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REVIEW ARTICLE

Complications of pancreatic surgery

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Abstract
Pancreatic resection is the only treatment option that can lead to a meaningful prolonged survival in pancreatic cancer and, in some instances, perhaps a potential chance for cure. With the advent of organ and function preserving procedures, its use in the treatment of chronic pancreatitis and other less common benign diseases of the pancreas is increasing. Furthermore, over the past two decades, with technical advances and centralization of care, pancreatic surgery has evolved into a safe procedure with mortality rates of $<5\%$. However, postoperative morbidity rates are still substantial. This article reviews the more common procedure-related complications, their prevention and their treatment.

Key Words: *Abscess, chronic pancreatitis, complication, fistula, haemorrhage, morbidity, mortality, pancreatic cancer, pancreatic surgery, somatostatin*

Introduction

Pancreatic surgery, in particular pancreaticoduodenectomy (PD), has been called a ‘formidable’ operation [1]. It is not only a technical challenge to surgeons, it is also demanding for patients, and it exerts a substantial logistical strain on healthcare resources. Resection of the pancreatic head includes the standard PD popularized by Whipple, as well as its modifications such as the pylorus-preserving (PP) PD and the duodenum-preserving pancreatic head resection (DPPHR). Distal pancreatectomy is used to resect lesions in the body and/or tail of the pancreas. Early series published in the late 1960s reported postoperative morbidity rates of 60% and mortality rates approaching 25% [2]. Since that time, significant advances have been made. Crist *et al.* observed that, over a 17-year period, there was a gradual reduction of mortality from 11% to 2% and of complications from 41% to 36% [3]. More recent series from specialized surgical centers have reported mortality rates following PD to be less than 5% [1,4–6]. However, morbidity rates remain high (30%–60%) [2,4,7]. Whilst the majority of perioperative complications are not life-threatening, they can, however, amount to increased lengths of stay and costs, and for cancer patients, delays in adjuvant therapy.

Pancreatic cancer is the fourth and fifth leading cause of cancer-related death in men and women respectively in the United States [8], as in Europe [9]. Pancreatic cancer is notoriously resistant to non-surgical forms of oncological treatment such as radio-, chemo-, and immunotherapy [10–14]. Surgical resection offers the only chance for cure for pancreatic cancer [15,16]. PD is also the primary treatment for resectable periampullary tumors. It has been shown that curative resection is the single most important factor determining the outcome in patients with pancreatic adenocarcinoma [17].

Surgery is also becoming increasingly important in the treatment of chronic pancreatitis. The main goals of surgery are the relief of intractable pain and decompression of adjacent organs [18]. Modifications to the Whipple procedure to preserve anatomic and functional structures have led to complete pain relief in about 75%–82% [19,20]. Long-term pain relief and excellent long-term survival have also been documented [21]. In addition, surgical treatment of chronic pancreatitis using a resectional procedure is associated with a very low mortality of less than 3%. While no apparent difference in mortality rates has been found among standard PD, PPPD and DPPHR, the duodenal-preserving procedures are associated with significantly lower morbidity rates, ranging between 9% and 22% [18].

Therefore, despite the risks, pancreatic surgery continues to be a viable undertaking. With 30-day mortality rates of 5%, or even less, being commonly reported today [22], focus has now turned on attempts to lower the morbidity rates, especially since

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Table I. Hospital mortality after pancreaticoduodenectomy–results of low- and high-volume centers and selected results from specialized centers

		Hospital mortality (%)	
Lead author (state and country)	Year	High-volume centers	Low-volume centers
Liebermann (New York, USA) [32]	1995	2.2	19.0
Gouma (Netherlands) [33]	1997	1	16
Bramhall, Neoptolemos (UK) [34,35]	1995/1997	5.9	28
Gordon (Maryland, USA) [36]	1997	1.8	14.2
(Finland) [37]	1996	4.8	11.0
Birkmeyer (Nationwide, USA) [38]	1999	4.1	16.1
Trede [119]	1985–1990	0	
Fernandez-del Castillo [112]	1990–1994	0.4	
Yeo [1]	1990–1996	1.4	
Büchler [26]	1993–1999	2.1	

postoperative complications contribute to the overall mortality [23,24]. Medical complications evoked as a consequence of surgery include cardiac problems, cerebrovascular accidents, respiratory distress, renal dysfunction, pneumonia, pulmonary embolism, hepatic and metabolic dysfunction. Due to improved perioperative intensive care, medical complications such as myocardial, pulmonary and thromboembolic problems have dramatically decreased [18]. The postoperative medical complication rate is in the order of 4%–19% [25]. Consequently, efforts to reduce morbidity rates are now tuned to the four most frequent procedure-related complications [26] following pancreatic resection, namely pancreatic fistula, delayed gastric emptying (DGE), septic complications in particular intra-abdominal abscess, and abdominal hemorrhage.

Who should perform pancreatic resection: the role of caseload

The dramatic decline in mortality after PD represents the most impressive advance of pancreatic surgery during the past two decades [18]. Many factors have contributed to this phenomenon, including better understanding of pancreatic diseases, careful preoperative assessment, advances in diagnostics, better patient selection and improvements in perioperative care. The development of a variety of surgical techniques has also allowed a more individualized, disease-directed approach [27–30]. But perhaps one of the most critical contributing factors is the concept of centralization. This stemmed from the recognition of the association between high patient volumes (caseloads) and good outcome [31], as demonstrated by various publications (Table I). The development of such specialist pancreatic centers has been credited with the dramatic improvement of the immediate outcome following pancreatic resectional surgery. Subsequently, another study found that hospital volume strongly influenced long-term survival after PD. This suggests that better patient selection and differences in quality of care may underlie better outcomes at such high-volume centers [39]. However, sporadic publications of excellent results have also been reported from dedicated centers at community hospitals and university centers [40–42]. Some of these centers are not high-volume centers [42]. This challenged the notion that hospital size is a determining factor and the theory that 'practice makes better and safer'. Birkmeyer *et al.* [43] investigated the association between surgeon volume and operative mortality, and the extent to which the observed effects of hospital volume can be explained by the experience of the surgeon. They found that, while for many procedures the observed associations between hospital volume and operative mortality are largely mediated by surgeon volume, this was not the case for pancreatic resection. For pancreatic surgery, patients at high-volume hospitals had lower mortality rates than those at low-volume hospitals, regardless of the surgeon volume. Many other mechanisms may be at play. High-volume hospitals have a broader range of specialist and technology-based services, better-staffed intensive care units, and other resources that are not available at smaller centers. In addition, such referral centers tend to have a higher level of experience in the various departments involved in the detection and management of postoperative complications, such as gastroenterology and radiology.

Besides using volume as a marker of quality, postoperative complications are a valid indicator of quality of care. Dimick *et al.* [44] found that pancreatic resection at high-volume hospitals had a lower risk of aspiration, pneumonia, pulmonary failure, renal failure and septicemia. However, interestingly, the rates of surgical complication were not significantly different between high-volume hospitals and low-volume hospitals. This finding again reinforces that while surgical expertise is necessary, this is not sufficient to guarantee optimal outcomes after high-risk operations. Notwithstanding, the overwhelming evidence today indicates that for high-risk procedures, better outcomes can be achieved at high-volume centers where one is more likely to find high-volume surgeons as well as resources that are better equipped to deliver the complex perioperative care required by patients who are undergoing high-risk surgery. The finding that patients with one or more complications after pancreatic resection had a mortality of 18% versus only 5.2% for those without complications [44] further underscores the importance of initiatives to reduce morbidity rates. We shall now review the four most frequent procedure-related complications, and discuss their prevention and treatment.

Pancreatic leakage

The pancreaticoenteric anastomosis is the Achilles heel of PD and its modifications. Drainage of the pancreatic remnant to the gastrointestinal tract remains a crucial step, but it runs the risk of anastomotic breakdown. Most leaks may run a benign course, requiring just maintenance of intraoperatively placed drains [45]. However, if it leads to retroperitoneal sepsis with abscess formation and/or destruction of the surrounding tissues and blood vessels with the potential for severe hemorrhage, it is the major cause of postoperative mortality [46].

The reported incidence of pancreatic leaks varies widely. This can perhaps be explained by different definitions and reporting of pancreatic leakage, differences in the underlying disease, and different surgical techniques. The Heidelberg and Johns Hopkins units used a similar definition, namely drainage of >50 ml of amylase-rich fluid per day from intra-abdominal drains, on or after the tenth postoperative day. However, many of these leaks are clinically insignificant [45]. Furthermore, the use of operative site drains has recently been brought into question. A study by Conlon *et al.* [47] failed to show a significant reduction in surgical morbidity with peritoneal drainage. But instead, a significantly increased proportion of patients in the drain group developed intraperitoneal sepsis, fluid collection or fistula. Consequently, here in Heidelberg, we have changed our practice towards the earlier removal of drains, by the second or third postoperative day. In light of these findings, with the declining use of peritoneal drains or their earlier removal, there is perhaps a need to universally adopt a definition that emphasizes the clinical significance rather than one just based on amount of drainage fluid output or its amylase content per se. Furthermore, peritoneal drain outputs cannot differentiate a true pancreaticoenteric anastomosis breakdown from extravasation of pancreatic secretions from the pancreatic stump, which is usually clinically unimportant [48]. A clinical leak occurs when the drainage of amylase-rich drainage fluid is associated with fever, leukocytosis, sepsis or the need for percutaneous drainage of an amylase-rich fluid collection [2] or confirmation of pancreatic anastomosis breakdown through fistulogram [49]. Data from level 1 studies have shown a pancreatic leak rate following PD and its modifications to be from 0% to 13% [18]. The associated mortality of pancreatic leaks has markedly declined over the past two decades, now ranging between 0% and 5% [18]. This remarkable feat, when compared to previously reported rates of 40% [45], perhaps reflects the advancement in diagnostics and perioperative management that allows the early and aggressive management of this complication [50].

In the approach to pancreatic leaks, prevention is certainly better than cure. Particular risk factors for breakdown of the pancreatic anastomosis are a soft parenchymal texture of the pancreatic remnant, the duct size, the size of the remnant gland, the degree of pancreatic exocrine function and the anastomotic technique [46]. A distinct association was found between the size and the degree of fibrosis of the remnant gland, and the occurrence of complications [51,52]. It is logical that a fibrotic remnant will facilitate the performance of the pancreaticoenteric anastomsis, while a soft and friable gland will make it more difficult. The secretion capacity of the remnant gland is also a determining factor, as continuous pancreatic secretion has been hypothesized to hinder healing of the pancreatic stump [53]. The exocrine function has an inverse relationship to the degree of parenchymal fibrosis [54]. Patients with chronic pancreatitis best exemplify this. It is therefore not surprising that the results of a review of 2,664 pancreatic resections showed that the pancreatic fistula rate in chronic pancreatitis was 5%, whilst that for pancreatic cancer, ampullary cancer and bile duct cancer are 12%, 15% and 33% respectively [55]. While nothing can be done about the texture of the parenchyma intraoperatively, pharmacological manipulation of the pancreatic exocrine function is possible.

Role of prophylactic octreotide after pancreatic resection

Octreotide is the octapeptide analogue of somatostatin which is a powerful inhibitor of pancreatic exocrine secretion. A number of randomized prospective trials have examined the role of prophylactic perioperative octreotide and its impact on the outcome after pancreatic surgery (Table II). Four level 1 multi-center studies from European centers used a similar protocol with the first doses given preoperatively, followed by three daily doses of 100 μg for 7 days [51,56–58]. In contrast, two single-center North American studies in patients with pancreatic cancer used daily doses of 150 μg or 250 μg given for 5 or 7 days [52,59], while a multicenter study used vapreotide 0.6 mg twice daily for 7 days [60]. Each European study showed a 40%–50% decrease in overall morbidity rates, with two of the four trials reporting a specific reduction in pancreatic leak rates [57,58]. A meta-analysis that used these four European trials further concluded that the use of octreotide was a cost-effective strategy [61].

Table II. Outcomes data for prospective randomized controlled trials of prophylactic somatostatin analogues versus placebo for patients undergoing elective pancreatic resection

			Pancreatic fistula (%)		Overall morbidity (%)		Overall mortality (%)	
Author	Year	*N*	Placebo	Octreotide	Placebo	Octreotide	Placebo	Octreotide
Büchler [51]	1992	246	38	18	55	32*	5.8	3.2
Pederzoli [56]	1994	252	19	9	29	16*	3.8	1.6
Montorsi [57]	1995	218	20	9*	36	22*	5.6	8.1
Friess [58]	1995	247	22	10*	30	16*	0.8	1.6
Lowy [59]	1997	110	6	12	25	30	0	2
Yeo [52]	2000	211	11	9	34	40	0	1
Sarr** [50]	2003	275	23	24	26	30	1	0
Suc [53]	2004	230	19	17	37	29	7	12

* $p < 0.05$ versus corresponding control group. ** this group used vapreotide instead of octreotide.

All North American studies, however, failed to demonstrate any benefits. A recent multicenter study from France showed that the usefulness of octreotide is somewhere between the conclusions of the European studies, which advocated its routine use, and those of the North American trials, which concluded that it was useless [53]. While octreotide decreased (though not significantly) the rate of intra-abdominal complications, its use significantly decreased intra-abdominal complication rates in certain patient subsets, namely those whose pancreatic duct was less than 3 mm and when PD was completed by pancreatojejunostomy (PJ). In agreement with Li-Ling and Irving [62], who reviewed this topic recently, while current studies have shown that prophylactic administration of octreotide did not uniformly reduce the incidence of pancreatic leak, overall morbidity or mortality after pancreatic resection, a subset of patients might benefit from it. Octreotide use is recommended in high-risk pancreatic glands (soft consistency with small duct) and in centers with leak rates greater than 10% [2]. To be effective, the first dose must be given 1–2 hours preoperatively followed by 3 doses of 100 μg for 5–7 days [18].

Role of surgical technique following PD

The surgical management of the pancreatic stump following PD demonstrates how science and art can be applied in unison. Various surgical techniques to deal with the pancreatic stump have been described with the aim of achieving low pancreatic leak rates. With regard to the pancreaticoenteric reconstruction, creative techniques like end-to-side PJ, end-to-end (invaginating/telescoping) PJ, pancreaticogastrostomy (PG) have been used. In a recent report, using a creative technique called 'binding PJ', the authors have reported impressive results in 150 consecutive patients [63]. Efforts have also targeted the pancreatic duct, and include ductal occlusion or drainage. Sealing of the pancreaticoenteric anastomosis using fibrin glue has also been proposed. With regard to the performance of pancreatic transection, a group from Japan experimented with ultrasonically activated shears (UAS) [64]. They found that UAS eliminated bleeding and pancreatic juice leakage from the branches of the PD, thereby keeping the cut surface dry, which consequently facilitated the anastomosis.

With such a myriad of techniques and innovations to choose from, one needs to consider the evidence behind each of these. Investigators at the Johns Hopkins Hospital prospectively compared PJ and PG [65]. The incidence of pancreatic anastomotic leak was 11% for PJ and 12% for PG reconstructions. Another group compared end-to-end (invaginating/telescoping) anastomosis to the end-to-side (duct-to-mucosa) anastomosis in a prospective, randomized trial [66]. The end-to-end invaginating technique was associated with higher pancreatic leak rates. Increasingly, more reports on the safety of the duct-to-mucosa end-to-side PJ have been published since [4,26,67–69]. Addition of a temporary external stent to the pancreatic duct has been hypothesized to further reduce the leak rate, and indeed this has been shown in a prospective non-randomized study where the fistula rate was reduced from 29% to 7% [70]. Other groups, however, have not observed similar benefits [23,71,72]. In contrast, ductal occlusion was shown unequivocally to have higher fistula rates, in addition to increasing the risk of pancreatic exocrine and endocrine insufficiency [73]. The role of fibrin glue, whether for temporary ductal occlusion or sealing of the pancreaticoenteric anastomosis, has been shown to be ineffective in preventing intra-abdominal complications by three controlled trials [73–75].

These are but some of the studies that have shed some light on a largely gray area, and they have given us some sense of where we might tread safely. However, most of these technical issues will remain controversial [46]. As such, for now, the preference of the surgeon and the technique with which the surgeon feels comfortable with will prevail.

Treatment of pancreatic leak

The key to the successful management of an established leak is early recognition. Subsequent management algorithm will be dictated by the patient's condition. The general consensus is for conservative management in the absence of peritonitis, sepsis, hemorrhage or organ failure [4,25,46]. This would consist of effective control of the leak through some form of external drainage, intravenous antibiotics, adequate nutritional support and close monitoring [45]. Abdominal computed tomography (CT) scans are mandatory to exclude intra-abdominal fluid collections or abscess. The value of octreotide in the treatment of established pancreatic fistula is not clear, with studies showing conflicting results [76–80]. The majority of cases (70%–90%) with low-output fistula can be successfully managed in this manner.

On the other hand, early intervention is indicated if there is an appreciable major complication that cannot be managed by other means, such as hemorrhage or an uncontrollable fistula [45,50,81]. The degree of destruction and inflammation in the retroperitoneum will likely determine the surgical strategy as well as prognosticate its success. Completion pancreatectomy is said to be able to salvage up to 50% of patients [50,81]. Other procedures short of completion pancreatectomy include extensive peripancreatic drainage with or without continuous irrigation, or occlusion of the pancreatic duct [45]. Such 'lesser' procedures are often insufficient [82].

Intra-abdominal abscess

The incidence of intra-abdominal abscess following pancreatic resection ranges from 1% to 12% [25], and is frequently secondary to an anastomotic leak at the pancreaticoenterostomy, hepaticojejunostomy, gastrojejunostomy or duodenojejunostomy. These often manifest as right subhepatic or left subdiaphragmatic collections [46,83]. Whenever an intra-abdominal collection is suspected, a high-quality contrast-enhanced CT should be performed. The preferred method of drainage is by percutaneous radiologically-guided technique. For as long as the underlying cause (fistula, leakage) is controlled, such measures are usually adequate. Surgical exploration and drainage become necessary should such measures fail.

Hemorrhage

Postoperative bleeding occurs in 3%–13% of patients following pancreatic surgery as reported by some recent series [4,53,84]. The incidence of bleeding complications appears to be related to the type of resection. The duodenum-preserving procedures (Beger and Frey) tend to be associated with a slightly increased rate of gastrointestinal hemorrhage, ranging from 5% to 10% [18]. Reactionary hemorrhage (within the first 24 hours) is often the result of inadequate hemostasis at the time of surgery, a slipped ligature or bleeding from an anastomosis. While in the latter case, management is initially conservative, immediate reoperation is usually necessary in the former situations. Stress ulcer can be prevented by prophylactic use of acid secretion inhibitory agents. In any case, it usually can be managed medically and/or endoscopically [85]. Another cause of early postoperative bleeding is diffuse hemorrhage from the retroperitoneal operation field. Because of its widespread nature, an underlying coagulopathy might be a plausible cause. Coagulation disturbances are frequently seen in jaundiced patients. This hypothesis is supported by a multiple-variant regression analysis which identified jaundice (bilirubin level >5.8 mg/dl) as a significant risk factor for postoperative hemorrhage [86]. Other groups have also observed this association [85,87]. This calls to question the role of preoperative biliary drainage (PBD). There are at least two meta-analyses published on this subject. Sewnath *et al.* [88] found that there was no difference in the overall death rate between patients who had PBD and those who had surgery without PBD. Instead the overall complication rate was significantly adversely affected by PBD. The length of hospital stay was also prolonged. They concluded that PBD carries no benefit. In the more recent meta-analysis, Saleh *et al.* [89] found no evidence of either a positive or an adverse effect of preoperative biliary stent placement on the outcome of surgery in patients with pancreatic cancer. The role of PBD in patients with biliary obstruction undergoing PD remains, at best, controversial. Despite this, in clinical practice in Europe as well as in the United States, most patients with jaundice who present to the surgeon would have already received biliary stenting [84]. Unless the risks of PBD are proven conclusively through randomized trials, the treatment policy of the gastroenterologist will probably remain the same.

In contrast to early hemorrhage, late hemorrhage (1–3 weeks following surgery) often has a more sinister underlying cause. It is often secondary to an anastomotic leak with consequent erosion of retroperitoneal vessels [90]. The associated mortality rates ranged from 15% to 58% [87,91]. Another sinister cause is a pseudoaneurysm. Diagnostics would include endoscopy to exclude an intraluminal source, and contrast-enhanced CT to look for evidence of a leak. Selective angiography could be considered if a bleeding source could not be identified by endoscopy. Bleeding from the pancreaticojejunostomy is a particularly challenging problem. Management choice includes completion pancreatectomy or refashioning of the anastomosis.

Delayed gastric emptying

With the decline in the incidence of pancreatic leaks, DGE has emerged as the leading procedure-related morbidity [1,4]. The reported incidence ranged from

8% to 45% [18]. This wide range may be due to different definitions used, as there is still no accepted general criterion. It has been previously attributed specifically to pylorus preservation. There are eight studies (evidence level I and II) comparing PD and PPPD. While three studies showed no difference, three favored PPPD, and two showed lower DGE rates after PD compared to PPPD [26,92–98]. Only duodenum-preserving procedures compared favorably [26,92,99]. Therefore PD has no clear advantage concerning DGE when compared to PPPD, whilst for chronic pancreatitis with focal disease in the head, duodenum-preserving procedures probably offer significant advantages. On the other hand, presence of postoperative complications other than DGE [92,93,100] and extended radical surgery significantly increased the rates of DGE [101,102]. Horstmann *et al.* showed that patients without any complications had a DGE rate of 1%. But this climbed to 28% and 43% in the presence of moderate and severe postoperative complications [92]. Cameron *et al.* demonstrated that extended lymphadenectomy not only did not translate into longer survival, it significantly increased the rate of complications including DGE (16% versus 6%) [101].

A mechanical etiology for DGE has also been proposed, and this relates to the method of reconstruction of the gastrointestinal continuity, which may cause transient torsion or angulation of the duodenojejunostomy. One group believed that a retrocolic reconstruction using a single jejunal limb for all three anastomoses was responsible for much of their DGE. Postoperative gastroparesis may lead to temporary gastric distension, which can then potentially lead to angulation of the anastomosis because it lies relatively fixed through its retrocolic position. Additionally, the close proximity of the duodenojejunostomy to the pancreaticojejunostomy also predisposes the incidence of DGE in the event of a small pancreaticojejunostomy leak or a transient postoperative remnant pancreatitis. Since adopting an antecolic technique, their incidence of DGE has dropped from 28% to 12%. Then there are those who believed that the real culprit is an antecolic reconstruction [100], predisposing the relatively fixed stomach to angulation or torsion. By placing the duodenojejunstomy in the infracolic compartment through a mesenteric window, and away from the pancreatic and biliary anastomosis, which lie in the supracolic compartment, the risk of DGE caused by local inflammation is reduced.

Whilst DGE mostly resolves spontaneously, it is still a major source of discomfort to the patients because of the prolonged gastric decompression, not to mention prolonged hospital stay and higher healthcare costs. Yeo *et al.* [103] have shown that DGE could be reduced by up to 37% following PD with intravenous erythromycin, a motilin agonist. But if such measures still fail, the immediate task is to exclude concomitant intra-abdominal complications, since DGE may herald an otherwise undetected pancreaticoenteric or bilioenteric anastomotic leak. Treatment consists of nasogastric decompression, attention to nutritional support, reassurance and watchful waiting.

PD for chronic pancreatitis

There are four types of resection of the head of the pancreas for focal disease in chronic pancreatitis: standard PD, PPPD, the Beger procedure, the Frey procedure and its modifications [104]. With the exception of total pancreatectomy, the reported operative mortality of operations for chronic pancreatitis is less than 3% [19], but yet able to achieve long-lasting pain relief in about 75%–80% of those treated [105]. The early and late morbidity after PD is related to the reduction in insulin secretion, the occurrence of early and late dumping complaints, and attacks of cholangitis [20]. This formed the rationale behind the use of these organ-preserving pancreatic head resections, with the major advantage being derived from conservation of the endocrine capacity, and preservation of the stomach, duodenum and bile duct. Certainly, being a lesser procedure, when compared to PD, postoperative morbidity rates following such local pancreatic head resection are predicted to be lower. In a prospective randomized trial by Izbicki *et al.* [99] comparing PPPD with the Frey's procedure, the postoperative morbidity rates were 53.3% for the former and 19.4% for the latter. DGE was observed to occur only in the PPPD group. However, when the Frey procedure was compared with the Beger procedure in another prospective randomized study [106], the postoperative morbidity rates were not significantly different (22% versus 32%). As reported in the seminal review by Bartoli *et al.* [55], the risk of pancreatic leak was the lowest in those with chronic pancreatitis. This is not surprising as, in most cases, the gland is fibrotic and there is usually some degree of exocrine insufficiency. Such factors would enhance the safety of the pancreatic anastomosis. However, in a recent report by Büchler *et al.* [26], the fistula rate was almost similar between patients with chronic pancreatitis (2.3%) and patients without pancreatitis (2.0%). We may have perhaps arrived at an era when technical refinements and advances in perioperative care can offset the risks posed by a soft gland.

With regard to the long-term sequelae of the endocrine and exocrine functions, studies have shown that, given time, there was no difference in the incidence of diabetes between operated patients and non-operated patients [107]. This suggests that, with regard to endocrine status, progression of disease has a greater impact than the surgical intervention. In contrast, two randomized studies had showed better weight gain and lower rates of exocrine insufficiency after the Beger procedure when compared to the standard PD and PPPD [28,108]. The postoperative exocrine function was comparable between the Frey procedure and the Beger procedure [106].

Morbidity following distal pancreatectomy

Distal pancreatectomy has long been held as a lesser, and hence safer, procedure when compared to resection of the pancreatic head. Published complication rates following distal pancreatectomy had ranged from 22% to 37% [109,110], thus challenging this notion. The reason behind such morbidity rates may be the incidence of pancreatic leak, which has been reported to be as high as 26% in a recent series [111]. Büchler *et al.* [4] observed that the pancreatic leak rate was in fact significantly higher following distal pancreatectomy (5.7%) when compared to pancreatic head resections (3.2%). Various factors have been implicated as having a bearing on the development of pancreatic leak. These include method of stump closure, underlying disease process and concomitant splenectomy [111].

The conventional method for preventing leakage of pancreatic juice from the cut surface is ligation of the main pancreatic duct and additional suturing of the stump to approximate the anterior and posterior capsule [112]. With the advent of surgical stapling devices, a new tool was added to the armamentarium of techniques for sealing the pancreatic stump, which includes harmonic scalpel, fibrin glue and prolamine injection. Stapling has been touted as simple, quick and secure. However, three groups reported no difference in pancreatic leak rates when the stump was stapled or sutured [110,111,113]. Perhaps the trick lies in the type of staples used. Kajiyama *et al.* [114] reported that the use of the Multifire GIA 80 stapler (US Surgical Corporation, Norwalk, CT, USA) was associated with a lower leak rate when compared to the TA-55 staple (Autosuture, Ascot, UK). Consequently, Takeuchi *et al.* [115] reported an impressive zero fistula rate with the use of the Powered Multifire GIA 60. A point to note is that all these reports were retrospective non-randomized reviews of individual centers' experience. As always, properly conducted prospective randomized controlled trials are needed to resolve this issue.

Emergency distal pancreatomy, especially for trauma, has also been identified as a risk factor for development of complications [111,116]. Complications in general occurred at a rate of 50% in trauma patients compared to 11% in elective patients [111]. This might be confounded by the presence of concomitant injuries to other organ systems. As for pancreatic leak, the incidence in trauma patients was 60% compared to 11% for patients who had elective distal pancreatectomy. It remains unclear if the leak after distal pancreatectomy for trauma is related to the method of closure or to additional trauma to the pancreas. Concomitant splenectomy has not been shown to influence the pancreatic leak rates [109,117,118]. Fortunately, most of these fistulae heal with external drainage and seem to have fewer propensities to cause further complications. This is perhaps because the pancreatic secretion is not activated through contact with intestinal enzymes.

Conclusion

Despite being labeled as a 'formidable' task, pancreatic surgery has evolved into a safe procedure with mortality rates of <5% reported by high-volume centers. One of the main contributors to this achievement is the concept of centralization. While the surgeon's experience is important, the pooling together of multidisciplines in such high-volume centers and dedicated staff experienced in the diagnosis and management of complications have no doubt contributed to this phenomenon. Adjunctive therapeutics like the use of octreotide and preoperative biliary drainage have yet to be unequivocally proven to be beneficial. Increasingly, the duct-to-mucosa pancreaticojejunostomy is recognized to be a safe anastomotic technique. Consequently DGE has now emerged to be the most common postoperative morbidity. The development of organ-preserving pancreatectomy has given additional choices for patients with chronic pancreatitis or benign pancreatic tumors. Such procedures, like the Beger procedure and the Frey procedure, combines good efficacy for pain relief with low surgical morbidity and mortality. While distal pancreatectomy has low mortality rates, the incidence of complications and, in particular, pancreatic leaks are still substantial. Further studies and research will, no doubt, be focused on strategies to lower the morbidity rates of pancreatic surgery.

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