (**Figure 8**), retromesenteric in 13.4% of cases, and retrocolic in 10.2% of cases.

The majority of GJ and DJ anastomoses were handsewn (n = 491/566; 86.7%); mechanical anastomoses using stapler were performed in only 13.2% of cases and always to perform GJ anastomosis.

In a randomized multicentric study on 440 patients, Keck et al. [37] compared the outcomes of PG vs. PJ: although POPF rate was 20%, without significant differences between the two techniques, the rate of anastomotic bleeding was higher for PG.

Surprisingly in a meta-analysis [38] based on 676 patients underwent to PD, a significantly lower rate of POPF was found in favor of PG, while there were no differences in the incidence of BL, PPH, or DGE between the two anastomoses.

4. Postoperative outcomes

4.1 Short-term outcomes

Despite the technical and technological progress made in recent years, postoperative morbidity for PD remains high (30–50%) [39].

The most frequent postoperative complications for PD are DGE (19–23% of cases), POPF (9–18%), intra-abdominal abscess (9–10%), and intra-abdominal or GI bleeding (1–8%) [40].

Many authors questioned the possibility to improve postoperative outcomes through the use of mini-invasiveness.

Compared to open PD, LPD has been found to require longer operative time [30, 41–43] (**Tables 1** and **2**); however, it leads to

- reduce intraoperative blood loss and the need for transfusions [6, 26, 30, 41, 43–45]
- reduce postoperative pain [30]
- reduce intensive care unit (ICU) monitoring [42].
- reduce length of hospitals stay (LOS) [6, 30, 41–43, 45, 46] with differences varying between 2 and 5 days.
- reduce number of unscheduled readmissions [46].
- Thirty-day mortality and morbidity, including POPF, DGE, PPH, BL, and surgical site infection (SSI), are comparable between laparoscopic and open PD [30, 42–47].

4.2 Oncological outcomes

Regarding oncological radicality, laparoscopic PD appears to be at least noninferior to open PD.

Considering tumors of similar size and histological type, the number of harvested lymph nodes and the rate of negative resection margins have been found to be either comparable [20, 30, 45, 46, 48] between laparoscopic and open PD or superior in laparoscopic PD [6, 26, 41–43].

Author	Year	No of patients		Operative time (min)		Intraop blood loss (ml)		Postop LOS (days)		30-days mortality	
		VL	Op	VL	Op	VL	Op	VL	Op	VL	Op
Stauffer	2016	58	193	375	518	250	600	6	9	—	—
Sharpe	2015	384	4037	nr	nr	nr	nr	10	12	5.2	3.7
Song	2015	104	576	482	348	570	609	14	19	—	—
Speicher	2014	25	84	381	326	200	425	8	10	—	1.2
Dokmak	2014	46	46	342	264	368	293	23	25	2	—
Croome	2014	108	214	379	387	492	866	6	9	1	2
Mesleh	2013	75	nr	551	nr	nr	nr	7	nr	—	nr
Asbun	2012	53	215	541	401	195	1032	8	12	5.7	8.8

Abbreviations: N, number; min, minutes; Intraop, intraoperative; Postop, postoperative; VL, laparoscopic; Op, open.

Table 1.
Postoperative outcomes: comparison between laparoscopic and open PD.

Author	Year	Compl rate (CD > 3)		POPF rate		PPH rate		Median *n* of LNs harvested		R0 rate		Reop rate	
		VL	Op	VL	Op	VL	Op	VL	Op	VL	Op	VL	Op
Stauffer	2016	22	30	8	9	7	4	27	17	80	84	2	6
Sharpe	2015	nr	nr	nr	nr	nr	nr	16	18	80	74	nr	nr
Song	2015	7.5	5.4	6.5	6.5	nr	nr	15	16	72	81	nr	nr
Speicher	2014	nr	nr	16	22.6	nr	nr	14.5	12	83.3	78.6	8.7	10.7
Dokmak	2014	28	20	44	32	24	7	20	23	60	50	24	11
Croome	2014	6	14	11	12	7	6	21.4	20.1	77.8	76.6	nr	nr
Mesleh	2013	31	31	9	6	nr	nr	nr	nr	nr	nr	2	4
Asbun	2012	24.5	24.7	7.1	5.1	9.4	5.6	23.4	16.8	95	83	3.8	7

Abbreviations: Compl, complication; CD, Clavien-Dindo; POPF, postoperative pancreatic fistula; PPH, postpancreatectomy hemorrage; LNs, lymph nodes; Reop, reoperation; VL, laparoscopic; Op, open.

Table 2.
Postoperative outcomes: comparison between laparoscopic and open PD.

Overall survival between laparoscopic and open PD is comparable [6, 30, 45]. However, the reduction in postoperative pain and physical impairment, paired with the reduced rate of surgical site complications, may allow for a broader access to adjuvant chemotherapy and an earlier start of treatment in patients who underwent laparoscopic PD [11, 49].

Current studies comparing laparoscopic PD vs. open PD have been criticized because they may suffer from selection bias, as many of them excluded patients with vascular involvement, high intraoperative risk, and multiple previous abdominal operations, all of which have higher chances of undergoing an open procedure.

However, the results from Croome et al. [6] and the review from Wang et al. [43] showed promising results also in complex cases, which required vascular resections.

5. Learning curve

The learning curve for LPD is particularly steep and represents an obstacle to a more widespread use of the procedure; it seems that learning curve can be shortened with specific training strategies, e.g., ex vivo training, proctoring, and simulation in loco.

The majority of studies about surgical learning curves define it as the number of procedures needed to achieve a decrease in operative time and blood loss and in the number of conversions.

With increased experience in those kinds of procedures, the surgeon is also able to deal laparoscopically with more technical complex situations, such as vascular resections (portal, mesenteric, and arterial), without increasing postoperative complications.

As shown in the review published by De Rooij et al. [12], there are three strategies to learn how to carry out PD completely laparoscopically (i.e., not only the demolitive phase, which is more commonly performed laparoscopically, but also the reconstructive one, which represents a considerable obstacle for some).

The first strategy consists of tutoring. The second one is a hybrid approach, i.e., performing the demolitive phase through laparoscopy and the reconstructive phase through a service minilaparotomy. The third one is also a hybrid approach, but the reconstructive phase is carried out robotically.

Each strategy has its own learning curve and needs to be performed only in specialized centers with high volumes of pancreatic surgeries to avoid unnecessarily high rates of morbidity and mortality. Recent studies suggest that using hybrid techniques before performing the procedure completely laparoscopically might be useful. A cut off of 10 hybrid procedures is considered enough to start with full laparoscopy, although 50 hybrid procedures are required for significant improvements in operative outcomes to appear/significant improvements in operative outcomes appear after 50 hybrid procedures.

A study by Speicher et al. [41] shows that laparoscopic PD's learning curve goes through a slow and difficult initial phase (first 10 cases), a much faster improvement phase (10–20 cases), and finally a plateau with a slow but steady improvement with time (after 50 cases).

However, these considerations can only be applied to surgeons with great expertise in open PD and in advanced laparoscopic surgery; it is often difficult to satisfy both conditions, as many centers with high volumes of pancreatic surgeons do not have high volumes of laparoscopic surgery and vice versa.

Many years are required to overcome the learning curve and reach an adequate outcome level [50]. Pancreatic surgery should be centralized in dedicated centers, as this has been shown in many studies to improve outcomes [51, 52].

A review by Gumbs et al. [53] that analyzed 285 LPDs shows that the length of hospital stay and the operative time for the procedure decrease proportionally to the higher volume of cases of the center.

Different studies show that, as one moves along the learning curve, there is a decrease in operative time, blood loss, morbidity, and open conversions, resulting in a reduced length of hospital stay.

Kim et al. [24] analyzed 100 consecutive cases of pylorus-preserving LPD, of which all performed by the same surgeon and divided them in three time periods. With increased experience, operative time decreased from 9.8 hours in the first-time period to 6.6 in the third. Length of hospital stay went from 20.4 to 11.5 days. Morbidity, including pancreatic fistula, intraoperative bleeding, delayed gastric emptying, and ileus, decreased from 33.3 to 17.6%.

Similar results, demonstrating an improvement in the surgical outomes increasing the learning curve, also reported by Speicher et al. [41], with diminished operative time and blood loss with increased experience, and Song et al. [30].

Song et al. divided LPD's cases into two cohorts (the first 47 consecutive cases vs. the next 50 cases). The second cohort had decreased operative time (399.4 vs. 566.5 minutes, $p < 0.0001$), decreased intraoperative blood loss (503 vs. 685 cc, $p = 0.018$), and decreased length of hospitals stay (11.2 days vs. 17.3, $p < 0.001$).

Another cohort study shows that rates of postoperative pancreatic fistulas diminished from 36 to 18% after only 11 LPDs [1]. Other study also confirmed that morbidity is inversely proportional to the number of procedures performed in a single center [9, 20, 30].

Mortality also decreased with an increase in experience [54]; analyzing a national database with over 7000 patients who underwent PD from 2010 to 2011, higher 30-day mortality with LPD than with open PD was found. However, this result only applied to those centers with less than 10 LPDs in 2 years, where 30-day mortality was twice that of open PD. In centers with more than 10 LPDs, 30-day mortality was similar in laparoscopic and open procedures.

The dramatic improvement shown by these authors as they progress along the learning curve is encouraging and may bring much more surgeons to perform PD laparoscopically.

6. Costs

Most of the financial benefit of laparoscopic vs. open PD is attributed to the reduced length of hospital stay [15, 17, 20, 30]. However, laparoscopy significantly increases operative time (usually by 2 hours) [30] and requires expensive materials with an increase in cost of 35%, $p < 0.0001$, both of which lead to increased costs [30].

Speicher et al. and Mesleh et al. compared open vs. laparoscopic PD costs [41, 44]. They concluded that total costs were comparable. According to Speicher et al. [41], laparoscopic PD costs 24,590 dollars vs. 19,720 dollars in open technique ($p = 0.19$).

According to Mesleh et al. [44], laparoscopic PD is significantly more expensive ($p < 0.0001$) than open PD, due to the cost of the surgical material and the increased operative time (551 vs. 355 minutes).

Morbidity and postoperative length of hospital stay were comparable and did not influence the overall cost. However, the post-operative management for open PD is slightly more expensive than laparoscopic PD when single categories are taken into account (expenses for nursing, anaesthesia, drugs, labs, and imaging).

As recovery expenses represent 65–70% of the overall cost, the decreased postoperative cost of laparoscopic PD balances out its increased intra-operative cost when compared to open PD.

7. Conclusions

LPD is a safe, standardizable, and oncologically adequate surgical technique, but only if performed by surgeons with extensive experience both in pancreatic surgery and in laparoscopy and, at least at the beginning of the learning curve, on appropriately selected cases.

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