

# Minimally Invasive Surgery for Pancreatic Disease – Current Status

G. Alsfasser S. Hermeneit B.M. Rau E. Klar

Department of General, Thoracic, Vascular and Transplantation Surgery, University of Rostock, Rostock, Germany

## Key Words

Laparoscopic surgery · Pancreatic surgery · Review

## Abstract

Laparoscopic procedures have advanced to represent the new gold standard in many surgical fields. Although application in pancreatic surgery is hampered by the friable nature of the gland and the difficulty of its exposure, advanced technology and surgeons' experience are leading to an expansion of minimally invasive pancreatic surgery. Addressing the whole range of main operative procedures, this review analyzes the literature data so far to give an overview about the current status of minimally invasive pancreatic surgery, its indications and limitations. In acute pancreatitis, a step-up approach from percutaneous drainage to retroperitoneoscopic necrosectomy seems beneficial. Transgastric necrosectomy also preserves the retroperitoneal compartment in contrast to the laparoscopic approach, which has widely been abandoned. In tumor pathology, laparoscopic access is adequate for small benign lesions in the pancreatic tail and body. Oncological outcome shows to be at least equal to the open procedure. Concerning laparoscopic pancreaticoduodenectomy, there is no evidence for a patients' benefit currently although several studies prove that it can be done.

© 2016 S. Karger AG, Basel

## Introduction

Ever since the very first description of a minimally invasive approach to the abdominal cavity by Bernheim [1], laparoscopic surgery has emerged as integral operative technique in almost every surgical discipline around the turn of the millennium. Driven by major technical progress and developments, laparoscopic procedures have advanced to represent the new gold standard in gastrointestinal surgery such as cholecystectomy, inguinal hernia repair or fundoplication. Besides colorectal surgery, efforts to extend the minimal access approach to more complex gastrointestinal procedures have reached pancreatic surgery a few years ago as well.

The role of laparoscopy as a staging tool for pancreatic diseases was described by Bernheim [1], Cuschieri et al. [2], Ishida [3] and Meyer-Burg et al. [4], years ago. Subsequently, Gagner and Pomp [5] performed the first major laparoscopic pancreatic resection, represented by a Whipple's procedure.

The laparoscopic approach to pancreatic surgery is essentially hampered by the anatomic location of the organ in the retroperitoneum and its proximity to major blood vessels. Furthermore, the friable nature of the gland itself and the difficulty of its exposure are major drawbacks to minimally invasive surgery [6]. Along

with advanced technology and surgeons' experience, minimally invasive procedures are now applied to drain pancreatic pseudocysts, benign tumors and even to resect malignant tumors including pancreatoduodenectomy (PD).

This review aims at providing an overview about the current status of minimally invasive pancreatic surgery, its indications and limitations.

### **Current State of Minimally Invasive Pancreatic Surgery**

A number of recent studies have shown impressively that almost all open procedures may be performed laparoscopically as well [7]. Besides the sole aspect of technical feasibility, questions remain as to whether the laparoscopic approach offers any benefit for the patient.

While the procedural trauma is basically the same, laparoscopy minimizes the surgical access trauma [8]. Patients suffer less pain, have a shorter ICU and total hospital stay, and experience a faster postoperative recovery [9]. Because of the early mobilization, non-surgical postoperative morbidity can be reduced. Long-term complications such as incisional hernias are observed less frequently.

Furthermore, the laparoscopic technique improves the surgical preparation by its magnified view [9]. Operation time is equal or longer, but blood loss is significantly lower, because small arteries and veins can be identified much better and bleeding can be easily controlled. Finally, it is discussed that laparoscopy, especially in case of malignant tumors, has less immunosuppressive effects due to the blunt stress response [10].

Bearing in mind the aforementioned advantages of minimally invasive over open approaches to pancreatic surgery, there are a number of indications that have been published in the literature.

### **Diagnostic Laparoscopy**

Diagnostic laparoscopy was the first minimally invasive approach in pancreatic disorders such as staging of pancreatic tumors, which still remains an indication for selected patients with pancreatic cancer [11]. Nowadays, technical improvements allow single-port access with curved instruments by an umbilical incision <15 mm and a 45–60 min operation time as described by Dapri et al. [12].

### **Pancreatic Necrosis**

Until the 1990s, the standard procedure for infected necrosis was open necrosectomy combined with various approaches to manage the peri-pancreatic space postoperatively such as open packing, scheduled re-explorations or continuous closed lavage [13]. Hence, minimally invasive procedures are increasingly applied in necrotizing pancreatitis and seem to reduce the incidence of postoperative new-onset organ failure compared with the open procedures [14–18]. There are a number of different laparoscopic and minimally invasive techniques with favorable results currently used in this setting.

#### *Percutaneous/Endoscopic Retroperitoneal Necrosectomy*

This technique employs CT-guided pigtail catheter drainage of the necrotic/infected collections as the first step. This canal is then widened up to 30 F allowing access by an endoscope with subsequent removal of necrosis and infected debris in piecemeal technique. This procedure can be followed by placement of large bore drains for continuous postoperative lavage [14–16].

A clear advantage of this technique is the fact that it preserves the cavity as walled-off compartment thus avoiding contamination of the whole abdomen. On the other hand, a major limitation may be represented by a diffuse spreading pattern of pancreatic or peri-pancreatic necrosis without clear-cut walled-off cavity.

#### *Laparoscopic Necrosectomy*

As in open surgery, laparoscopic necrosectomy uses a retrogastric transmesocolic or retroperitoneal approach to the lesser sac – a transgastric route may also be possible. The technical success rates are up to 85% in the literature [19–23]. However, choosing this route, a considerable risk remains with regard to pancreatic fistulas and damage of the colic or splenic vessels [24]. Thus, laparoscopic techniques are modified by current developments of hand-ports and robotic surgery.

Irrespective of the laparoscopic approach, most experts agree that re-interventions after any laparoscopic approach are extremely difficult [22]. Furthermore, the relationship between capnoperitoneum and abdominal compartment syndrome remains unknown yet [24]. So far, there is no convincing evidence that any of the laparoscopic techniques discussed above are superior to open surgery. However, depending on specific, individual indications and personal experience, good outcomes can be achieved [25].

### Transluminal Endoscopic Necrosectomy

To avoid the disadvantages of the laparoscopic technique, some authors prefer a transgastric or transduodenal approach [24]. Usually this is done by a transluminal puncture. These tracks are dilated and necrosectomy is performed via an endoscope. Pigtail drainage can be left in the cavity [25]. In 9 studies with 157 patients treated this way, 20% suffered from major complications and 5% died [25].

However, transgastric access leads to bacterial or fungal contamination of the retroperitoneum. Furthermore, the access to the area of necrosis is often restricted, so that more distant locations of collections or necrotic cavities cannot be reached [22].

Seifert et al. [26] reached an initial success of 80% in 93 patients. The complication rate was 26% with a 30-day mortality of 7.5%. A median of 6 endoscopic necrosectomy sessions were necessary and 4% of patients needed subsequent open surgery.

### Conclusion

A wide array of different laparoscopic/minimally invasive procedures is available for the treatment of infected necroses in necrotizing pancreatitis. The available literature is limited by non-comparable case series devoid of uniform definitions lacking indications for and timing of interventions or surgery.

Currently, a step-up approach using escalating levels of low to maximum invasive drainage procedures seems to be the optimum treatment algorithm of complicated necrotizing pancreatitis. A retroperitoneal approach should be applied if possible.

Open necrosectomy still seems to represent the final gold standard for an effective evacuation of infected necrosis. Indications for minimally invasive surgery should generally be identical to those of conventional techniques. Therefore, it must be avoided that minimally invasive approaches imply expansion of operative therapy such as earlier point in time or increased frequency. The laparoscopic access techniques often result in a loss of compartment and are therefore inferior to the described alternatives.

### Distal Pancreatectomy

The first distal laparoscopic pancreatectomy was performed by Sussman et al. [27]. Hence, indications for laparoscopic distal pancreatectomy improved and even confined malignant tumors are currently treated this way. Localization of the tumor is usually verified by intraoperative ultrasound. Pancreatic tissue is laparoscopically

**Table 1.** Literature review: laparoscopic vs. open distal pancreatectomy

	LLP	OLP
Cases	336.0	372.0
Mean operative time, min	228.9	212.1
Mean blood loss, ml	248.4	518.6
Splenic preservation, %	32.8	11.6
Mean length of stay, days	8.2	12.1
Overall morbidity, %	30.7	45.1
Fistula rate, %	8.8	14.5
Mortality, %	0	0.003

LLP = Laparoscopic left pancreatectomy; OLP = open left pancreatectomy.

transected with a linear cutter [28]. Beyond that, some surgeons prefer hand-ports.

By using a laparoscopic approach for this indication, Fernández-Cruz et al. [7] could reduce the hospital stay of 7 patients with inflammatory tumors in chronic pancreatitis to 1 week and patients could return to normal activities within 3 weeks [9]. In contrast, hospital stay was 12 days in open left resection and patients returned to normal activities after >5 weeks. Recent meta-analyses confirmed lower rates of blood loss, wound infection and hospital stay in laparoscopic distal pancreatectomy [29, 30].

Table 1 shows the results of laparoscopic versus open distal pancreatectomy [28, 31]. Nineteen studies between 1996 and 2008 reported a mean conversion rate of 12.1% (n = 442) [32].

As far as preservation of the spleen is concerned, 2 methods are described in the literature. The first approach divides the small arterial and venous connections between pancreas and the splenic vessels as in the open procedure. The magnified laparoscopic view allows spleen preservation easier than in open surgery, because of a better separation of the splenic artery and vein from the pancreatic parenchyma [9, 28].

The second approach, described by Warshaw for the open procedure, is the resection of the splenic vessels. Using this method, the spleen is supplied by the short gastric vessels [28]. There are no large series comparing these 2 methods but complications, for example, splenic infarction and gastric variceal hemorrhage, seem to be higher in the second group [33]. The authors show a higher morbidity in the case of spleen preservation [33].

Beyond that, randomized controlled studies concerning function of the spleen and outcome after spleen-preserving distal pancreatectomy are still missing. There are

only few single-center studies such as the one published by Yoon et al. [34], including 22 patients. The authors could show that splenic vessel-preserving laparoscopic distal pancreatectomy had a short-term benefit only, whereas long-term outcome was seriously hampered by a high risk of left-sided venous hypertension as a consequence of a splenic vein occlusion.

However, a major problem of left pancreatic resections is pancreatic fistulas. In open techniques, fistula rates range between 5 and 18% [28]. A meta-analysis comparing hand-sewn and stapled techniques so far could show 'no significant differences between suture and stapler closure with respect to the pancreatic fistula or intra-abdominal abscess after distal pancreatectomy' [35]. Even a randomized, multicenter study could not show any difference in fistula rate between hand-sewn and stapled closure technique [36]. Bilimoria et al. [37] found that the identification and selective duct ligation could decrease the risk of pancreatic fistulas.

The magnified view of laparoscopy could possibly improve the identification and ligation of the duct. On the other hand, laparoscopic ligation may be more difficult. Another issue is the quality of long-term outcome of laparoscopic versus open surgery in malignant disease. According to the review of Briggs et al. [32], only 4 studies between 1996 and 2008 reported lymph node yield at all. The mean was 13 (2–20). Eight of 194 cases showed a positive resection margin (4.1%). Two recent reviews on distal pancreatectomy showed no difference between laparoscopic or open distal pancreatectomy in regard to lymph node yield or R-status [30, 38].

### Conclusion

According to the current evidence of the literature, laparoscopic distal pancreatectomy is safe and feasible for benign and confined malignant tumors of the pancreatic body and tail in experienced hands. It is associated with lesser blood loss, reduced postoperative pain and shorter hospital stays, although operation time is still longer. The decision to preserve the spleen has to be left to the surgeon's experience, since comparable studies on this issue are still missing. In cases of malignant tumors the spleen should not be preserved.

### Enucleation

Indications for open enucleation (OE) are benign lesions located away from the main duct. However, a clear-cut distance has not been established yet. In 1995,

**Table 2.** LE vs. OE for insulinomas of the pancreas [28, 40, 41]

	OE	LE
Cases	33	88
Conversion rate, %	–	14.3 (0–33.3)
Mean tumor size, cm	1.47	1.3–2.0
Mean operative time, min	119	115.9 (66.7–159)
Mean blood loss, ml	91	195.7 (77–255)
Mean length of stay, days	16	6.2 (2.3–11.8)
Overall morbidity, %	36	28
Pancreatic fistula rate, %	28.57	27.8 (0–77.8)
Mortality, %	0	0

Amikura et al. [39] performed the first laparoscopic enucleation (LE) for an adrenocorticotrophic hormone producing tumor. Both open and laparoscopic procedures are only indicated in cases of benign appearing tumors up to 3 cm, which are mostly located in the body and tail of the pancreas. On the other hand, there are also reports on superficial tumors of the head and neck.

Several studies have shown that LE is safe and feasible [7, 40–43]. Patients seem to benefit from the laparoscopic technique because of a reduced endocrine and exocrine insufficiency and because of the general advantages of a smaller surgical trauma [28]. However, the main problem of enucleation is the treatment of the resection margin. Possible techniques are suturing, omentum-patch, cauterization and fibrin-sealing with or without application of somatostatin. None of these techniques show a significant reduction of the fistula rate. In case of laparoscopy, fistula rates range from 0 to 78% [28]. Several studies have shown that complication rates in laparoscopy are not higher than in open surgery [39, 44]. However, fistulas following enucleation have been more often clinically apparent than after distal pancreatectomy [28]. Comparing laparoscopic with OEs, overall morbidity, pancreatic fistula rate and mortality do not show any significant differences (table 2), whereas hospital stays seem to be significantly shorter [40, 45, 46].

### Conclusion

LE of pancreatic tumors is safe and effective. Patients with small tumors in the body and tail seem to benefit from the laparoscopic approach. Further studies are needed to compare advantages and disadvantages of distal pancreatectomy versus enucleation, especially regarding the rate of pancreatic fistulas.

## Pancreaticoduodenectomy

Despite first reports of Gagner and Pomp [5], pancreaticoduodenectomy still remains a challenging procedure even in the hand of experienced laparoscopic surgeons. The largest series currently available in the literature report of 108 [47], 100 [48] and 53 [49] total laparoscopic pancreaticoduodenectomies. However, evidence-based data about the benefits and long-term outcome of laparoscopic versus open techniques are still missing.

In general, the steps of laparoscopic Whipple's procedures are fairly similar to the open procedure. Some studies differ in the use of hand-ports or hand-assisted techniques [28]. As far as reconstruction is concerned, pancreatogastrostomy and pancreaticojejunostomy seem to be equal to the open approach [50–52]. Nine recent meta-analyses showed a lower complication rate of pancreatogastrostomies compared to pancreaticojejunostomies regarding a reduced pancreatic fistula rate in open pancreatic surgery [53–61]. Pancreatogastrostomy offers the advantage of being more easily and quickly performed than pancreaticojejunostomy [62], which renders this reconstruction more feasible for the laparoscopic approach.

A major clinical question remains the exocrine and endocrine function of pancreatogastrostomy compared to pancreaticojejunostomy. Rault et al. [63] report worse exocrine function after pancreatogastrostomy; however, Morera-Ocon et al. [64], do not see any difference. Even the endocrine function does not seem to differ between these 2 reconstruction methods [65].

Almost all studies came to the conclusion that laparoscopic PD can be safely performed in appropriately selected patients by experienced surgeons [28, 47, 49, 66]. According to the limited number of series, morbidity and mortality are equal to the open procedure including the rate of pancreatic fistulas which is reported to range between 7 and 35% [47–49, 67–69]. The mean operative time is still longer than in open surgery, a common feature observed in all laparoscopic procedures, which however mainly depends on the individual surgeon's experience and case load [28]. Further advantages are a lower blood loss due to preparation under magnifying view [28].

On the other hand, oncological appropriateness in laparoscopic resections is still a matter of controversy. However, no difference could be detected in resection margin status so far [31, 33] and most studies report that lymph node dissection can be done as extended as in open surgery [28] or even better [49]. In a review by Briggs et al. [32], 15 lymph nodes per case were harvested, although

studies on this specific issue lack a detailed description of the histopathological work-up of the resected tumor specimen. Moreover, long-term follow-up studies in laparoscopically resected oncological patients are still scarce [10]. Palanivelu et al. [70] reported about 5-year survival rates ( $n = 42$ ) similar to those of the open techniques in laparoscopic surgery for pancreatic carcinoma in general (32%), ampullary carcinoma (30.7%), cystadenocarcinoma (33.3%), ductal pancreatic head adenocarcinoma (19.1%) and bile duct carcinoma (50%). Croome et al. [47] could report a significantly higher progression-free survival over 60 months following total laparoscopic PD versus the open approach.

Dismissing the fact that laparoscopic PD can be done with as adequate oncological dissection and comparable morbidity and mortality as by open surgery, questions remain as to whether patients truly benefit from the laparoscopic approach. At present, most authors are unable to provide any proof in favor of laparoscopy lacking significant reduction of postoperative morbidity [47, 71, 72]. However, mean length of stay is significantly reduced with the laparoscopic approach [47, 72]. Well known laparoscopy-attributed advantages such as a lower rate of incisional hernias, faster procedure-related recovery or better quality of life have not been targeted so far.

There may be selected patients that benefit from the laparoscopic technique, as long as the overall operative access trauma remains less than that compared with the open technique.

Future studies will have to show if there is any advantage of the laparoscopic over the open approach for this demanding surgical procedure. Table 3 summarizes results and complications of laparoscopic PDs.

### Conclusion

Up to now, PD can be done laparoscopically in selected patients by experienced surgeons, but clear advantages remain to be defined.

### New Techniques

A new method for the dissection of the pancreas is by using high-energy radio waves. The first study on 14 patients by Fronza et al. [73] showed that radiofrequency energy was safe, feasible and easy to use. It is speculated that this technique may be able to reduce pancreatic fistulas.

A further development of laparoscopy is robot-assisted procedures as recently reported by a number of studies

**Table 3.** Outcome of laparoscopic PD from 2011 to 2014

	Lai et al. [67]	Chalikonda et al. [68]	Buchs et al. [69]	Asbun et al. [49]	Kim et al. [48]	Croome et al. [47]	Mean
Cases	20	30	44	53	100	108	–
Conversion rates, %	5	10	4.5	15*	4.7	5.6	7.5
Mean operative time, min	491.5	476	444	541	474	379.4	467.7
Mean blood loss, ml	247	485	387	195	N/A	492.4	361.3
Mean length of stay, days	13.7	9.79	13	8	11.5	6	10.3
Pancreatic fistula rate, %	35	6.7	18.2	16.7	27	7**	18.4
Overall morbidity, %	50	30	36.5	47.2	25	5.6***	32.8
Mortality, %	0	4	4.5	5.7	1	1	2.7
Positive margins, %	16.7	0	9.1	5.1	0	22.2	8.85
Mean number of lymph nodes	10	13.2	16.8	23.44	13	21.4	16.3

\* Converted patients were excluded, data are from 53 total laparoscopic procedures; \*\* only grades B and C fistulas are mentioned; \*\*\* only complications grade  $\geq$ IIIb (Clavien–Dindo) are mentioned.

[67, 68]. By robotic arms, excellent stability of the operation field can be achieved. Furthermore, 3D and magnified view seem to improve the operative procedures [74]. Even central pancreatectomies [75] and PDs [67] can be performed by this robot-assisted technique.

### Conclusion

Over the last decade, the laparoscopic approach in pancreatic surgery has been extended to a degree that almost all open procedures today can be executed via the minimally invasive route. In general, these methods should be restricted to high volume centers of pancreatic surgery, which have experience in the full range of open operative procedures.

The current challenge is to optimize indications for laparoscopic techniques in differentiation to the well-established open surgery. Two questions have to be answered:

- (1) Can the minimally invasive technique be applied with the same safety and efficacy as open surgery?
- (2) What is the ultimate benefit for the patient?

Necrosectomy in acute pancreatitis should be part of a step-up approach starting with CT-guided catheter drainage followed by minimally invasive retroperitoneal debridement. Open surgery remains the gold standard of ultimate removal of pancreatic necrosis. Alternatively, endoscopic transgastric necrosectomy is a successful option especially in obese patients with comorbidities. However, the method requires great experience and is therefore limited to few experts in this field. It should be un-

derscored that the indication for necrosectomy must not be changed by a minimally invasive approach and should be equally stringent as in open surgery. Concerning pancreatic resection or enucleation, laparoscopic surgery has been shown to reduce intraoperative blood loss and wound infection as well as intensive care and hospital stay in selected patients. Furthermore the incidence of incisional hernia is lower.

According to the current literature, the laparoscopic approach is an adequate alternative to open surgery. In oncological patients, laparoscopic resections seem to reach equal results, but further studies are required to substantiate the data and to demonstrate any convincing advantage. In the specific set-up of pancreatic head tumors with the need for PD, there is currently no evidence for a patient's benefit. Further technical developments may open new avenues to the demanding field of laparoscopic pancreatic surgery in malignant disease.

### Disclosure Statement

The authors declare no conflicts of interest.

### References

- 1 Bernheim BM: IV. Organoscopy: cystoscopy of the abdominal cavity. *Ann Surg* 1911;53: 764–767.
- 2 Cuschieri A, Hall AW, Clark J: Value of laparoscopy in the diagnosis and management of pancreatic carcinoma. *Gut* 1978;19:672–677.
- 3 Ishida H: Peritoneoscopy and pancreas biopsy in the diagnosis of pancreatic diseases. *Gastrointest Endosc* 1983;29:211–218.

- 4 Meyer-Burg J, Ziegler U, Palme G: [Supragastric pancreascopy. Results of 125 laparoscopies]. *Dtsch Med Wochenschr* 1972;97:1969–1971.
- 5 Gagner M, Pomp A: Laparoscopic pylorus-preserving pancreatoduodenectomy. *Surg Endosc* 1994;8:408–410.
- 6 Mabrut JY, Boulez J, Peix JL, et al: [Laparoscopic pancreatic resections]. *Ann Chir* 2003;128:425–432.
- 7 Fernández-Cruz L, Sáenz A, Astudillo E, et al: Laparoscopic pancreatic surgery in patients with chronic pancreatitis. *Surg Endosc* 2002;16:996–1003.
- 8 Cuschieri SA, Jakimowicz JJ: Laparoscopic pancreatic resections. *Semin Laparosc Surg* 1998;5:168–179.
- 9 Fernández-Cruz L, Cesar-Borges G, López-Boado MA, et al: Minimally invasive surgery of the pancreas in progress. *Langenbecks Arch Surg* 2005;390:342–354.
- 10 Morgan KA, Adams DB: Solid tumors of the body and tail of the pancreas. *Surg Clin North Am* 2010;90:287–307.
- 11 Adler G, Seufferlein T, Bischoff SC, et al: [Carcinoma of the pancreas: summary of guidelines 2007, issued jointly by 15 German specialist medical societies]. *Dtsch Med Wochenschr* 2007;132:1696–1700.
- 12 Dapri G, Carnevali P, Himpens J, et al: Single-access transumbilical diagnostic laparoscopy for pancreatic tumor using curved and reusable instruments. *Ann Surg Oncol* 2011;18:628.
- 13 Beger HG, Rau BM: New advances in pancreatic surgery. *Curr Opin Gastroenterol* 2007;23:522–534.
- 14 Carter CR, McKay CJ, Imrie CW: Percutaneous necrosectomy and sinus tract endoscopy in the management of infected pancreatic necrosis: an initial experience. *Ann Surg* 2000;232:175–180.
- 15 van Santvoort HC, Besselink MG, Bollen TL, et al: Case-matched comparison of the retroperitoneal approach with laparotomy for necrotizing pancreatitis. *World J Surg* 2007;31:1635–1642.
- 16 Raraty MG, Halloran CM, Dodd S, et al: Minimal access retroperitoneal pancreatic necrosectomy: improvement in morbidity and mortality with a less invasive approach. *Ann Surg* 2010;251:787–793.
- 17 Rodriguez JR, Razo AO, Targarona J, et al: Debridement and closed packing for sterile or infected necrotizing pancreatitis: insights into indications and outcomes in 167 patients. *Ann Surg* 2008;247:294–299.
- 18 van Santvoort HC, Besselink MG, Bakker OJ, et al: A step-up approach or open necrosectomy for necrotizing pancreatitis. *N Engl J Med* 2010;362:1491–1502.
- 19 Adamson GD, Cuschieri A: Multimedia article. Laparoscopic infracolic necrosectomy for infected pancreatic necrosis. *Surg Endosc* 2003;17:1675.
- 20 Pamoukian VN, Gagner M: Laparoscopic necrosectomy for acute necrotizing pancreatitis. *J Hepatobiliary Pancreat Surg* 2001;8:221–223.
- 21 Parekh D: Laparoscopic-assisted pancreatic necrosectomy: a new surgical option for treatment of severe necrotizing pancreatitis. *Arch Surg* 2006;141:895–902; discussion 902–903.
- 22 Wysocki AP, McKay CJ, Carter CR: Infected pancreatic necrosis: minimizing the cut. *ANZ J Surg* 2010;80:58–70.
- 23 Zhou ZG, Zheng YC, Shu Y, et al: Laparoscopic management of severe acute pancreatitis. *Pancreas* 2003;27:e46–e50.
- 24 Ammori BJ: Laparoscopic transgastric pancreatic necrosectomy for infected pancreatic necrosis. *Surg Endosc* 2002;16:1362.
- 25 Babu BI, Siriwardena AK: Current status of minimally invasive necrosectomy for post-inflammatory pancreatic necrosis. *HPB (Oxford)* 2009;11:96–102.
- 26 Seifert H, Biermer M, Schmitt W, et al: Transluminal endoscopic necrosectomy after acute pancreatitis: a multicentre study with long-term follow-up (the GEPARD Study). *Gut* 2009;58:1260–1266.
- 27 Sussman LA, Christie R, Whittle DE: Laparoscopic excision of distal pancreas including insulinoma. *Aust N Z J Surg* 1996;66:414–416.
- 28 Kooby DA, Chu CK: Laparoscopic management of pancreatic malignancies. *Surg Clin North Am* 2010;90:427–446.
- 29 Nakamura M, Nakashima H: Laparoscopic distal pancreatectomy and pancreatoduodenectomy: is it worthwhile? A meta-analysis of laparoscopic pancreatectomy. *J Hepatobiliary Pancreat Sci* 2013;20:421–428.
- 30 Mehrabi A, Hafezi M, Arvin J, et al: A systematic review and meta-analysis of laparoscopic versus open distal pancreatectomy for benign and malignant lesions of the pancreas: it's time to randomize. *Surgery* 2015;157:45–55.
- 31 Kooby DA, Gillespie T, Bentrem D, et al: Left-sided pancreatectomy: a multicenter comparison of laparoscopic and open approaches. *Ann Surg* 2008;248:438–446.
- 32 Briggs CD, Mann CD, Irving GR, et al: Systematic review of minimally invasive pancreatic resection. *J Gastrointest Surg* 2009;13:1129–1137.
- 33 Fernández-Cruz L, Cosa R, Blanco L, et al: Curative laparoscopic resection for pancreatic neoplasms: a critical analysis from a single institution. *J Gastrointest Surg* 2007;11:1607–1621; discussion 1621–1622.
- 34 Yoon YS, Lee KH, Han HS, et al: Patency of splenic vessels after laparoscopic spleen and splenic vessel-preserving distal pancreatectomy. *Br J Surg* 2009;96:633–640.
- 35 Zhou W, Lv R, Wang X, et al: Stapler vs suture closure of pancreatic remnant after distal pancreatectomy: a meta-analysis. *Am J Surg* 2010;200:529–536.
- 36 Diener MK, Seiler CM, Rossion I, et al: Efficacy of stapler versus hand-sewn closure after distal pancreatectomy (DISPACT): a randomized, controlled multicentre trial. *Lancet* 2011;377:1514–1522.
- 37 Bilimoria KY, Bentrem DJ, Ko CY, et al: Multimodality therapy for pancreatic cancer in the U.S.: utilization, outcomes, and the effect of hospital volume. *Cancer* 2007;110:1227–1234.
- 38 Björnsson B, Sandström P: Laparoscopic distal pancreatectomy for adenocarcinoma of the pancreas. *World J Gastroenterol* 2014;20:13402–13411.
- 39 Amikura K, Alexander HR, Norton JA, et al: Role of surgery in management of adrenocorticotrophic hormone-producing islet cell tumors of the pancreas. *Surgery* 1995;118:1125–1130.
- 40 Karaliotas C, Sgourakis G: Laparoscopic versus open enucleation for solitary insulinoma in the body and tail of the pancreas. *J Gastrointest Surg* 2009;13:1869.
- 41 Liu H, Peng C, Zhang S, et al: Strategy for the surgical management of insulinomas: analysis of 52 cases. *Dig Surg* 2007;24:463–470.
- 42 Machado MA, Surjan RC, Goldman SM, et al: Laparoscopic pancreatic resection. From enucleation to pancreatoduodenectomy. 11-year experience. *Arq Gastroenterol* 2013;50:214–218.
- 43 Fernández-Cruz L, Molina V, Vallejos R, et al: Outcome after laparoscopic enucleation for non-functional neuroendocrine pancreatic tumours. *HPB (Oxford)* 2012;14:171–176.
- 44 Assalia A, Gagner M: Laparoscopic pancreatic surgery for islet cell tumors of the pancreas. *World J Surg* 2004;28:1239–1247.
- 45 Lo CY, Chan WF, Lo CM, et al: Surgical treatment of pancreatic insulinomas in the era of laparoscopy. *Surg Endosc* 2004;18:297–302.
- 46 Sa Cunha A, Beau C, Rault A, et al: Laparoscopic versus open approach for solitary insulinoma. *Surg Endosc* 2007;21:103–108.
- 47 Croome KP, Farnell MB, Que FG, et al: Total laparoscopic pancreaticoduodenectomy for pancreatic ductal adenocarcinoma: oncologic advantages over open approaches? *Ann Surg* 2014;260:633–638.
- 48 Kim SC, Song KB, Jung YS, et al: Short-term clinical outcomes for 100 consecutive cases of laparoscopic pylorus-preserving pancreatoduodenectomy: improvement with surgical experience. *Surg Endosc* 2013;27:95–103.
- 49 Asbun HJ, Stauffer JA: Laparoscopic vs open pancreaticoduodenectomy: overall outcomes and severity of complications using the accordion severity grading system. *J Am Coll Surg* 2012;215:810–819.
- 50 Bassi C, Falconi M, Molinari E, et al: Reconstruction by pancreaticojejunostomy versus pancreaticogastrostomy following pancreatectomy: results of a comparative study. *Ann Surg* 2005;242:767–771; discussion 771–773.
- 51 Fang WL, Shyr YM, Su CH, et al: Comparison between pancreaticojejunostomy and pancreaticogastrostomy after pancreaticoduodenectomy. *J Formos Med Assoc* 2007;106:717–727.
- 52 Wente MN, Shrikhande SV, Müller MW, et al: Pancreaticojejunostomy versus pancreaticogastrostomy: systematic review and meta-analysis. *Am J Surg* 2007;193:171–183.

- 53 Hallet J, Zih FS, Deobald RG, et al: The impact of pancreaticojejunostomy versus pancreaticogastrostomy reconstruction on pancreatic fistula after pancreaticoduodenectomy: meta-analysis of randomized controlled trials. *HPB (Oxford)* 2015;17:113–122.
- 54 Xiong JJ, Tan CL, Szatmary P, et al: Meta-analysis of pancreaticogastrostomy versus pancreaticojejunostomy after pancreaticoduodenectomy. *Br J Surg* 2014;101:1196–1208.
- 55 Zhang X, Ma L, Gao X, et al: Pancreaticogastrostomy versus pancreaticojejunostomy reconstruction after pancreaticoduodenectomy: a meta-analysis of randomized controlled trials. *Surg Today* 2015;45:585–594.
- 56 Chen Z, Song X, Yang D, et al: Pancreaticogastrostomy versus pancreaticojejunostomy after pancreaticoduodenectomy: a meta-analysis of randomized control trials. *Eur J Surg Oncol* 2014;40:1177–1185.
- 57 Ma S, Li Q, Dai W, Pan F: Pancreaticogastrostomy versus pancreaticojejunostomy. *J Surg Res* 2014;192:68–75.
- 58 Liu FB, Chen JM, Geng W, et al: Pancreaticogastrostomy is associated with significantly less pancreatic fistula than pancreaticojejunostomy reconstruction after pancreaticoduodenectomy: a meta-analysis of seven randomized controlled trials. *HPB (Oxford)* 2015;17:123–130.
- 59 Lei P, Fang J, Huang Y, et al: Pancreaticogastrostomy or pancreaticojejunostomy? Methods of digestive continuity reconstruction after pancreaticoduodenectomy: a meta-analysis of randomized controlled trials. *Int J Surg* 2014;12:1444–1449.
- 60 Menahem B, Guittet L, Mulliri A, et al: Pancreaticogastrostomy is superior to pancreaticojejunostomy for prevention of pancreatic fistula after pancreaticoduodenectomy: an updated meta-analysis of randomized controlled trials. *Ann Surg* 2015;261:882–887.
- 61 Clerveus M, Morandeira-Rivas A, Picazo-Yeste J, et al: Pancreaticogastrostomy versus pancreaticojejunostomy after pancreaticoduodenectomy: a systematic review and meta-analysis of randomized controlled trials. *J Gastrointest Surg* 2014;18:1693–1704.
- 62 Fernández-Cruz L, Cosa R, Blanco L, et al: Pancreaticogastrostomy with gastric partition after pylorus-preserving pancreaticoduodenectomy versus conventional pancreaticojejunostomy: a prospective randomized study. *Ann Surg* 2008;248:930–938.
- 63 Rault A, SaCunha A, Klopfenstein D, et al: Pancreaticojunal anastomosis is preferable to pancreaticogastrostomy after pancreaticoduodenectomy for longterm outcomes of pancreatic exocrine function. *J Am Coll Surg* 2005;201:239–244.
- 64 Morera-Ocon FJ, Sabater-Orti L, Muñoz-Fornier E, et al: Considerations on pancreatic exocrine function after pancreaticoduodenectomy. *World J Gastrointest Oncol* 2014;6:325–329.
- 65 Ishikawa O, Ohigashi H, Eguchi H, et al: Long-term follow-up of glucose tolerance function after pancreaticoduodenectomy: comparison between pancreaticogastrostomy and pancreaticojejunostomy. *Surgery* 2004;136:617–623.
- 66 Hu MG, Zhao GD, Luo Y, et al: [Clinical applications of laparoscopic pancreatectomy]. *Zhonghua Yi Xue Za Zhi* 2010;90:1948–1951.
- 67 Lai EC, Yang GP, Tang CN: Robot-assisted laparoscopic pancreaticoduodenectomy versus open pancreaticoduodenectomy – a comparative study. *Int J Surg* 2012;10:475–479.
- 68 Chalikhonda S, Aguilar-Saavedra JR, Walsh RM: Laparoscopic robotic-assisted pancreaticoduodenectomy: a case-matched comparison with open resection. *Surg Endosc* 2012;26:2397–2402.
- 69 Buchs NC, Addeo P, Bianco FM, et al: Robotic versus open pancreaticoduodenectomy: a comparative study at a single institution. *World J Surg* 2011;35:2739–2746.
- 70 Palanivelu C, Jani K, Senthilnathan P, et al: Laparoscopic pancreaticoduodenectomy: technique and outcomes. *J Am Coll Surg* 2007;205:222–230.
- 71 Al-Taan OS, Stephenson JA, Briggs C, et al: Laparoscopic pancreatic surgery: a review of present results and future prospects. *HPB (Oxford)* 2010;12:239–243.
- 72 Correa-Gallego C, Dinkelspiel HE, Sulimanoff I, et al: Minimally-invasive vs open pancreaticoduodenectomy: systematic review and meta-analysis. *J Am Coll Surg* 2014;218:129–139.
- 73 Fronza JS, Bentrem DJ, Baker MS, et al: Laparoscopic distal pancreatectomy using radiofrequency energy. *Am J Surg* 2010;199:401–404; discussion 404.
- 74 Ntourakis D, Marzano E, De Blasi V, et al: Robotic left pancreatectomy for pancreatic solid pseudopapillary tumor. *Ann Surg Oncol* 2011;18:642–643.
- 75 Kang CM, Kim DH, Lee WJ, et al: Initial experiences using robot-assisted central pancreatectomy with pancreaticogastrostomy: a potential way to advanced laparoscopic pancreatectomy. *Surg Endosc* 2011;25:1101–1106.