How I Do It

Digestive Surgery

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Problems of Reconstruction during Pancreatoduodenectomy

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Key Words
Celiac artery stenosis · Pancreatoduodenectomy · Whipple procedure · Pancreatoenterostomy · Biliary-enteric anastomosis · Aberrant hepatic arteries · Vascular anomalies

Abstract
Pancreatoduodenectomy may be a difficult operation, not only during the resectional part of the procedure, but also during reconstruction. Usually, these problems are due to local conditions of the organs/tissues, such as small diameter of the common bile duct or pancreatic duct, friable soft pancreas, vascular anomalies, etc. Reconstruction may also be problematic because of the hemodynamic instability of the patient during surgery (subsequent to massive hemorrhage), and in those unusual cases, delayed reconstruction may be a life-saving, wise choice.

Abbreviations	
BEA	biliary enteric anastomosis
PD	pancreatoduodenectomy
RHA	right hepatic artery

'The best is always that which is farthest removed from the unsuitable.' *Hippocrates, Ancient Medicine XXIV, 460 B.C.*

'Experience with success or failure only enables the individual operator to justify methods.' *Charles H. Mayo, MD*

Introduction

Pancreatoduodenectomy (PD) has become increasingly common as a safe and appropriate procedure in selected patients with malignant and benign periampullary disorders. Hospital mortality, which in the recent past was prohibitive (over 20%), should now be less than 4% [1–3]. Documentation of higher operative mortalities and morbidities speak to inexperience with this specific operation and a low volume of experience, questioning the justification for performing these procedures by ill-equipped surgeons or hospitals [2–6]. Nevertheless, even in high volume centers with defined pancreatic surgical experience, morbidity remains relatively high (~30–40%), and PD is still considered a formidable surgical undertaking. Meticulous surgical technique is a must to avoid severe intraoperative complications during the resection, most commonly massive hemorrhage from the major peripancreatic vessels [4]. However, PD may be technically difficult not only during the resectional part of the procedure but also during reconstruction. This usually is due to the conditions of tissues, but occasionally the general status of the patient may dictate a different approach after PD (i.e.

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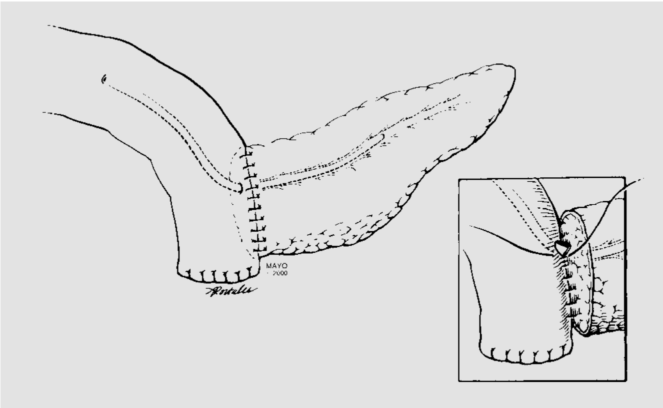

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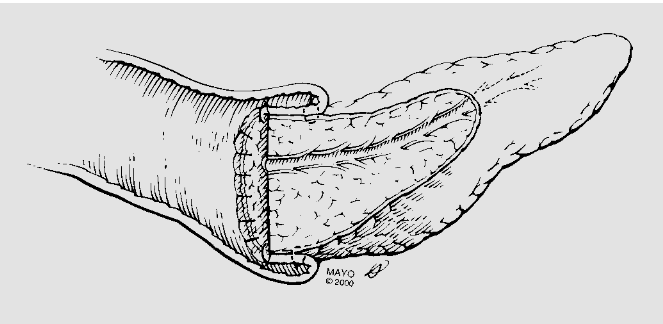

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Fig. 1. Stented duct-to-mucosal anastomosis; an intraluminal stent is optional.
Fig. 2. Intussuscepted pancreatojejunostomy; an intraluminal stent is optional.

hemodynamic instability subsequent to massive intraoperative bleeding). Good surgical training, clinical judgment, and experience of the surgeon are prerequisites to successfully deal with these challenging conditions to avoid or minimize early and late significant morbidity and eventually mortality.

This paper will address some of the more unusual difficulties encountered on occasion during reconstruction involving the pancreatic and biliary anastomosis, vascular anomalies that require some type of specific intervention, and management of the patient with hemodynamic instability intraoperatively.

Pancreaticoenterostomy

Pancreaticoenterostomy may be the most technically demanding part of the reconstruction and is often considered as the 'weak point' of PD. Leakage from this anastomosis is the most feared complication after PD [5–7], and anastomotic leaks are directly responsible for 20–25% of postoperative death [6]. Although the majority of patients with a pancreatico-cutaneous fistula following PD heal with conservative measures, some patients (5–10%) develop significant intra-abdominal complications, such as sepsis or bleeding that may require surgical intervention [5, 6]. Completion pancreatectomy, itself a technical feat, is the procedure that may be required when repair/drainage is impossible because of local conditions; mortality is, however, very high [5–7], and prevention is the best way to avoid the need for this drastic measure.

There are many variations of pancreatoenterostomy, and we will not be presumptuous enough to recommend one specific technique. Indeed, the experienced pancreatic surgeon needs to have several options in his/her repertoire including pancreatojejunostomy and pancreatogastrostomy. The 'duct-to-mucosa' type of anastomosis (fig. 1) [8] is considered by many as the preferred method of pancreatoenterostomy. Use of operating magnification markedly aids placement of sutures; most surgeons would advocate interrupted sutures with an absorbable material. Use of an intraluminal stent is optional, and no good evidence is available to support its routine use. If a small pancreatic duct is difficult to identify after parenchymal transection, especially when the pancreatic head is amputated with electrocautery, secretin (1 IU/kg) can be given intravenously to promote pancreatic exocrine secretion and to aid identification of the duct. When the main pancreatic duct is not believed wide enough to permit a safe anastomosis, even under magnification, an 'invaginating' type of pancreatojejunostomy is a valuable alternative (fig. 2). Generally, pancreatoenterostomy is safer after PD for chronic pancreatitis than for pancreatic cancer, because the diseased parenchyma of the pancreatic remnant is fibrotic and holds the sutures well, and possibly because the enzyme content (proteases, phosphatases, elastases etc.) in the pancreatic juice is low [9, 10]. The risk of dehiscence of the pancreatoenterostomy is increased when the parenchyma of the pancreatic remnant is soft and friable, and especially so when the main pancreatic duct is thin-walled and of small diameter [11]. Under these latter circumstances pancreatoenterostomy may be very difficult and problematic. When faced with this significant problem, the following options are available:

(A) External drainage of the pancreatic remnant by careful placement of peripancreatic drains [12]. The main pancreatic duct can be left open and not ligated [12], in which case the pancreatic secretions will be drained via the peripancreatic drains, or a stent may be introduced within the duct in addition to peripancreatic drains [13] (fig. 3a). By this means a controlled pancreatico-cutaneous fistula results. Although no fatal complications were caused by use of this technique, its disadvantage is that a pancreatico-cutaneous fistula invariably occurs. Surprisingly, in many patients (~80%) the fistula will close spontaneously [12], probably by formation of an internal pancreatic fistula to adjacent small bowel. However, a significant proportion of patients require reoperation for internal drainage of a persistent external fistula or development of a pseudocyst.

(B) Ligation of the main pancreatic duct with drainage of the peripancreatic area (fig. 3b). The concept and rationale with this approach is that the gland will atrophy. However, this approach often results in further complications from the pancreatic remnant, such as pseudocyst formation and leakage from the ligated pancreatic duct [14–16]. A high rate of leak from the ligated pancreatic duct (70%) is to be expected [14], given the usual local conditions of the tissue in the situations in which this technique is necessary (thin-walled pancreatic duct, friable/soft pancreatic parenchyma), and a pancreatico-cutaneous fistula frequently results.

(C) Occlusion of the main pancreatic duct by Neoprene® (a liquid synthetic rubber composed of polychloroprene homopolymer) [17, 18], Ethibloc® (a slowly hardening but degradable prolamine solution) [19] and fibrin glue injection [20]. These techniques have been reported to be a safer method for the management of the pancreatic remnant and therefore – especially under difficult circumstances – may be useful [17–20]. The disadvantage of this technique, as with ductal ligation, is the subsequent development of pancreatic exocrine insufficiency which, however, can be reasonably controlled symptomatically with oral pancreatic enzyme replacement therapy. Pancreatic endocrine function is largely preserved with this technique [17].

(D) Total pancreatectomy at the time of PD. This approach eliminates the morbidity and potential mortality of an anastomotic leak from the pancreatoenterostomy but establishes a complete apancreatic state with endocrine and exocrine pancreatic insufficiency. The former may be a significant source of late morbidity and even mortality, especially in medically unreliable or non-compliant patients [21].

Among the numerous operative techniques employed allegedly to augment anastomotic integrity is the use of intraluminal 'venting' tubes [1–3, 6]. These externally draining tubes have their distal tip located within the bowel or bile duct in close association with the pancreatic or biliary anastomosis, or within the pancreatic duct itself

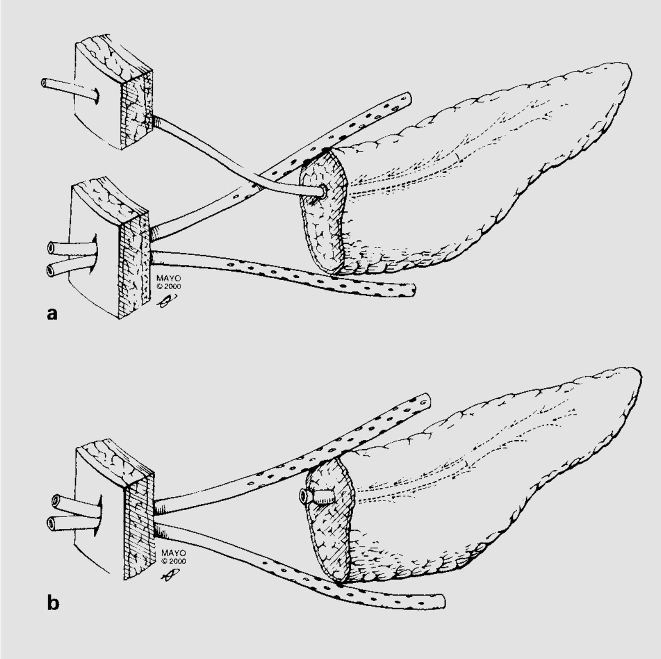
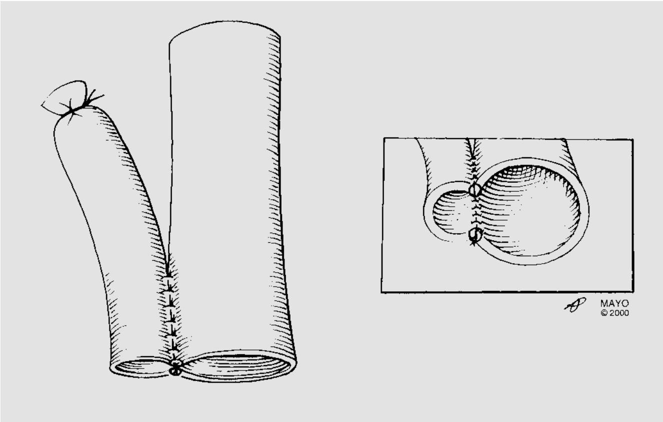


Fig. 3. Management of pancreatic exocrine secretion without anastomosis. **a** Controlled external pancreatic ductal drainage without anastomosis. **b** Ductal ligation with peripancreatic drainage.

transgressing the pancreatoenterostomy. In theory, such tubes prevent overdistention of the afferent limb and divert potentially harmful secretions away from the anastomoses. Additionally, in instances of anastomotic leak, the presence of a venting tube for diversion may provide improved local control and thereby promoting a better outcome. However, in a recent report [22] routine use of small diameter intraluminal stents afforded no advantage in terms of shortening the postoperative length of stay, decreasing operative morbidity and mortality, or improving local control with regional sepsis.

Biliary-Enteric Anastomosis

The biliary-enteric anastomosis (BEA) is usually the second step in reconstruction. Frequently, the extrahepatic bile duct is dilated in patients undergoing PD secondary to an obstructing mass distally, but this is not always the case. For example, PD may be performed for a nonobstructing cancer of the uncinate process, for a nonperiampullary cancer of the duodenum, in patients with painful chronic pancreatitis, or in those patients who have had preoperative biliary decompression by a biliary endoprosthesis.



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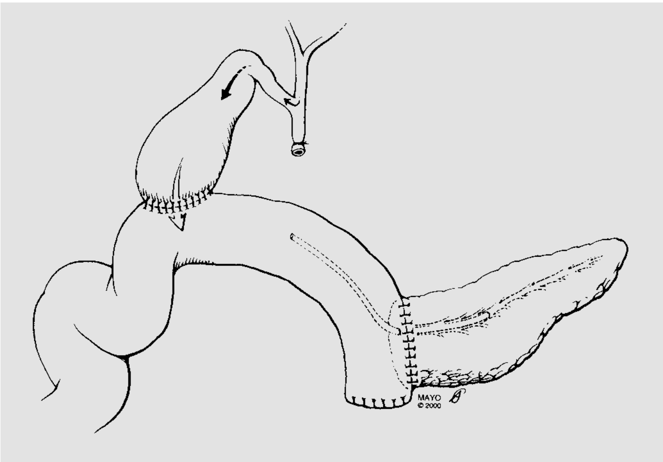

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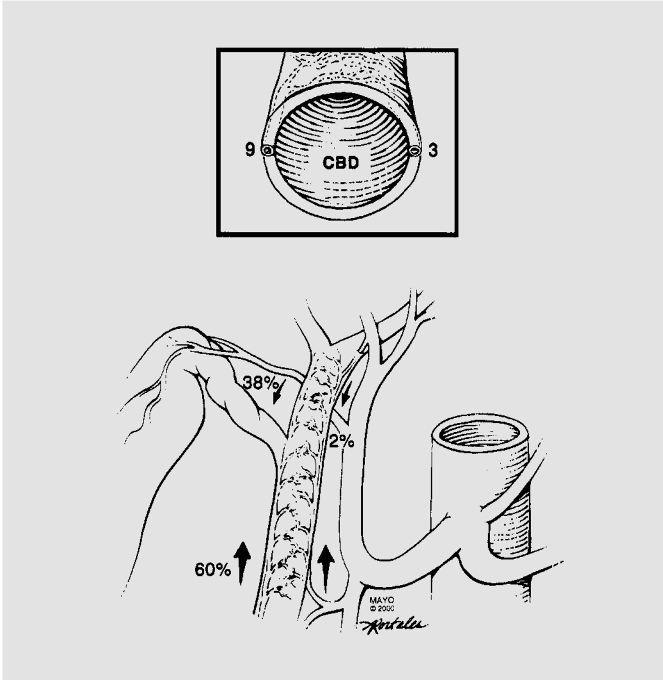

Fig. 6. The arterial blood supply to the bile duct is in the form of a submucosal plexus fed by small branches from longitudinal arteries running in the 3 o'clock and 9 o'clock positions [22]. The longitudinal arteries are supplied by small branches from the hepatic arteries in the middle and hilar portion and from the gastroduodenal and retroduodenal arteries in the distal portion.

Fig. 4. Cystic duct/common duct anastomosis to increase diameter of bile duct for enteric anastomosis.

Fig. 5. Cholecystojejunostomy with PD; note need to preserve communication between common hepatic duct and cystic duct.

The small diameter of the bile duct can greatly complicate the BEA. To avoid subsequent stenosis of the BEA after PD, the surgeon should achieve a wide, safe BEA, while preserving the residual blood supply of the bile duct. Biliary leakage causes an intense reactive fibrosis and predisposes to stenosis of the BEA.

When the Bile or Hepatic Duct Is Not Dilated, Two Options Are Available

The cystic duct (or its remnant if the patient had a previous cholecystectomy) can be anastomosed side-to-side with the common hepatic duct (fig. 4) [9]. The resulting common orifice is of greater diameter than the original bile duct. This side-to-side anastomosis can be performed more easily when there is a long cystic duct (or its remnant) with a course parallel with the common hepatic duct.

Although retaining the gallbladder after PD is not the usual practice, this approach allows a cholecystojejunostomy [23] to be performed to establish biliary-intestinal continuity, provided that the cystic duct enters the bile duct sufficiently high enough to preserve retrograde flow of bile from hepatic duct to gallbladder (fig. 5) [9].

To avoid stricture of the BEA, preservation of a good blood supply to the biliary end of the anastomosis is important, especially when the bile duct is not dilated. Knowledge of the blood supply of the extrahepatic duct is crucially important [24] (fig. 6). Because PD requires ligation of the pancreatoduodenal artery and transection of the common bile duct, the blood supply to the common hepatic duct must come from the hepatic side. Therefore proximal dissection of the periductal structures should be minimized. Similarly, the cystic artery should be ligated distally more near the gallbladder wall to preserve any branches to the bile duct. In addition, all attempts should be made to preserve the main hepatic arteries, especially when aberrant (e.g. replaced right hepatic artery arising from superior mesenteric artery) or when obstructed (e.g. celiac stenosis) – see below 'Vascular Anomalies'.

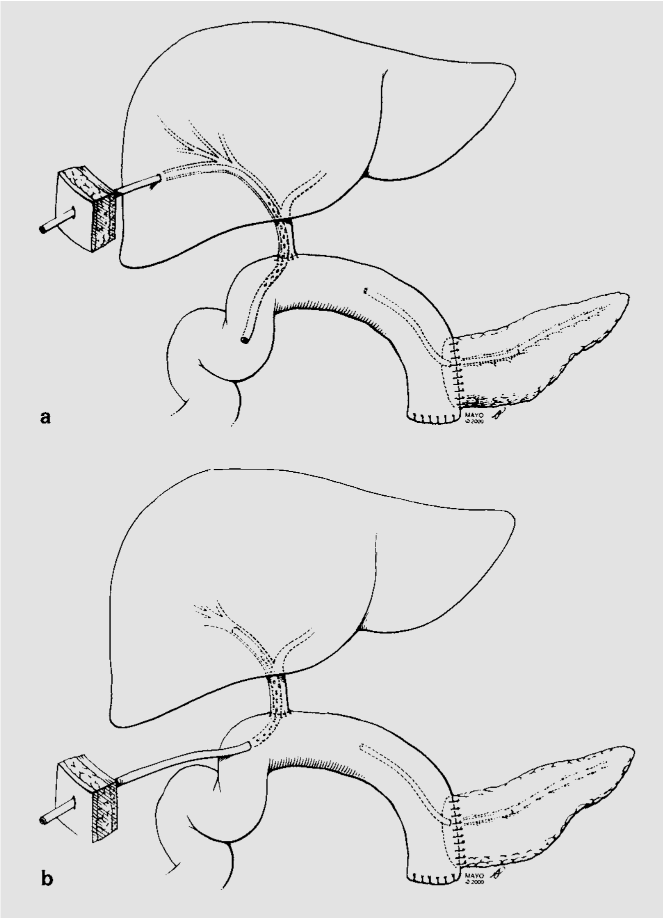

Fig. 7. Biliary decompression. **a** Transhepatic tube. **b** Retrograde transjejunal tube.

In addition to the above methods to preserve the blood supply of the bile duct, external biliary decompression may be a wise precaution as well. Under these circumstances, possibly the best way to achieve this is via a transhepatic stent (fig. 7a) or via a straight stent passed again through the anastomosis into the jejunum which can also be exteriorized (fig. 7b) [15, 24]. Under these circumstances, a T-tube type choledochostomy is usually contraindicated, because the length of proximal bile duct available is short, and being thin-walled the risk of a leak and subsequent stenosis may be increased.

Gastro- or Duodenojejunostomy

Reestablishment of gastrointestinal continuity after PD is usually not difficult, either with pyloric preservation or after the classic PD involving antrectomy [24].

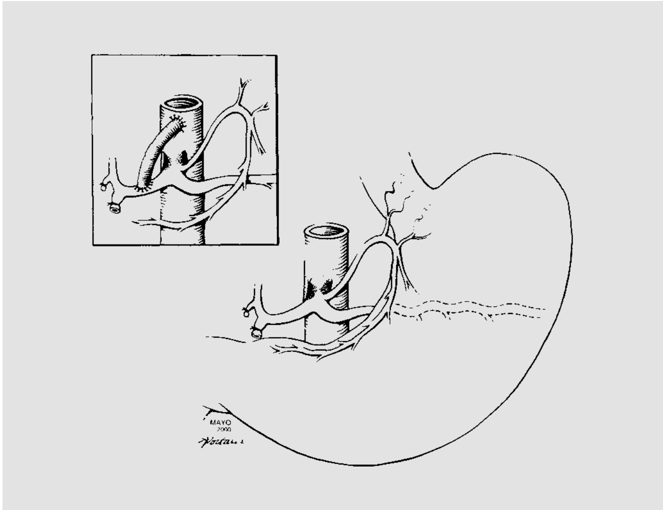

Fig. 8. Celiac artery stenosis. Note size of the gastroduodenal artery and vascular reconstruction of a jump graft from supraceliac aorta to common hepatic artery (inset).

However, in some patients the presence of celiac artery stenosis may be a potential source of difficulties if a splenectomy has been performed or is required. Splenectomy is not part of PD; however, splenectomy may be required during PD either because of iatrogenic injury or because the surgeon elects to perform a total pancreatectomy (or a completion pancreatectomy) for various reasons. After splenectomy, the vascular supply of the stomach after PD relies primarily on the left gastric artery (fig. 8). This is a potential problem when there is associated celiac artery stenosis. In this situation, a classical PD is to be preferred over a pylorus-preserving technique. In addition, a jump graft can be placed from the supraceliac aorta to the common hepatic artery to maintain hepatic arterial inflow.

During a pylorus-preserving PD, the mobility of the pyloroduodenal region is restricted if the right gastric artery is preserved. Many surgeons prefer to ligate the right gastric artery (which usually is of a very small diameter) to allow anterior mobilization of the duodenum such that the duodenojejunostomy will be further from the pancreaticojejunostomy. This latter maneuver is believed to decrease the chance of delayed gastric emptying should a leak occur at the pancreaticojejunostomy. Other surgeons prefer to maintain the right gastric artery and the nearby vagus branches in an attempt to maximize the blood supply to the proximal duodenum. The importance of either approach is unproven. Viability of the duodenum is rarely jeopardized by ligating the right gastric artery.

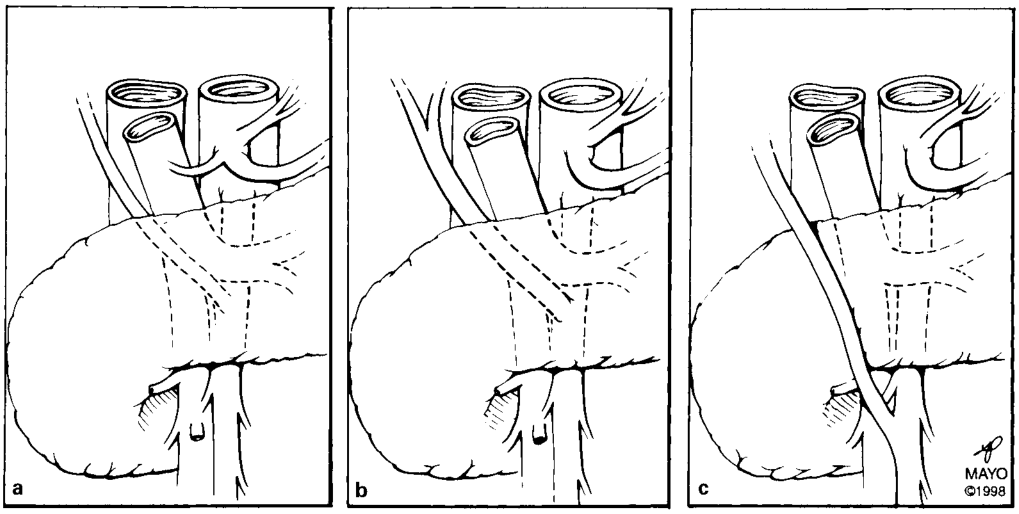

Fig. 9. Replaced right hepatic artery (RHA). **a** Most common, isolated replaced RHA. **b** Replaced common hepatic artery that provides both the right and left hepatic arteries. **c** The unusual replaced RHA that courses anterior to neck of the pancreas.

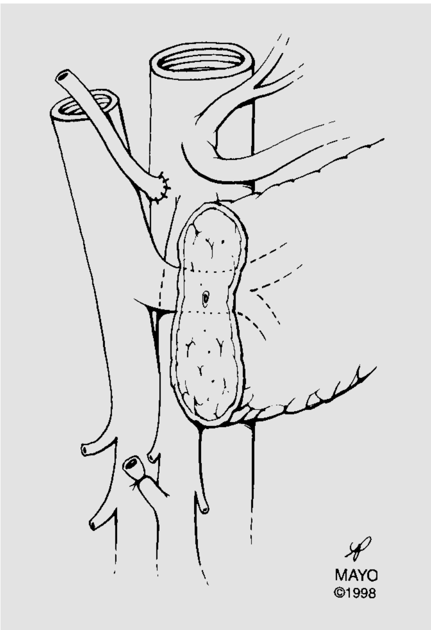

Fig. 10. Reimplantation of a replaced RHA into the aorta.

Vascular Anomalies

The vascular anomalies or abnormalities of note that would potentially alter the operative approach during PD include a 'replaced' right hepatic artery (RHA) and celiac artery stenosis. While a replaced left hepatic artery arising from the left gastric artery does not affect resection or reconstruction, a replaced RHA should be recognized as such early in the operation and carefully preserved during the resection. A replaced RHA arising from the superior mesenteric artery should be suspected first when the 'proper' hepatic artery appears to be 'too small' or when a prominent pulse/thrill is palpated in the posterior hepatoduodenal ligament (fig. 9a, b). An unusual variant of replaced RHA runs anterior to the neck of the pancreas (fig. 9c) and an exceedingly rare replaced hepatic artery actually runs within the pancreatic parenchyma [26]. Should the pancreatic resection require excision of a replaced RHA near its origin, the more distal RHA probably should be anastomosed either to the left hepatic artery or the aorta (fig. 10), not only to assure adequate arterial supply to the right liver but also to the bile duct (see above) [4].

A functionally significant celiac artery stenosis should be suspected when the surgeon encounters an unusually large gastroduodenal artery (fig. 8); loss of a pulse in the common or proper hepatic artery with temporary occlusion of the gastroduodenal artery should confirm the hemodynamic significance of the stenosis. Because ligation of the gastroduodenal artery during PD threatens the primary arterial flow both to the liver and to the bile duct anastomosis, many pancreatic surgeons feel strongly that revascularization of the hepatic artery by a short jump graft from the supraceliac aorta to the proximal common hepatic artery is indicated (fig. 8, inset). Revascularization is especially important in the rare situation in which the patient has had (previously) or requires a simultaneous splenectomy either because of iatrogenic injury or because of need for a total pancreatectomy; in this situation, PD will lead to ligation of right gastric and gastroepiploic arteries, and the remaining primary arterial blood supply to the stomach will depend on the left gastric artery which will lose its arterial inflow with ligation of the gastroduodenal artery.

The Hemodynamically Unstable Patient

It is clear that significant medical comorbidity may be a contraindication for PD. However, a patient may become hemodynamically unstable during PD either because of massive blood losses or because of intraoperative cardiopulmonary collapse (e.g. allergic reaction, cardiac events, etc.). In these difficult situations, delaying the reconstruction may be a wise choice; while this approach will require a subsequent anesthetic and reoperation, this approach allows aggressive resuscitation, restoration of stable hemodynamics, reversal of the coagulopathy, and a more controlled, semi-elective completion of the resection/reconstruction. This approach is based on experience in severe traumatic pancreatoduodenal and liver injury [27–29].

Summary

The recent marked improvements in morbidity and mortality after major pancreatic resections, and specifically after PD, are related to many factors in preoperative patient selection and postoperative care, but also to a better understanding of the technical factors involved in pancreatic surgery. This chapter addresses both the more common problems encountered as well as the more unusual technical challenges during PD. The pancreatic surgeon must maintain a versatile and diverse armamentarium of technical maneuvers to deal with expected as well as unusual problems encountered intraoperatively.

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