JOP. J Pancreas (Online) 2007; 8(1 Suppl.):102-113.

CONFERENCE REPORT

Vascular Complications of Pancreatectomy

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Summary

Despite decreased postoperative mortality, pancreatic resections continue to be associated with high morbidity rates. Vascular complications and, in particular, erosive bleeding from the large retroperitoneal vasculature are particularly difficult to treat and account for a large percentage of the residual postoperative mortality of pancreatic resections. We herein analyze the pathogenesis, diagnosis, preventive measures and possible remedies of either hemorrhagic or occlusive complications of pancreatic resections through a review of the literature and of our institutional experience consisting of 818 pancreatectomies.

Introduction

Post-operative mortality following pancreatectomy has considerably decreased over the past three decades and is currently below 5% in most large volume centers [1, 2]. Interestingly, this important result does not have a parallel reduction in post-operative morbidity which, instead, remains between 25.6% and 79.1% [3, 4, 5, 6, 7], but is explained by improved management of most life-threatening complications [8]. The prognosis of vascular complications, however, has not improved to the same extent and continues to have a high mortality rate, especially in the case of delayed erosion of large retroperitoneal peripancreatic vessels [9, 10, 11]. We herein review the pathogenesis, diagnosis, preventive measures and possible remedies of vascular complications associated with pancreatectomy through an analysis of our institutional experience.

Materials and Methods

Between November 1987 and August 2006, the clinical, operative, and pathologic data of 818 consecutive pancreatic resections were prospectively collected and put into a computer data base (Table 1). Overall, out of the 562 right-sided resections and pancreatectomies the entire stomach was preserved in 391 patients (69.6%) undergoing either a right-sided pancreatectomy (352) or a total pancreatectomy (39). Laparoscopy was considered only for left-sided resections especially if the pancreatic lesion was thought to be benign or low-grade. During conventional surgery, conservation of the spleen was always associated with preservation of the splenic vessels while, in 2 laparoscopic operations, the main trunks of both the splenic artery and the splenic vein were removed en-bloc with the specimen, as originally described by Sutherland *et al*. for

Table 1. Baseline characteristics.

Age: mean (range); years	**62.5 (15-88)**
Sex: males	**437 (53.4%)**
Type of resection	
- Pancreaticoduodenectomy	467 (57.1%)
- Total splenopancreatectomy	69 (8.4%)
- Spleen-preserving total pancreatectomy	26 (3.2%)
- Distal splenopancreatectomy	216 (26.4%)
- Spleen-preserving distal pancreatectomy	32 (3.9%)
- Central pancreatectomy	5 (0.6%)
- Enucleation	3 (0.4%)
Laparoscopic resection	**22 (2.7%)**
- Distal splenopancreatectomy	9 (1.1%)
- Spleen-preserving distal pancreatectomy	13 (1.6%)
Resection of peripancreatic vessels	**157 (19.2%)**
- Isolated venous segment	119 (14.5%)
- Isolated arterial segment	17 (2.1%)
- Multiple segments	21 (2.6%)
Resection of additional viscera	**99 (12.1%)**
- Liver lobectomy	2 (0.2%)
- Liver segmentectomy	4 (0.5%)
- Total gastrectomy	40 (4.9%)
- Right hemicolectomy	15 (1.8%)
- Nephrectomy	12 (1.5%)
- Resection of other abdominal organs	26 (3.2%)
Previous laparotomy/palliation	**77 (9.4%)**
Neoadjuvant treatments	**12 (1.5%)**
- Chemotherapy	2 (0.2%)
- Chemoradiotherapy	10 (1.2%)
Pathology	
- Ductal adenocarcinoma	364 (44.5%)
- Distal cholangiocarcinoma	32 (3.9%)
- Carcinoma of the papilla of Vater	63 (7.7%)
- Neuroendocrine tumor	71 (8.7%)
- Intraductal papillary mucinous tumor	25 (3.1%)
- Cystic mucinous tumor	31 (3.8%)
- Cystic serous tumor	34 (4.2%)
- Other tumor types	132 (16.1%)
- Chronic pancreatitis/benign histology	66 (8.1%)

segmental pancreas graft procurement from live donors [12] and subsequently used by Warshaw for distal pancreatic resection [13]. In 77 patients, a pancreatectomy was carried out after previous palliative therapy which was intended to be either the definitive treatment (73/77; 94.8%) or the initial step of a multimodality treatment with planned surgical re-exploration (4/77; 5.2%). Closed suction drains were placed retroperitoneally in proximity of digestive and/or vascular anastomoses in all patients.

Post-operative mortality was defined as any procedure-related death occurring during the post-operative period, even when it exceeded the 30th day. Post-operative morbidity included all events requiring specific intervention and/or resulting in prolongation of the hospital stay.

Vascular complications were categorized into occlusive and hemorrhagic. Occlusive complications were limited to stenosis/obstruction of the large visceral arteries resulting in a poor blood supply to the upper abdominal viscera leading to abscess formation, infarction, anastomotic dehiscence and/or organ failure. Hemorrhage was defined as any bleeding requiring specific intervention. Bleeding occurring during the first post-operative week was considered "early". Hemorrhage arising afterwards was defined as "delayed" and was further classified based on the site of origin (i.e., gastrointestinal or intra-abdominal). Finally, sentinel bleeding was defined as any hemorrhage preceding a major bleeding episode requiring urgent treatment [9, 14, 15].

Results

Overall, 316 patients were diagnosed with at least one postoperative complication (morbidity rate: 38.6%) and 48 of them subsequently died (mortality rate: 5.9%) (Table 2).

Table 2. Post-operative morbidity and mortality.

	Morbidity	Mortality
Overall (n=818)	**316 (38.6%)**	**48 (5.9%)**
Type of resection		
- Pancreaticoduodenectomy (n=467)	218 (46.7%)	25 (5.4%)
- Total splenopancreatectomy (n=69)	27 (39.1%)	8 (11.6%)
- Spleen preserving total pancreatectomy (n=26)	4 (15.4%)	4 (15.4%)
- Distal splenopancreatectomy (n=216)	59 (27.3%)	10 (4.6%)
- Spleen-preserving distal pancreatectomy (n=32)	5 (15.6%)	0
- Central pancreatectomy (n=5)	2 (40.0%)	1 (20.0%)
- Enucleation (n=3)	1 (33.3%)	0
Laparoscopic resection (n=22)	**7 (31.8%)**	**0**
Resection of peripancreatic vessels (n=157)	**56 (35.7%)**	**8 (5.1%)**
Resection of additional viscera (n=99)	**46 (46.5%)**	**8 (8.1%)**
Previous laparotomy/palliation (n=77)	**30 (39.0%)**	**3 (3.9%)**
Neoadjuvant treatments (n=12)	**5 (41.7%)**	**1 (8.3%)**
Pathology		
- Ductal adenocarcinoma (n=364)	155 (42.6%)	20 (5.5%)
- Other tumor types (n=388)	146 (37.6%)	28 (7.2%)
- Chronic pancreatitis/benign histology (n=66)	15 (22.7%)	0

Occlusive Vascular Complications

Occlusive vascular complications occurred in 5 patients (0.6%). Two patients (0.2%) were diagnosed with celiac trunk stenosis/obstruction following interruption of pancreatico-duodenal arcades during pancreaticoduodenectomy or total pancreatectomy (Figures 1 and 2). A diagnosis of occlusive vascular complications was made following the detection of poor/absent pulse in the hepatic and splenic arteries and was confirmed by contact ultrasonography with color-Doppler. Revascularization of the hepato-gastric-spleno-pancreatic (tail) compartment was thought to be necessary only when the arterial blood flow was undetectable at Doppler, and

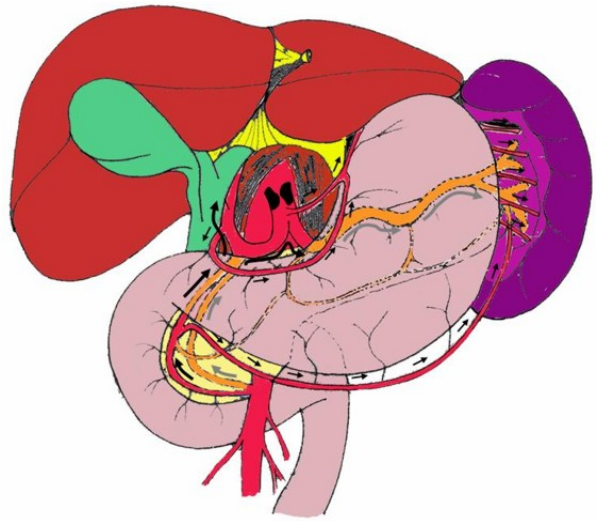

Figure 1. In the presence of occlusion or severe stenosis of the celiac trunk, collateral circulation through the pancreatic head (pancreaticoduodenal arcades) provides an arterial supply to liver, stomach and spleen.

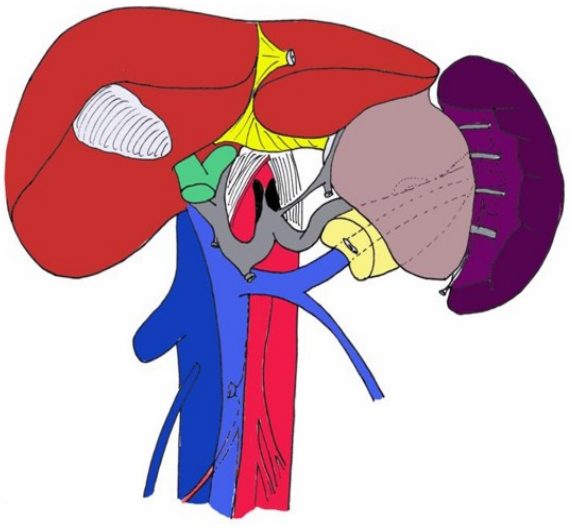

Figure 2. Resection of the pancreatic head interrupts collateral circulation to the liver, distal pancreas, stomach and spleen.

the trial section of the small visceral vessels resulted in scanty arterial bleeding. The remaining patients were managed by watchful waiting. Based on this management strategy, revascularization was deemed necessary in two patients and was achieved by means of a jump bypass between the right renal artery and the stump of the gastro-duodenal artery in a patient undergoing pancreaticoduodenectomy (Figures 3 and 4), and by resection of the stenotic segment with reimplantation of the common hepatic artery in a patient undergoing total pancreatectomy with en-bloc resection of the portal-superior mesenteric vein.

Hemorrhagic Vascular Complications

Early post-operative bleeding occurred in 29 patients (3.5%) after a mean period of 3 days (range 0-7 days). It was usually related to technical failure (e.g., slipped ligature or suture line bleeding) and/or medical reasons (e.g., excessive anti-thrombotic prophylaxis resulting in derangement of the coagulation profile). Early bleeding was not noted more frequently following spleen-preserving procedures and it was rarely associated with profound shock and multiple organ failure. Most patients were either managed non-operatively (transfusion of blood and blood products, and/or percutaneous drainage of fluid collections) or by means of reintervention. Early bleeding, however, prolonged the length of the post-operative stay (29.9 days *vs*. 19.5 days) and, arguably, was associated with a parallel increase in costs, although this issue could not be reliably assessed due to the retrospective nature of this study covering a 19-year period.

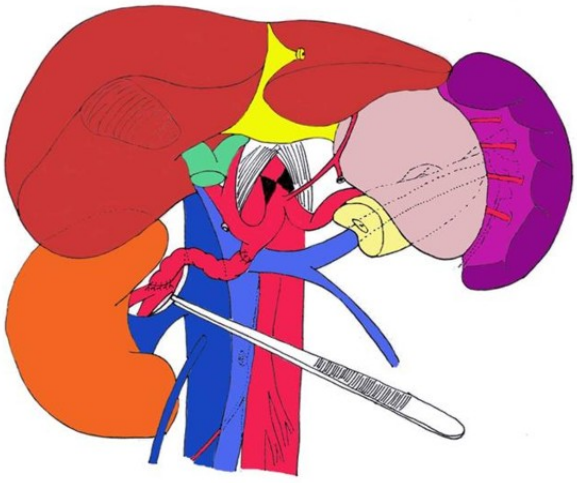

Figure 3. Greater saphenous vein bypass jumping from the right renal artery to the stump of the gastroduodenal artery, thus revascularizing upper abdominal viscera.

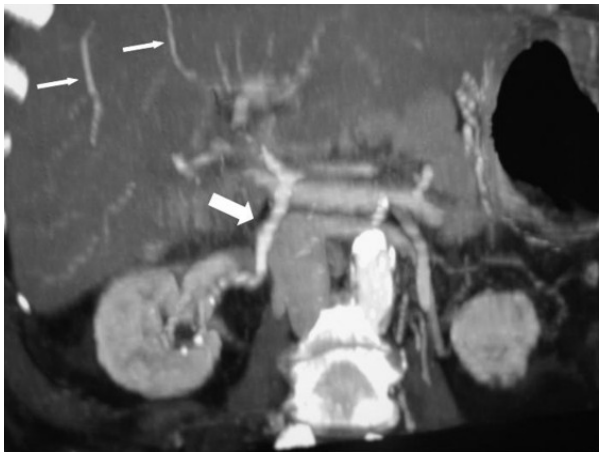

Figure 4. CT scan showing patency of a saphenous bypass (larger arrow) with intrahepatic arterial flow (smaller arrows).

Delayed post-operative bleeding occurred in 19 patients (2.3%) after a mean period of 17.7 days (range 10-33 days) and was heralded by sentinel bleeding in 21.1% of them (4/19). Three bleeding episodes (15.8%) first became evident through the gastrointestinal tract, although the majority of them resulted from erosion of the large retroperitoneal vessels with fistulization into the bowel. In the remaining 16 patients (84.2%) bleeding appeared to be primarily of intra-abdominal origin and was also often related to erosion of the retroperitoneal vasculature. Seven patients (36.8%) developing delayed hemorrhage had a febrile post-operative course and were either diagnosed with or suspected of harboring retroperitoneal abscesses of pancreatic fistulas.

Patients with gastrointestinal bleeding, if hemodynamically stable or readily responding to resuscitation, were first subjected to endoscopy. A gastrointestinal source of bleeding was identified in 10 patients (20.8%) and appeared to be treatable endoscopically in two (20.0%) of them. Overall, permanent

hemostasis was achieved endoscopically in two patients, angiographically (coil embolization) in one patient, and surgically in 35 patients. In 4 patients the bleeding was initially stopped either endoscopically or angiographically but permanent hemostasis could be achieved only by means of repeat surgery.

Bleeding control in patients with intra-abdominal bleeding was attempted in all but one patient with massive arterial bleeding who could not be resuscitated and was not operated on again. In one patient, bleeding was temporarily stopped angiographically by means of coil embolization and subsequently secured surgically. All the remaining 34 patients were immediately operated on again. All but one bleeding episode, originating from erosion of the portal-mesenteric vein, originated from retroperitoneal arteries. The arterial segments involved included the stump of the gastroduodenal artery (n=1), the hepatic artery (n=4), the splenic artery (n=3), the celiac trunk (n=2), and the superior mesenteric artery (n=3). Interestingly enough, erosive bleeding did not occur more frequently following the resection of the vascular segments as compared to standard procedures. Permanent bleeding control was associated with a total pancreatectomy in 7/24 patients undergoing right-sided pancreatectomy (29.2%) and in none of those undergoing distal pancreatectomy. Splenectomy was required in 2 patients in whom the spleen had originally been preserved.

The mortality rates of different bleeding modalities, divided according to type of pancreatic resection, are summarized in Table 3.

Discussion

The high incidence of post-operative complications after pancreaticoduodenectomy is explained by performing an intrinsically complex operation [16, 17] in a patient population with decreased healing powers due to a combination of poor nutritional status, jaundice, ageing [18] and associated co-morbidities [17, 18]. Accordingly, the prevention of complications begins with careful candidate selection and meticulous pre-operative patient preparation. Operative experience also plays a major role [16]. Despite all possible precautions, however, it seems virtually impossible to eliminate post-operative complications including those leading to patient mortality. Indeed, if, on the

Table 3. Vascular complications.

Type of complication	Pancreaticoduodenectomy (n=467)	Total pancreatectomy (with or without splenectomy) (n=95)	Distal pancreatectomy (with or without splenectomy) (n=248)	Central pancreatectomy (n=5)
Occlusion	**2 (0.4%)**	**3 (3.2%)**	**0**	**0**
Causing mortality	0	2 (2.1%)	0	0
Sentinel bleeding	**2 (0.4%)**	**2 (2.1%)**	**0**	**0**
Bleeding (overall)	**34 (7.3%)**	**7 (7.4%)**	**6 (2.4%)**	**1 (20.0%)**
Causing mortality	9 (1.9%)	3 (3.2%)	2 (0.8%)	1 (20.0%)
- Early bleeding	20 (4.3%)	4 (4.2%)	5 (2.0%)	0
Causing mortality	3 (0.6%)	1 (1.1%)	1 (0.4%)	0
- Delayed bleeding	14 (3.0%)	3 (3.2%)	1 (0.4%)	1 (20.0%)
Causing mortality	6 (1.3%)	2 (2.1%)	1 (0.4%)	1 (20.0%)
- Gastrointestinal bleeding	2 (0.4%)	1 (1.1%) [a]	0	0
Causing mortality	1 (0.2%)	1 (1.1%) [a]	0	0
- Abdominal bleeding	12 (2.6%)	3 (3.2%) [a]	1 (0.4%)	0
Causing mortality	5 (1.1%)	2 (2.1%) [a]	1 (0.4%)	0

[a] One case presented associated gastrointestinal and abdominal bleeding

one hand, numerous consecutive series involving over 100 pancreatectomies without operative mortality have been reported by centers of excellence [1, 2]; on the other hand, adding further cases will eventually involve fatalities. Post-operative complications which require reintervention are currently associated with mortality rates between 23 and 67% [17]. Hence, post-operative complications, if not completely preventable, should be recognized as soon as possible and treated as soon as possible by a multidisciplinary team, hopefully, before they progress to a stage when repeat surgery is mandatory.

Post-operative bleeding, especially when delayed and massive, continues to be associated with high mortality rates. As opposed to early bleeding, often caused by technical failure and usually associated with a benign prognosis [16, 19], delayed bleeding frequently originates from the erosion of the retroperitoneal vasculature as a consequence of local sepsis and/or pancreatic fistula [20, 21], and results in profound shock [11]. Even when bleeding can be permanently controlled, the severity of the shock, requiring multiple vasopressors and massive replacement of blood and blood products, often leads to systemic complications and/or failure of multiple organs eventually resulting in patient death [9]. Accordingly, most of the chances of survival depend on early bleeding control. Several predisposing factors, such as febrile post-operative course [9, 10, 11], poorly drained pancreatic fistulae [9, 10, 11], pre-operative radiation with a cumulative dose exceeding 50 Gy [9], especially if associated with an extended lymphatic clearance [9, 11], have been limited to an increased risk of erosive bleeding. However, in most patients, erosive bleeding is unexpected, arising after a seemingly uneventful post-operative course in the absence of well-defined predisposing factors, occurring several weeks after surgery and even after patient discharge [9, 11], and is massive, requiring immediate and vigorous resuscitation. Thus, the management of erosive bleeding is compounded by technical and organizational difficulties. The entire team caring for these patients should therefore be mentally and technically prepared to face this catastrophic complication according to previously agreed upon management algorithms and protocols. At our institution, patients with delayed bleeding are rushed into the operating room while being resuscitated. Endoscopy and/or angiography are then performed, as necessary, with the patient lying on the operating table and with the surgical team ready to intervene. However, if the patient cannot be promptly resuscitated and/or the bleeding cannot be stopped, we prefer to proceed immediately with repeat surgery. Since time is crucial and the eroded vessel is often difficult to reach, due to its retroperitoneal position, the presence of adhesions, a surrounding inflammation, scars, and the interposition of stomach and/or bowel loops (Figure 5), our policy favors early division of the interposing intestine (either stomach or small bowel) to gain prompt and direct access to the eroded vessel. After stopping the hemorrhage, our preference is a complete pancreatectomy since we feel that this procedure reduces the likelihood of bleeding recurrence which might be caused by the persistence of either an occult or a poorly drained pancreatic fistula. The gastrointestinal tract is hence reconstructed and large bore drains are left in the upper retroperitoneum.

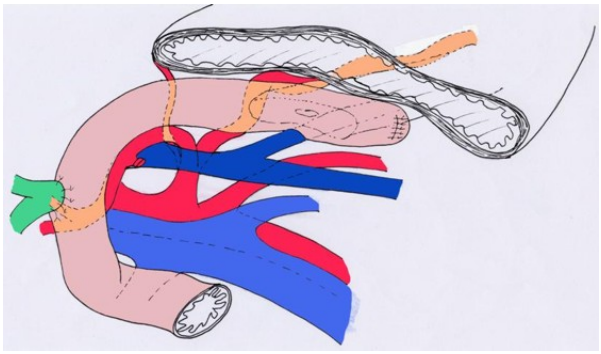

Figure 5. Sagittal, cross-sectional drawing showing the deep location of potentially eroded retroperitoneal vessels behind viscera used for reconstruction of the gastrointestinal tract.

This management algorithm explains our infrequent use of angiography. Although the literature shows that repeat surgery can be avoided in some of these patients by means of angiography with coil embolization, there are

also reports of patients who have died before reaching the radiology suite or during angiography [11, 22]. From our perspective, further incentives to repeat surgery are the risk of delaying surgery beyond the limits of shock reversibility as well as the inability of interventional remedies to eliminate the etiologic factors, such as retroperitoneal sepsis and pancreatic fistula, possibly leading to bleeding recurrence [10]. In one of our patients, hemorrhage recurred 24 hours after technically successful coil closure of the splenic artery, due to the persistence of an incompletely drained pancreatic fistula. Interestingly enough, this pancreatic fistula had originated from a pancreatic remnant managed by duct injection and was therefore being nourished with non-activated pancreatic juice thought to have limited autodigestive powers [23]. We acknowledge, however, that angiographic procedures have been used successfully as the sole permanent treatment of erosive bleeding by other authors [10, 11, 21]. Sohn *et al*., analyzing the Johns Hopkins experience on 1,061 pancreaticoduodenect-omies, reported 18 bleeding episodes treated by angiography (2%). In 11 of these patients, however, the hemorrhage was thought to be caused by percutaneous biliary drainage or cholangiography. Moreover, in 6 patients (33%), surgery could not be avoided due to failure to achieve hemodynamic stability and/or the need to correct etiologic factors [10]. Makowiec *et al*., analyzing the outcome of 456 pancreaticoduodenectomies and 8 total pancreatectomies, reported 12 patients with delayed erosive bleeding. In this series, all 7 patients with signs of gastrointestinal bleeding underwent angiography, after the failure of upper gastrointestinal endoscopy to demonstrate the bleeding source. Of the 5 patients with abdominal bleeding, 2 underwent immediate surgery and 3 underwent angiography. As mentioned earlier, one of the latter patients, bleeding from the stump of the gastroduodenal artery, died during angiography. The bleeding source could be traced angiographically in all the remaining 9 patients and was controlled permanently by this method in 6 of them (67%) [11].

At surgery, controversy continues regarding the need for a complete pancreatectomy [9, 11, 16, 19, 24, 25, 26] as opposed to conservative management by means of disconnection of the pancreatic remnant from the gut, closure or external catheter drainage of the pancreatic duct, and drainage of the peripancreatic space [11, 14, 27]. The rationale for this approach is provided by the prevention of pancreatic juice activation in the absence of enterokinase (disconnection from the gut), avoidance/reduction of retroperitoneal pancreatic juice extravasation (occlusion/external drainage of the pancreatic duct), and drying the peripancreatic, retroperitoneal, space (placement of large bore drains) [27]. Additional incentives for avoiding a complete pancreatectomy include reduced operating time, limited surgical dissection and preservation of endocrine function [14], although this latter issue will become relevant only if the patient survives. Some authors also suggest refashioning the pancreaticojejunal anastomosis after a limited resection of the jejunum and the pancreas at anastomosis [17, 21]. According to Berberat *et al*. [16], we do not advise constructing a new anastomosis or to sew over the leaking defect of pancreaticointestinal anastomosis.

When the splenic artery is eroded, as often occurs due to its proximity to the pancreatic remnant, coil embolization or ligature can be carried out without incurring the risk of visceral ischemia, thanks to the rich collateral circulation to the stomach and the spleen. On the contrary, when the hepatic artery or the superior mesenteric artery are involved, often revascularization cannot be avoided. Moreover, unless collateral liver circulation is provided by the accessory hepatic vasculature or the bowel is supplied by the inferior mesenteric artery through colic arcades, closure of these vessels will eventually result in hepatic abscess, disruption of hepaticojejunostomy or intestinal infarction, respectively. The presence of retroperitoneal sepsis, however, puts surgical revascularization at a high risk of failure due to pseudoaneurysm formation and/or

anastomotic disruption with catastrophic bleeding recurrence. An inframesocolic by-pass, avoiding any direct contacts with the peripancreatic area, could reduce the risk of superior mesenteric artery revascularization. Angiographic stenting is an additional, and perhaps even more conducive, option for revascularization of the visceral arteries [11, 21]. Makowiec *et al*. described stenting of the hepatic artery in two patients resulting in permanent bleeding control [11]. One further option, shown to be valuable in salvaging dearterialized liver allografts [28, 29], is portal vein arterialization as achieved by anatomizing the inferior mesenteric artery to the inferior mesenteric vein. This method was proven to be efficacious in reversing liver necrosis due to either hepatic artery thrombosis or fulminant hepatic failure. The arteriovenous shunt may be closed, by coil embolization, once the acute phase has been overcome in order to avoid long-term complications of portal hypertension, provided that the liver arterial supply can be furnished through a different route. To the best of our knowledge, however, this technique has not yet been used to revascularize native livers after closure of the hepatic artery in the post-operative period of a pancreatic resection.

The added therapeutic challenges incurred in the treatment of erosive bleeding either from the hepatic artery or the superior mesenteric artery are reflected in a 3 to 4 fold increase in the risk of death as compared to implication of the splenic artery. Since the weakest site along the hepatic artery is the stump of the gastroduodenal artery [9, 14], double or triple closure of this vessel, possibly including suture ligation, has become an important issue during pancreaticoduodenectomy.

Delayed erosive bleeding is heralded, in approximately one-half of patients [9], by the so-called “sentinel bleed” [14, 15] consisting of relatively mild bleeding episode(s) preceding the major hemorrhage by hours or days. These patients should therefore undergo diagnostic and therapeutic intervention after this first bleeding episode before the catastrophic final event. Sentinel bleeding

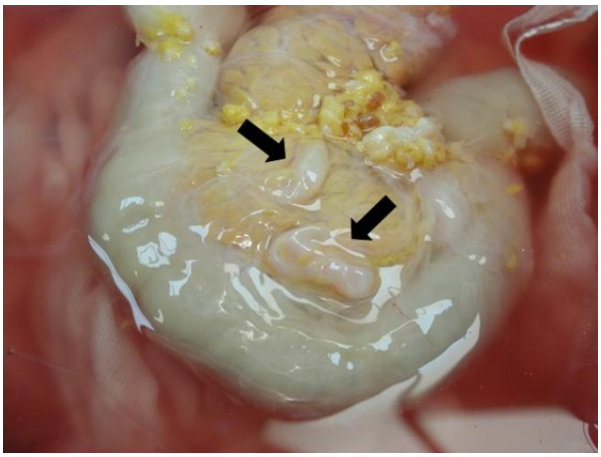

Figure 6. Intraoperative photograph of a donated pancreas. Arrows point to the enlarged anterior pancreaticoduodenal arteries demonstrating the *in vivo* vicarious blood flow through the pancreatic head.

may become evident as either gastrointestinal or abdominal hemorrhage. This has been shown by cervical and inguinofemoral hemorrhages where sentinel bleeding herald carotid or femoral artery blowout. This terrible complication can be prevented by covering the exposed vessels with a viable muscle flap. The occurrence of erosive bleeding after a pancreatectomy could be likewise reduced by wrapping the denuded retroperitoneal vessels with residual omentum [14].

Occlusive vascular complications of clinical relevance occur infrequently after a pancreatectomy and almost exclusively as a consequence of interruption of pancreaticoduodenal arcades in the presence of stenosis/obstruction of the celiac trunk. Since this condition is not usually accompanied by symptoms, unless the arterial flow is reduced by more than 60 to 75%, the diagnosis is rarely made preoperatively [30], even though modern imaging modalities are powerful enough to accurately define the vascular anatomy of the peripancreatic area. Failure to establish a preoperative diagnosis is therefore mostly explained by the rarity of this condition and the absence of specific symptoms in a setting where the energies of clinicians and radiologists are focused on establishing a diagnosis and defining operability. Predisposing lesions, indeed, are often identified when sought retrospectively.

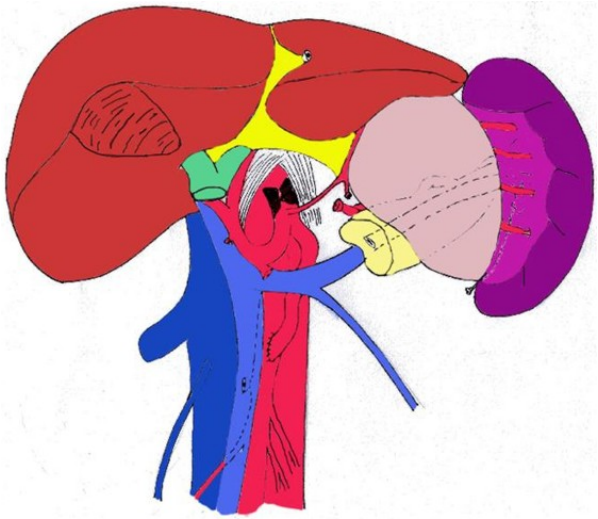

Figure 7. Jump bypass between the superior mesenteric artery and the celiac trunk, using the native splenic artery rotated clockwise, as described by Thompson *et al*. [30].

The incidence of celiac trunk stenosis/ obstruction varies widely between autopsy/ angiography series, in which it ranges from 3 to 49.7%, and clinical series, in which it ranges from 0.8 to 3.9%, respectively [30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40]. As underscored previously, the diagnosis is mostly intraoperative and incidental. Observation of an unusually large and tortuous gastroduodenal artery (Figure 6) with cessation or marked fall in the width of the arterial pulsations in the branches of the celiac trunk following cross-clamping or ligature of the gastroduodenal artery, should alert the surgeon to the presence of an obstruction or a high degree of stenosis of the celiac axis. If the diagnosis is established before the surgeon is technically committed to resection, such as before sectioning the neck of the pancreas, resection could be withheld although, to the best of our knowledge, this condition is not listed among the contraindications to pancreatectomy. If there is a serious risk of visceral ischemia, the surgeon can face the difficult decision of revascularizing the hepato-gastro-spleno-pancreatic (tail) compartment. Visceral ischemia is indeed a serious complication, potentially leading to life-threatening consequences such as a breakdown of pancreatic, biliary and enteric anastomoses, necrosis of the gastric remnant, splenic infarction/necrosis, and liver failure/abscess formation. Possible remedies include sectioning of the median arcuate ligament, as first described by Fortner and Watson [31], or bypass revascularization. In 1981, Thompson *et al*. first reported two patients in whom the proximal splenic artery was rotated clockwise and anastomized end-to-side to the superior mesenteric artery (Figure 7) [30]. Seven years later, Miyata *et al*. described the creation of an end-to-side jump bypass, using a saphenous vein graft, between the infrarenal aorta and the common hepatic artery (Figure 8) [32]. More recently, Kurosaki *et al*. described two cases of the preservation of the collateral pathways between the superior mesenteric artery and the celiac branch during pancreatico-duodenectomy [40]. However, for oncological reasons, this method seems to be more appropriate for benign diseases such as chronic pancreatitis, where it is preferentially employed [37, 38], as opposed to pancreatic cancer.

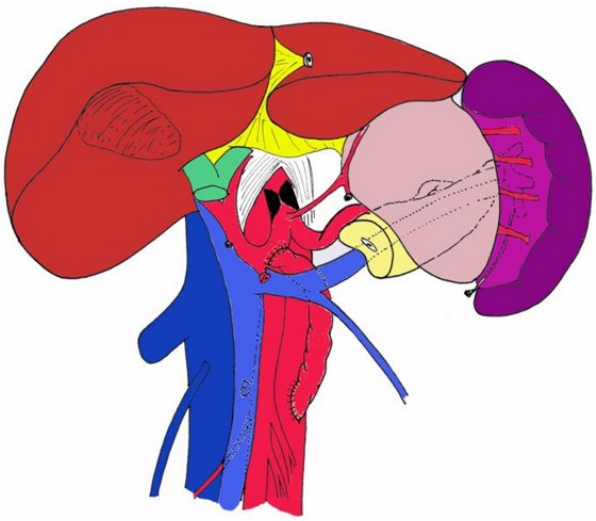

Figure 8. A jump bypass between the infrarenal aorta and the hepatic artery, using a greater saphenous graft, as described by Miyata *et al*. [32].

We have herein described a new method for revascularization of the hepato-spleno-gastric compartment which, taking inspiration from the hepatorenal bypass used for right kidney revascularization in the setting of renovascular hypertension [41], creates a jump bypass between the right renal artery and the stump of the gastroduodenal artery (Figures 3 and 4). This technique has several

potential advantages as compared to other bypass methods. In the first place, the right renal artery, when dissected off to the right of the infrahepatic inferior vena cava, lies close to the hepatic artery reducing the length of the jump graft and proportionally reducing the risk of thrombosis. Secondly, both anastomoses are located at the right lateral boundary of the operative field, hopefully at a safe distance from the pancreatic remnant with its attendant risk of fistula. Thirdly, in the event of a pseudoaneurysm or anastomotic disruption, reintervention would be easier, and subject to fewer consequences, as compared to methods involving the superior mesenteric artery or the aorta. Indeed, the worst consequence of proximal vascular control would be a right nephrectomy (as opposed to ligature of the superior mesenteric artery or troublesome closure of an aortic defect with the residual risk of bleeding recurrence) while distally the stump of the gastroduodenal artery could be ligated without compromising the anatomic integrity of the hepatic artery.

We conclude that vascular complications of a pancreatectomy, either hemorrhagic or occlusive, continue to challenge pancreas surgeons. Prevention begins with careful candidate selection and preparation, continues with meticulous surgical technique, and is completed with thorough postoperative care. Despite all these precautions, however, it is not likely that vascular complications can be completely avoided. Accordingly, timely and appropriate treatment depends on knowledge of the pathogenesis and possible remedies, and strongly relies on a multidisciplinary approach.

Keywords Hemorrhage; Ischemia; Pancreatectomy

Conflict of interest The authors have no potential conflicts of interest

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Document URL: http://www.joplink.net/prev/200701/27.html

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