

Pancreatic cancer: Open or minimally invasive surgery?

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Abstract

Pancreatic duct adenocarcinoma is one of the most fatal malignancies, with R0 resection remaining the most important part of treatment of this malignancy. However, pancreatectomy is believed to be one of the most challenging procedures and R0 resection remains the only chance for patients with pancreatic cancer to have a good prognosis. Some surgeons have tried minimally invasive pancreatic surgery, but the short- and long-term outcomes of pancreatic malignancy remain controversial between open and minimally invasive procedures. We collected comparative data about minimally invasive and open pancreatic surgery. The available evidence suggests that minimally invasive pancreaticoduodenectomy (MIPD) is as safe and feasible as open PD (OPD), and shows some benefit, such as less intraoperative blood loss and shorter postoperative hospital stay. Despite the limited evidence for MIPD in pancreatic cancer, most of the available data show that the short-term oncological adequacy is similar between MIPD and OPD. Some surgical techniques, including superior mesenteric artery-first approach and laparoscopic pancreatoduodenectomy with major vein resection, are believed to improve the rate of R0 resection. Laparoscopic distal pancreatectomy is less technically demanding and is accepted in more pancreatic centers. It is technically safe and feasible and has similar short-term oncological prognosis compared with open distal pancreatectomy.

Key words: Laparoscopic; Minimally invasive; Robotic; Pancreaticoduodenectomy; Distal pancreatectomy; Pancreatic cancer

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Core tip: Minimally invasive pancreaticoduodenectomy is as safe and feasible as open pancreaticoduodenectomy (OPD) and shows some superiority. The

short-term oncological results are similar between laparoscopic pancreaticoduodenectomy (LPD) and OPD. However, in some experienced hands, better prognosis is detected in the LPD group because the patients can receive adjuvant therapy faster because of the benefits of minimal invasiveness. Minimally invasive distal pancreatectomy is a well-established procedure and widely accepted. It is safe, feasible, and has similar short-term oncological results compared with open distal pancreatectomy.

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INTRODUCTION

Pancreatic cancer ranks as the 4th highest cause of cancer-related death in the United States and the 5-year survival is about 6%^[1]. Surgical R0 resection is the best chance for a cure and remains the cornerstone of treatment of pancreatic malignancy^[2,3]. However, pancreatic surgery is believed to be one of the most challenging procedures because of the high risks of postoperative morbidity and mortality associated with intraoperative bleeding and postoperative complications including pancreatic fistula^[2,4,5]. Another key point for surgical treatment of pancreatic malignancy is oncological adequacy. R0 resection is the best chance for patients to have a good prognosis^[3,6].

Minimally invasive techniques, including laparoscopic and robotic approaches, have rapidly evolved and include a variety of abdominal surgical procedures^[7-10]. They provide the patients with better short-term outcomes, including smaller incisions, shorter hospital stay and less blood loss. Some surgeons in large-volume pancreatic centers have tried minimally invasive pancreatic surgery^[11-16]. However, the short- and long-term outcomes of pancreatic malignancy remain controversial, especially for oncological prognosis.

Many pancreatic surgeons doubt the safety and oncological adequacy of minimally invasive pancreatic surgery. Here, we collected and analyzed the published data about minimally invasive pancreatic surgery.

LAPAROSCOPIC PANCREATICODUODENECTOMY

Background of laparoscopic pancreaticoduodenectomy

Following the first report of laparoscopic pancreaticoduodenectomy (LPD) in 1994^[17], Gagner and Pomp^[18] subsequently published a series of 10 patients in 1997. In Gagner's series, the conversion rate was 40% and the operating time was 8.5 h. Dependent upon these

results, the authors concluded that the minimally invasive approach was not advocated because there was no apparent advantage over traditional open approaches. After that, surgeons spent a decade improving their laparoscopic skills, until a large LPD cohort was reported in France in 2005^[12] and then in India in 2009^[15]. During 1994-2009, several surgeons tried to apply hybrid, laparoscopic-open approaches to avoid the complexity of a purely laparoscopic procedure^[13,19]. Although these approaches may overcome some of the limitations, they may reduce the potential benefits of purely laparoscopic approaches, including less pain, improved postoperative recovery and shorter hospital stay. After Palanivelu *et al.*^[15] reported 75 cases of LPD in 2009, large cohorts of LPD have been reported in the United States^[11,20,21], South Korea^[16], China^[22], Italy^[23] and France^[24]. LPD eventually gained momentum, following its 30 years' development, and it has emerged as a well-established procedure with acceptable morbidity and mortality rates in some specialized high-volume pancreatic centers^[12,15,16,20,22,23]. Although LPD has been accepted in many specialized minimally invasive pancreatic centers, the short- and long-term results remain controversial. We collected clinical reports with comparative data between minimally invasive PD (MIPD) and open PD (OPD) (Table 1).

Safety and feasibility of LPD

PD is a complex procedure because of the dissection around important vessels and three complex reconstructions. Moreover, it is a procedure with high morbidity^[25]. Although LPD has been accepted in some specialized centers, it is still a challenging operation for most pancreatic surgeons; still, there has been a rapid increase in the number of LPDs performed in different centers. Some large-volume centers have published their comparative studies between LPD and OPD^[11,15,16,20,21,24,26-31], demonstrating the safety of LPD; although, long-term oncological benefits of this approach remain debatable.

Croome *et al.*^[20] reviewed their data for patients with pancreatic ductal adenocarcinoma (PDAC) undergoing LPD ($n = 108$) and OPD ($n = 214$). A significantly reduced blood loss and blood transfusion requirement and a shorter postoperative stay (6 d vs 9 d) were observed in the LPD group compared with the OPD group.

A case match study was performed by Dokmak *et al.*^[24] comparing 46 LPD and OPD procedures. Patients were matched for demographic data, associated comorbidity and underlying disease. The results suggested that a high rate of severe morbidity due to severe pancreatic fistula was detected in patients with a high risk of pancreatic fistula. In a subgroup of patients with a low risk of pancreatic fistula, the outcome of the two approaches was similar. The result of this study suggested that, in a subgroup of patients with a high risk of pancreatic fistula, LPD was associated with high

Table 1 Safety and feasibility of laparoscopic pancreaticoduodenectomy: Clinical cohorts of minimally invasive pancreaticoduodenectomy and open pancreaticoduodenectomy including comparative results

Ref.	Year	Country	Technique	Cases	Operating time, min	EBL, mL	LHS, D	CD ≥ III	PF	DGE	Readmission rate	Mortality
Sharp <i>et al</i> ^[21]	2015	United States	LPD	384	NR	NR	NR	NR	NR	NR	5.0%	5.2% (30 D)
			OPD	4037	NR	NR	NR	NR	NR	NR	9.0%	3.7% (30 D)
Song <i>et al</i> ^[6]	2015	South Korea	LPPPD	93	482.5 ± 117.6	609 ± 375	14.3 ± 7.8	7.5%	6 (6.5)	3.2%	5 (5.4)	NR
			OPPPD	93	347.9 ± 87.2	570 ± 448	19.2 ± 8.8	5.4%	6 (6.5)	7.5%	3 (3.2)	NR
Chen <i>et al</i> ^[24]	2015	China	RPD	60	410 ± 103	400 (200-600)	20 ± 7.4	11.7%	13.3%	8.3%	NR	1.7%
			OPD	120	323 ± 80	500 (350-800)	25 ± 11.2	13.3%	24.9%	15.0%	NR	2.5%
Dokma <i>et al</i> ^[24]	2015	France	LPD	46	342 (240-540)	368 (50-1200)	25 (6-104)	28.0%	48.0%	17.0%	9.0%	2.0%
			OPD	46	264 (120-400)	293 (50-1200)	23 (7-115)	20.0%	41.0%	15.0%	9.0%	0
Baker <i>et al</i> ^[31]	2015	United States	RPD	22	454 (294-529)	425 (50-2200)	7 (4-25)	13.6%	4.6%	13.6%	22.7%	0
			OPD	49	364 (213-948)	650 (150-6100)	9 (5-48)	20.4%	12.2%	30.6%	29.8%	4.1%
Tran <i>et al</i> ^[24]	2015	United States	LPD	681	NR	NR	12 (9-20)	NR	NR	NR	NR	3.8%
			OPD	14893	NR	NR	11 (8-16)	NR	NR	NR	NR	5.0%
Tan <i>et al</i> ^[25]	2015	China	LPD	30	513.17 ± 56.13	NR	9.97 ± 3.74	NR	10/30	2/30	NR	0
			OPD	30	371.67 ± 85.53	NR	11.87 ± 4.72	NR	6/30	3/30	NR	1/30
Adam <i>et al</i> ^[32]	2015	United States	MIPD	983	NR	NR	NR	NR	NR	NR	4.8%	NR
			OPD	6078	NR	NR	NR	NR	NR	NR	3.7%	NR
Chalikonda <i>et al</i> ^[33]	2014	United States	HPD	30	476.00	485	9.79	30.0%	NR	NR	NR	4.0%
			OPD	30	366.48	775	13.26	43.0%	NR	NR	NR	0
Bao <i>et al</i> ^[26]	2014	United States	RPD	28	431 (340-628)	100 (50-300)	7.4 (5.5-17.1)	NR	29.0%	NR	25.0%	7.0% (90 D)
			OPD	28	410 (190-621)	300 (100-800)	8.1 (6.5-15.3)	NR	29.0%	NR	25.0%	7.0% (90 D)
Croome <i>et al</i> ^[20]	2014	United States	LPD	108	379.4 ± 93.5	492.4 ± 519.3	6 (4-118)	5.6% (≥ IIIb)	11% (B/C)	9% (B/C)	NR	1.0% (1 H)
			OPD	214	387.6 ± 91.8	866.7 ± 733.7	9 (5-73)	13.6% (≥ IIIb)	12% (B/C)	18% (B/C)	NR	2.0% (1 H)
Speicher <i>et al</i> ^[77]	2014	United States	LPD	25	381 (342-465)	200 (100-425)	8.5 (7-11.2)	NR	16% (B/C)	NR	30.4%	0 (30 D)
			HPD	31	442 (386.5-486.5)	600 (312.5-700)	12 (8.5-18.5)	NR	35.5%	NR	35.5%	3.2% (30 D)
			OPD	84	425.5 (345.8-478.8)	425 (300-700)	10 (8-14)	NR	22.6%	NR	39.3%	1.2% (30 D)
Asbun <i>et al</i> ^[11]	2012	United States	LPD	53	541 ± 88	195 ± 136	8.0 ± 3.2	NR	16.7%	11.3%	NR	5.7% (100 D)
			OPD	215	401 ± 108	1032 ± 1151	12.4 ± 8.5	NR	17.3%	15.3%	NR	8.8% (100 D)
Lai <i>et al</i> ^[28]	2012	China	RPD	20	491.5 ± 94.0	247 (50-889)	13.7 ± 6.1	NR	35.0%	5%	NR	0%
			OPD	67	264.9 ± 63.7	774.8 (50-8000)	25.8 ± 23.1	NR	17.9%	11.9%	NR	3%

CD: Clavien-Dindo; DGE: Delayed gastric emptying; EBL: Estimated blood loss; HPD: Hybrid pancreaticoduodenectomy; LHS: Length of hospital stay; LPD: Laparoscopic pancreaticoduodenectomy; LPPPD: Laparoscopic pylorus-preserving pancreaticoduodenectomy; MIPD: Minimally invasive pancreaticoduodenectomy; NR: Not reported; OPD: Open pancreaticoduodenectomy; OPPPD: Open pylorus-preserving pancreaticoduodenectomy; PF: Pancreatic fistula; RPD: Robotic pancreaticoduodenectomy.

morbidly. Thus, it should be considered only in patients with a dilated pancreatic duct and a hard pancreas texture, who are believed to have a low risk of pancreatic fistula.

Adam *et al*^[32] reviewed patients undergoing PD from the National Cancer Database between 2010 and 2011, including 983 MIPDs and 6078 LPDs. Their results suggested that, for patients with PDAC, no difference was detected in number of lymph nodes (LNs) removed, rate of R0 resection, length of hospital stay or readmission. However, the 30-d mortality was lower in the OPD group than in the MIPD group. The authors suggested that the widespread adoption of the technique should be paused. MIPD is a complex procedure that needs comprehensive protocols outlining criteria for implementation.

Asbun and Stauffer^[11] presented retrospective clinical data from Mayo Clinic of 215 OPD and 53 LPD patients. They also showed significantly better results in LPD

groups, such as less blood loss ($P < 0.001$) and blood transfusion requirements ($P < 0.001$), and a shorter postoperative hospital stay ($P < 0.001$). While a significantly longer operating time was observed in LPD ($P < 0.001$), the LPD patients had a greater number of LNs removed than the OPD patients ($P = 0.007$). This series also demonstrated that LPD is safe and feasible and showed some benefits for patients.

Results from another cohort with PDAC in the United States treated with LPD were presented at the Western Surgical Association 122nd Scientific Session^[21]. The researchers compared 4037 OPDs with 384 LPDs and showed significant differences favoring LPD for length of hospital stay and unplanned readmission. A lower risk of 30-d mortality was found in high-volume centers and in centers with experience of performing more than 10 LPDs; moreover, the 30-d mortality for LPD was similar to that for OPD. Finally, the researchers demonstrated that there is a learning curve for LPD.

Song *et al*^[16] compared 137 laparoscopic pylorus-preserving PDs (LPPPDs) with 2055 open PPPDs (OPPPDs) in South Korea. They found that operating time was longer for LPPPD than for OPPPD, and the perioperative complications were similar in both groups. Fewer analgesic injections were administered in the LPPPD group ($P < 0.001$). The oncological results were similar between the two groups, including number of LNs removed and long-term survival.

In addition to LPD, a few studies have compared robotic PD (RPD) with OPD. Chalikhonda *et al*^[33] from the Cleveland Clinic reviewed the results of 30 matched laparoscopic RPD (LRPD) and OPD procedures. LRPD and OPD groups were matched with demographics. A similar estimated blood loss and rate of reoperation were found in the two groups. However, there was a significant increase in operating time and shorter hospital stay for the LRPD group.

We found that most of the clinical studies showed that LPD is as safe and feasible as OPD technically, and has some of the superiority associated with minimally invasive surgery, such as less estimated blood loss and shorter hospital stay. However, some authors have suggested that MIPD should be advocated in a subgroup of patients with lower risk of pancreatic fistula. In our opinion, LPD is as safe as OPD. However, due to the complexity of LPD, it is a technically demanding procedure with a learning curve. In small clinical cohorts of LPD at the beginning of the learning curve, there might be higher morbidity and mortality for LPD than for OPD. The problem now is how to reduce the risks of LPD at the beginning of the learning curve. Apart from technical feasibility, the major arguments against LPD are oncological adequacy, especially for patients with PDAC.

Oncological adequacy of LPD for pancreatic malignancy
Pancreatic cancer still has a high fatality rate. Radical

resection is required for a good prognosis. Many clinical studies have reported LPD; however, most of those studies have included a variety of diseases requiring LPD. To the best of our knowledge, few studies have compared the oncological prognosis of PDAC treated with LPD or OPD (Table 2).

Song *et al*^[16] compared the oncological results of pancreatic cancer treated with OPPPD ($n = 261$) and LPPPD ($n = 11$). TMN stage, R0 resection rate, in-hospital stay and the overall survival were similar between the two groups. In a case-control study from France^[24], the results for LPD ($n = 15$) in patients with PDAC were similar to those with OPD ($n = 14$) with regard to tumor size, number of LNs harvested and rate of R0 resection. Croome *et al*^[20] reported a large single center study of pancreatic carcinoma treated with LPD. Clinical data of 108 cases of LPD were reviewed retrospectively and compared with 214 cases of OPD performed in the same period at their center. The short-term oncological results, including tumor size, LN positivity, R0 resection and overall survival, were similar between the two groups, and significantly longer progression-free survival was found in the LPD group. The authors thought that this difference might have been because the patients who underwent LPD had the advantage of minimal invasiveness and recovered faster from the operation. This allowed the patients to receive adjuvant therapy in a timely manner and probably led to better prognosis.

A large LPD cohort study^[21] from the National Cancer Data Base involved 384 LPDs and 4039 OPDs. The results showed no difference between the LPD and OPD groups with regard to length of stay, margin-positive resection, LN count and readmission rate.

Chen *et al*^[34] compared the oncological results of pancreatic cancer treated with RPD ($n = 19$) and OPD ($n = 38$). There was no difference in the R0 resection rate, number of LNs resected, cancer stage, overall survival and disease-free survival between the two groups.

All the results above show that in most of the experienced minimally invasive pancreatic centers, LPD has similar short-term oncological results as OPD. However, Croome *et al*^[20] reported the long-term prognostic benefit in the LPD group because of the advantages of minimal invasiveness. Furthermore, Croome *et al*^[20] presented the largest cohort with pancreatic cancer treated with LPD, thus, we can probably form the hypothesis that, if surgeons acquire enough experience of LPD, LPD can yield the benefits of minimal invasiveness as well as long-term oncological benefit, compared with OPD. To obtain oncological adequacy, some technical tips are suggested for application during the operation.

Surgical technique to improve rate of R0 resection

Superior mesenteric artery-first approach: To improve the long-term prognosis of patients with

Table 2 Oncological results of pancreatic cancer in minimally invasive pancreaticoduodenectomy and open pancreaticoduodenectomy: Clinical trials including comparative results of pancreatic ductal adenocarcinoma between minimally invasive pancreaticoduodenectomy and open pancreaticoduodenectomy

Ref.	Year	Country	Technique	No. of PDAC cases	Rate of R0 resection	No. of LN	Positive LN	Tumor size, cm
Sharp <i>et al</i> ^[21]	2015	United States	LPD	384	80.0%	18 ± 9.7	NR	3.2 ± 1.3
			OPD	4037	74.0%	16 ± 9.6	NR	3.3 ± 2.4
Song <i>et al</i> ^[16]	2015	South Korea	LPPPD	11	72.7%	15 ± 10	0.8 ± 1.2	2.8 ± 0.6
			OPPPD	261	81.0%	16.2 ± 9.6	1.5 ± 2.2	3.0 ± 1.2
Dokmak <i>et al</i> ^[24]	2015	France	LPD	15	60.0%	20 (8-59)	4.7 (0-32)	2.4 (1.5-4)
			OPD	14	50.0%	25 (8-47)	2.2 (0-12)	2.8 (2.5-4)
Chen <i>et al</i> ^[34]	2015	China	RPD	19	94.7%	18.1 ± 6.6	NR	3.0 ± 0.9
			OPD	38	92.1%	17.8 ± 7.1	NR	3.1 ± 1.0
Croome <i>et al</i> ^[20]	2014	United States	LPD	108	77.8%	21.4 ± 8.1	73.1%	3.3 ± 1.0
			OPD	214	76.6%	20.1 ± 7.5	72.0%	3.3 ± 1.3

LN: Lymph node; LPD: Laparoscopic pancreaticoduodenectomy; LPPPD: Laparoscopic pylorus-preserving pancreaticoduodenectomy; MIPD: Minimally invasive pancreaticoduodenectomy; OPD: Open pancreaticoduodenectomy; OPPPD: Open pylorus-preserving pancreaticoduodenectomy; PDAC: Pancreatic duct adenocarcinoma; NR: Not reported.

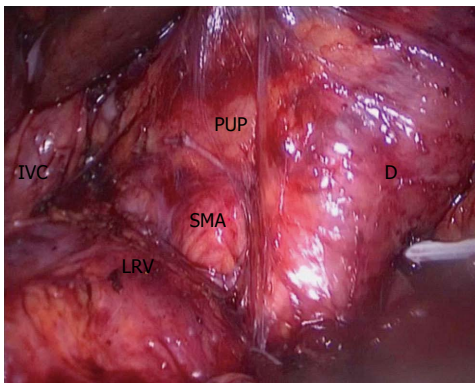


Figure 1 Superior mesenteric artery was exposed from the right posterior side after complete Kocherization. D: Duodenum; IVC: Inferior vena cava; LRV: Left renal vein; PUP: Pancreatic uncinus process; SMA: Superior mesenteric artery.

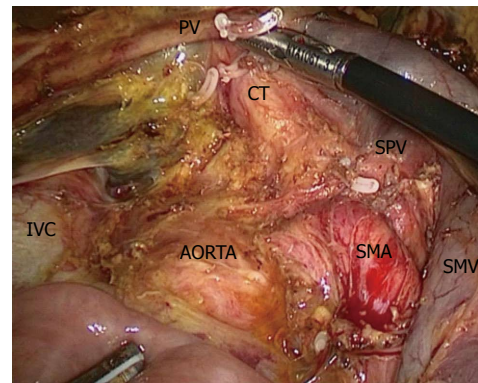


Figure 2 Local vision after removal of the specimen. CT: Celiac trunk; IVC: Inferior vena cava; PV: Portal vein; SMA: Superior mesenteric artery; SMV: Superior mesenteric vein; SPV: Splenic vein.

PDAC, curative (R0) resection is required initially. Many reports have discussed the value of R0 resection in prognosis of PDAC. The consensus among pancreatic surgeons is that positive surgical margins are associated with poor survival^[35-38]. The primary site of positive margins is from the right side of the superior mesenteric artery (SMA) (N14) to the right side of the celiac trunk (N9), including the mesopancreas^[39]. To improve R0 resection, the SMA-first approach was advocated in OPD. The artery-first approach has been proven as effective in reducing the risk of bleeding and improving the rate of R0 resection in pancreatic cancer.

However, few publications have reported the SMA-first approach in LPD. To the best of our knowledge, only two publications have described laparoscopic SMA-first approaches^[40,41]. Pittau *et al*^[40] reported the right posterior approach. The authors performed this procedure exactly like the Pessaux procedure in OPD^[42], and they dissected the SMA after complete Kocherization, including mobilization of the right colon. Cho *et al*^[41] described the left posterior SMA-first approach. They dissected the SMA at the ligament of

Treitz without mobilization of the duodenum or right colon^[43]. In our center, we perform the right posterior SMA-first approach, as described by Pittau *et al*^[40]. We expose the SMA from the right side after complete Kocherization (Figure 1). After exposure of the SMA, it would be easy to decide the resectability of the tumor. Another benefit is that this approach makes resection of the uncinus process from the SMA easier, and warrants complete removal of the neuro laminar tissue at the right side of the SMA up to the celiac axis (Figure 2).

Major vein resection: Involvement of the portal vein in locally advanced tumor is no longer a contradiction for surgical resection of pancreatic malignancy using traditional open procedures. A lot of data from larger pancreatic centers have provided evidence indicating that *en bloc* resection of tumor with involved vessels is safe and feasible, and can improve the rate of R0 resection^[44-51]. Patients who have *en bloc* resection with the involved vein have similar long-term oncological prognosis compared with patients who do not have vascular involvement^[44,45,48-50].

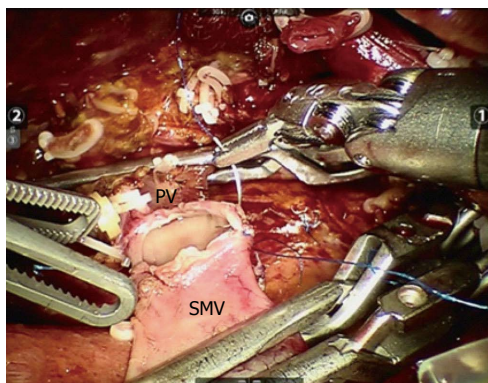


Figure 3 Vein reconstruction via robotic system. PV: Portal vein; SMV: Superior mesenteric vein.

Kendrick *et al.*^[52] reported the first example of LPD with vein resection. Later in that same year, Giulianotti *et al.*^[53] published data of RPD with major vein resection. Kendrick *et al.*^[52] reported 11 patients who underwent laparoscopic pancreatotomy with major venous resection. In their series, one segmental resection and 10 tangential venous resections were described. Giulianotti *et al.*^[53] described three cases of robot-assisted distal pancreatotomy (DP) with vascular resection (two cases of celiac trunk resection and one of portal vein resection) and two cases of RPD with portal vein resection. These initial results show that, for surgeons with considerable experience of minimally invasive pancreatic surgery, major vein resection during pancreatotomy is a safe and feasible adjunctive procedure. Kendrick *et al.*^[52] consequently reported a series of LPD with major vein resection. Thirty-one patients who underwent LPD with vascular resection were compared with 58 patients who underwent OPD with major vessel resection. The LPD group had decreased blood loss and shorter length of hospital stay, but there was no difference between LPD and OPD with regard to severe complications, mortality or overall survival. The authors concluded that LPD with vein resection is safe and feasible, and can achieve similar outcomes compared to patients undergoing OPD with vein resection. Most of the minimally invasive pancreatic centers considered LPD with vein resection a contraindication. However, for further application of LPD in patients with pancreatic malignancy with vein involvement, it is necessary for surgeons to master the minimally invasive technique of vein resection and reconstruction.

In our center, we have performed five MIPD procedures with major vein resection: four patients underwent LPD with tangential venous resection, and one underwent robotic vein segment resection (Figure 3). In our limited experience of LPD with major vein resection, tangential venous resections can be performed safely laparoscopically. However, for segmentectomy of the major vein, a robotic system is advocated. The first RPD was performed by Giulianotti *et al.*^[54] in 2001.

RPD has since been proven to be feasible and safe, with the minimally invasive advantages compared with open procedures^[30,31,33,34,55,56]. It is believed that the robotic surgical system provides surgeons with enhanced dexterity, superior magnified high-resolution 3D visualization, and greater precision and ergonomic comfort. This approach enables surgeons to control the surgical instruments with accuracy, flexibility and a wide range of motion, which is suggested for procedures that require complicated resection and reconstruction, such as prostatectomy, coronary surgery and PD. In our opinion, the application of robotic systems in PD with major vein resection can improve the quality of vein reconstruction, and we advocate them if possible.

LAPAROSCOPIC DP

Background

DP is widely accepted as an option for PDAC located in the distal pancreas. However, in past decades, laparoscopic DP (LDP) has been accepted increasingly with evidence of minimally invasive benefits. Compared with LPD, LDP is less technically demanding because there is limited dissection around the vessels and no reconstruction is required^[57,58]. So, more surgeons accept LDP than LPD.

Safety and feasibility of LDP

A recently published meta-analysis^[59-63] indicated that LDP was a safe and feasible option in terms of operating time and postoperative mortality and morbidities, such as postoperative bleeding and pancreatic fistula. Moreover, minimally invasive superiority was found in LDP, including significantly decreased estimated blood loss, time to first oral intake and length of hospital stay^[59-63]. These results clearly show that LDP is as safe and feasible as OPD.

Short-term oncological results

Microscopically, R0 resection is the most important part of treatment of resectable pancreatic cancer. Some non-comparative cohorts have shown that R0 resection of pancreatic cancer can be achieved by laparoscopic resection^[64,65]. Most of the comparative studies have shown that there is no difference in the rate of R0 resection in the final pathological results between LDP and OPD^[58,66,67]. To the best of our knowledge, only DiNorcia *et al.*^[68] have reported a decrease in R1 resection in the laparoscopic group; however, their series had mixed pathology, including neuroendocrine tumor and pancreatic adenocarcinoma. Another important short-term oncological marker is LN retrieval. A minimum of 12 LNs is required for resection of pancreatic adenocarcinoma^[69,70]. N0 patients with > 12 LNs have better survival than N0 patients with < 12 LNs ($P < 0.001$)^[70]. Most studies have found that the number of LNs harvested in laparoscopic and open procedures is similar^[58,66-68,71].

The data here demonstrate that most of the minimally invasive pancreatic surgeons have a consensus that LDP has the same short-term oncological results as ODP.

Long-term oncological outcomes of LDP

Only a few studies have described long-term prognosis after LDP, and few comparative data are reported. Mabrut *et al.*^[64] reported 16 patients with pancreatic malignancy, 4 of whom had pancreatic adenocarcinoma, and 23% of these patients had recurrence during 15 mo. Fernández-Cruz *et al.*^[72] reported 10 cases of laparoscopic radical antegrade modular pancreatectomy (RAMPS), with 3 having died within a year and a median survival period of 14 mo. Rehman *et al.*^[67] found a similar 3-year overall survival between 8 LDP and 14 ODP procedures for PDAC. Kooby *et al.*^[58] reported similar median survival (16 mo) after LDP and ODP in a matched study. Kim *et al.*^[73] reported 11 LDPs with diagnosis of malignancy in their postoperative pathological results, including 5 cases of PDAC; only 1 patient died of cancer during the follow-up period (3-60 mo). The results to date suggest that the long-term prognosis of LDP for adenocarcinoma is similar to that for open procedures. It was also found that there was no difference in short-term oncological markers, including tumor size, radiological stage, margin-negative resection, power of LN retrieval and LN metastasis between the two groups. The authors concluded that LDP is acceptable for patients with pancreatic malignancy. However, further larger studies are required to give solid evidence of the long-term oncological benefit of LDP.

CONCLUSION

After initial reports of LPD and LDP in the 1990s, laparoscopic pancreatectomy finally became a well-established procedure following 30 years' development of laparoscopic skills and equipment. The data here suggest that minimally invasive pancreatectomy is safe and feasible and has adequate evidence of good short-term outcome. However, randomized controlled trials and long-term oncological results are still lacking. The long-term oncological results should be further addressed by randomized controlled trials. Another problem now is how to generalize this procedure from experienced hands to other centers.

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