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Retroperitoneal Dissection in Patients with Borderline Resectable Pancreatic Cancer: Operative Principles and Techniques

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Borderline resectable pancreatic cancers are localized tumors that—unlike locally advanced cancers—may be safely resected with curative intent in specialized treatment centers. Nonetheless—unlike potentially resectable cancers—attempts at surgical resection are likely to be compromised by positive margins due to the proximity of the primary tumor to major vascular structures. We and others have established anatomic criteria that define borderline resectable primary tumors on the basis of radiographic abutment (at most a 180° interface) or encasement (greater than a 180° interface) by the primary tumor of the superior mesenteric vein (SMV), portal vein (PV) or common hepatic artery, or limited tumor abutment of the superior mesenteric artery (SMA) or celiac trunk (1-3).

Patients with borderline resectable cancers are often treated with preoperative chemotherapy and/or chemoradiation (2,4). We use preoperative therapy to select patients who appear to have relatively indolent, slow growing disease for aggressive surgical operations such as those described here (Figure 1). We do not resect primary cancers which progress locally or (more commonly) have metastasized to distant sites upon completion of preoperative therapy, so patients with rapidly progressive disease are spared the potential morbidity of surgery (5). Preoperative therapy may increase the rate of margin-negative resection in this population of patients with infiltrating tumors (6). Indeed, complete macroscopic and microscopic resection is often possible following such therapy, and patients with borderline resectable cancers who undergo successful resection following preoperative therapy have a prognosis similar to that of patients with anatomically resectable cancers treated with

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surgery first (7-9). Nonetheless, pathologic evidence of a significant response to treatment is rare, and, unlike in rectal or esophageal cancer, radiographic “downstaging” of primary pancreatic ductal adenocarcinoma (PDAC) tumors with chemotherapy and chemoradiation is uncommon. Vascular involvement therefore often persists following therapy, and major vascular resection is often necessary to achieve negative margins (5,8).

We have previously reported the short-term oncologic metrics and long-term overall survival rates of patients with borderline resectable PDAC treated with multimodality therapy and pancreaticoduodenectomy at our institution (5,8). The objective of this manuscript is not to further describe these outcomes, but instead to illustrate the specific technical strategies we use to perform the retroperitoneal dissection in these patients. For this purpose, we describe four pancreaticoduodenectomy procedures performed over the last year, each of which illustrates one or more unique technical challenges:

- encasement of the SMV-PV confluence alone,
- abutment of the SMA,
- abutment or encasement of the common hepatic artery, and/or
- abutment or encasement of an aberrant hepatic artery.

In all four of these clinical scenarios, the two primary surgical objectives are 1) meticulous exposure and dissection of the SMA to maximize the margin obtained while maintaining blood flow to the liver and small intestine, and 2) re-establishment of portal venous blood flow from the stomach and spleen, if necessary, to minimize the risk of postoperative sinistral portal hypertension.

Technical Details and Case Illustrations

Tumor encasement of the SMV-PV confluence

Tumor encasement of the SMV-PV confluence, either isolated or in combination with involvement of other vessels, represents an important technical challenge because it limits straightforward exposure and dissection of the proximal SMA. Although the SMV and its major branches can be resected and reconstructed with good short- and long-term results, the SMA cannot. The SMA margin, defined as the soft tissue margin directly adjacent to the proximal 3-4 cm of the vessel, is therefore the most frequently positive margin following pancreaticoduodenectomy (10-12). Because a complete periadventitial dissection of the SMA can reduce the incidence of residual cancer cells (R1 resection) at this margin, this maneuver represents a fundamental technical principle of pancreaticoduodenectomy (6).

Following mobilization of the pancreatic head, dissection of the porta hepatis, and division of the stomach or duodenum, the critical dissection of the SMA margin begins at the inferior border of the uncinate process and extends cephalad to where the SMA diverges from the aorta (Figure 2). The proximal SMA typically lies directly posterior to the SMV-PV confluence. To access this tissue safely, the SMV-PV confluence must be completely mobilized. For primary tumors that do not involve the SMV or PV, the confluence can be retracted to the patient's left, following dissection of the surgical specimen from the vein, to expose the underlying artery. When the pancreatic tumor involves the venous confluence,

however, division of the pancreatic neck superficial to the vein and leftward mobilization of the SMV-PV are both impossible.

In this circumstance, we typically divide the splenic vein and retract the SMV-PV to the patient's right. We begin the dissection by sharply accessing the proper periadventitial plane of the SMA caudal to the tumor and proceed cephalad along the vessel. The inferior mesenteric vein and first jejunal branch of the SMV are each freely ligated as they are encountered if they course anterior to the artery (Figures 2,3) but otherwise are typically left *in situ*. The splenic vein must be identified and carefully dissected from the posterior aspect of the pancreas to protect it as the pancreatic neck or proximal body is divided. Following division of the pancreas, the left aspect of the SMV-PV confluence is completely exposed and the splenic vein is safely ligated.

The periadventitial dissection of the SMA then proceeds cephalad toward the aorta (Figure 4). All fat, fibrous tissue, lymphatics, and nerves are swept to the patient's right, and the inferior pancreaticoduodenal artery or arteries are individually ligated. Importantly, we resect the tissues to the right of the SMA; we avoid circumferential dissection of the artery to prevent the intractable diarrhea that may be associated with overzealous dissection of the sympathetic nerves surrounding this vessel. The relatively avascular deep retroperitoneal tissues are then divided, leaving the specimen attached by only the portal vein and SMV. Division of these veins frees the specimen. Venous reconstruction can then be performed using our previously described methods (13,14).

Because resection of infiltrating tumors typically requires ligation of the other 3 major vessels that drain the stomach and spleen—the left gastric (coronary) vein, right gastric vein, and right gastroepiploic vein—return of portal venous blood from the stomach and spleen to the liver may be compromised following splenic vein ligation. This scenario arises most frequently in cases in which the IMV drains directly into the SMV and is ligated in the course of the retroperitoneal dissection (Figure 2). In this circumstance, we routinely construct a direct shunt between the splenic vein and the left renal vein (Figure 5). When the IMV drains more proximally into the splenic vein, we leave the IMV undisturbed and rely on it for retrograde sinistral flow. Although we do not formally measure pressures in the sinistral portal system, the need for shunting can be estimated following division of the splenic vein by the identification of dilated gastric veins, a dusky, boggy appearance to the stomach, and turgor in the divided splenic vein itself.

The possible need for construction of a splenorenal shunt is best anticipated prior to ligation of the splenic vein because dissection of a length of splenic vein sufficient to reach the left renal vein is easiest prior to ligation, when blood pressure through the vein is lowest. To construct the anastomosis, the left renal vein is identified to the left of the SMA and the ligated splenic vein is mobilized downward. Division of the left gonadal and/or adrenal vein may facilitate mobilization of the left renal vein and application of vascular clamps.

Case—An otherwise healthy 64-year-old woman presented with a localized cancer of the pancreatic head, which appeared on computed tomography (CT) to encase the SMV-PV confluence. She was treated with external-beam radiation to 50.4 Gy with concurrent

gemcitabine. Following chemoradiation therapy, her serum marker CA 19-9 level fell from 500 to 189 U/ml, but the anatomic relationship between her primary tumor and the SMV-PV confluence, depicted in figure 3, did not change. She was brought to surgery for resection of the primary tumor.

In this case, both the first jejunal branch of the SMV and the IMV coursed anterior to the SMA and were sequentially ligated prior to division of the pancreatic neck. The splenic vein was divided at the confluence to allow access to the proximal SMA and performance of a complete periadventitial dissection of the SMA to the aorta. Following resection of the specimen, the SMV-PV was reconstructed using an interposition graft harvested from the left jugular vein and a direct splenorenal shunt was constructed to return blood flow from the stomach and spleen. Estimated blood loss for this procedure was 1300 ml. There were no perioperative complications. Perioperative length of hospital stay was 11 days. Final pathology showed a 3.0 cm tumor with 60% viable cells. Histological evidence of tumor cell invasion of the wall of the resected vein was identified. All 18 lymph nodes examined were negative for cancer. The tumor margins were all negative, and the distance between the tumor and the inked SMA margin was 12 mm.

Tumor involvement of the SMA

Due to the proximity of the SMV-PV to the SMA, borderline resectable cancers that abut the artery often also abut or encase the venous confluence, which limits access to the underlying SMA margin. Exposure and dissection of the SMA are therefore both critical considerations in the surgical management of these cancers.

Tumor abutment of the SMA is typically associated with encasement of the inferior pancreaticoduodenal arteries as they course from the SMA into the uncinate process. Uncontrolled dissection in the desmoplastic tissue to the right of the SMA may therefore lead to significant hemorrhage. Safe dissection of the SMA in this scenario is accomplished following systemic heparinization and the placement of proximal and distal clamps directly upon the artery (Figure 6). The right lateral aspect of the SMA is then dissected sharply to prevent vascular trauma. Each pancreaticoduodenal artery is sharply divided at its origin and the SMA is then repaired primarily. Circumferential dissection of the vessel is avoided.

Case

A 62-year-old man presented with a primary PDAC that encased the SMV-PV confluence, abutted the first jejunal branch of the SMV, and abutted the SMA, as depicted in Figure 7A. He was treated with gemcitabine and cisplatin, followed by 50.4 Gy external beam radiation with concurrent capecitabine. Radiographically, his tumor did not progress (Figure 7B), so he was brought to surgery for resection of the primary tumor.

In this case, exposure of the SMA was accomplished using an approach similar to that described for the first patient above. Here, however, tumor involvement of the first (posterior) jejunal branch of the SMV mandated careful division of the branch proximal to the site of tumor involvement. The first jejunal branch was carefully dissected and ligated to the left of the main trunk of the SMV as the branch emerged behind the SMA. Following

division of the pancreas superficial to the left aspect of the SMA, the splenic vein was then ligated distal to the inflow of the coronary vein to expose the tissue around the proximal SMA. A complete periadventitial dissection of the right lateral aspect of the artery was then accomplished following placement of proximal and distal clamps.

Following division of the deep retroperitoneal tissues, reconstruction of the SMV-PV was accomplished primarily, as depicted in figure 4. Because the IMV emptied into the splenic vein proximal to the portosplenic confluence, revascularization of the splenic vein was not performed. The estimated blood loss during this operation was 700 ml. Perioperative length of hospital stay was 11 days, and there were no complications. Final pathology showed a 4 cm tumor with 50-90% viable cells. Adenocarcinoma was identified in the media of the resected vein. The 25 lymph nodes examined were negative for cancer. The tumor margins were negative, but the distance between the cancer cells and the inked SMA margin was < 1 mm.

Tumor abutment of the common hepatic artery

Tumors located in the head of the pancreas may extend cephalad along the gastroduodenal artery to abut or encase the common hepatic artery. Proximal and distal control of the hepatic artery in such cases is best achieved early during the portal dissection and should precede division of the pancreas and dissection of the SMA.

When the degree of tumor involvement of the hepatic artery is limited, the gastroduodenal artery can be divided directly at its divergence from the hepatic artery following control of the common hepatic and proper hepatic arteries with vascular clamps and suture ligation of the distal gastroduodenal artery. The orifice of the gastroduodenal artery can then be closed with pledgeted suture. When tumor involvement is more substantial, segmental resection of the artery followed by either primary reconstruction or reconstruction using a venous interposition graft is preferable (Figure 8). An interposition graft is typically used in order to create a tension-free reconstruction, particularly when the vessels demonstrate significant treatment effects from the preoperative chemoradiation therapy.

Case

A 71-year-old woman presented with a large mass in the neck of the pancreas that involved the SMV-PV confluence and common hepatic artery. She was treated with systemic gemcitabine and capecitabine, followed by external beam radiation to 50.4 Gy with concurrent capecitabine. The primary cancer decreased in size following therapy, but continued to encase the common hepatic artery and abut the SMV-PV confluence, as depicted in Figure 9A. Her serum CA 19-9 level fell from 450 to 16 U/ml. She was brought to surgery for resection of the primary tumor.

In this case, significant involvement of the common hepatic artery mandated short-segment resection and reconstruction with an autologous vein graft. The procedure was further complicated, however, by venous abutment, which required en bloc resection and reconstruction of the SMV-PV confluence.

The tumor encased the common hepatic, proper hepatic, and proximal first-order branches of the proper hepatic artery. Following control of the proximal hepatic artery just distal to the celiac trunk, distal control was attained on five small, extrahepatic branches of the left and right hepatic arteries. The involved arterial segment was then sharply resected en bloc with the PD specimen. Reconstruction of the common hepatic artery to these five distal branches was immediately accomplished using microsurgical techniques with a saphenous interposition graft (Figure 9B).

Following reconstruction of the hepatic artery, the pancreas was divided. The first jejunal branch of the SMV, which coursed anterior to the SMA in this case, was divided. The SMA dissection was subsequently completed, leaving the tumor tethered only by the portal and superior mesenteric veins. An interposition graft was fashioned to reconstruct the vein and then sinistral portal flow was re-established with a splenorenal shunt.

The estimated blood loss during this operation was 550 ml. Perioperative length of hospital stay was 10 days, and there were no complications. Final pathology showed ductal adenocarcinoma with 10-50% cells viable. 0 of 19 lymph nodes were positive for cancer. The tumor margins were negative, and the distance between cancer cells and the inked SMA margin was 18 mm.

Tumor encasement of an aberrant hepatic artery

Not uncommonly, an aberrant common or right hepatic artery may arise from the proximal SMA and may approximate the primary tumor. In many cases of borderline-resectable PDAC, an aberrant hepatic artery represents the only site of vascular abutment or encasement by cancer.

The origin of the replaced common or right hepatic artery is best approached during the dissection of the proximal SMA. Vascular control of the hepatic artery must be achieved both at its origin and distally in the porta hepatis. If the common hepatic artery is reconstructed, bifurcated grafts to the right and left hepatic arteries may reduce the effects of vascular thrombosis, should it occur.

Case

A 71-year-old man presented with biopsy-confirmed PDAC. His common hepatic artery aberrantly arose from the proximal SMA and coursed through the primary tumor in the pancreatic head, as depicted in Figure 10. The tumor also abutted the SMV-PV confluence. He was treated with external beam radiation therapy to 30 Gy with concurrent gemcitabine and had no radiographic evidence of tumor response or progression, so he was brought to surgery for resection of the primary tumor.

In this case, the pancreatic neck was divided over the SMA following dissection of the porta hepatis to expose the portal vein and the right and left hepatic arteries. The splenic vein was divided in order to complete the periadventitial dissection of the SMA to the aorta. The takeoff of the replaced common hepatic artery was identified upon cephalad dissection of the SMA. The portal vein and SMV were divided above and below the tumor, respectively,

and an interposition graft from the left jugular vein was immediately inserted. Finally, the specimen was removed by dividing the common, right, and left hepatic arteries between clamps. A bifurcated interposition graft fashioned of saphenous vein was used to reconstruct the arterial flow. The IMV drained into the proximal splenic vein, so a splenorenal shunt was not performed (Figure 11).

The estimated blood loss for this operation was 3600 ml. The perioperative length of hospital stay was 29 days and was complicated by a biliary leak from the afferent limb (Clavien-Dindo class IIIa, revised Accordion class III), which healed without sequelae following placement of a percutaneous drain, and the need for postoperative transfusion of 2 units of red blood cells (Clavien-Dindo and revised Accordion class II) (15, 16). Final pathology showed a 3 cm tumor with 80% viable cells. Cancer cells were identified adjacent to but not invading into the resected vein wall. One of 27 lymph nodes was positive for cancer. The surgical margins were negative, and the distance between cancer cells and the inked SMA margin was 3 mm.

Summary

Pancreatectomy with aggressive vascular resection is increasingly being recognized as an appropriate treatment strategy for patients with borderline resectable PDAC following the administration of chemotherapy and/or chemoradiation. Because tumor “downstaging” is an uncommon event, both venous and hepatic arterial resection and reconstruction may be necessary to achieve negative surgical margins and the favorable short-term and long-term outcomes we have previously reported (5,8). The technical approaches we have described here can be used as a basic foundation for operative safety and efficiency during these challenging operations.

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Figure 1.

Treatment approach for patients with borderline resectable pancreatic adenocarcinoma at our institution. Patients with borderline resectable cancers are treated most commonly with chemotherapy followed by chemoradiation. Surgery is performed approximately 6 weeks following completion of chemoradiation to maximize the cytotoxic effects of radiation while minimizing radiation-induced scarring. Patients whose tumors have progressed upon preoperative restaging do not undergo surgery. CTX, chemotherapy; CXRT, chemoradiation; OR, operating room (Figure adapted from Katz et al, JACS 2008; 206:833-846.⁸)

Figure 2.

In order to minimize the possibility of microscopically positive cancer cells being left on the superior mesenteric artery (SMA), we perform a periadventitial dissection along the right lateral aspect of the SMA for all patients with pancreatic ductal adenocarcinoma (dotted line). The appropriate plane can be developed expeditiously between the superior mesenteric vein (SMV) and the SMA caudal to the tumor. Division of the first jejunal branch (thin arrow) and/or inferior mesenteric vein (IMV, medium arrow) may facilitate the dissection if these vessels drain anterior to the SMA and enter directly into the SMV. Division of the splenic vein (thick arrow) affords access to the proximal aspect of the SMA. (Reprinted with permission from Visual Art, The University of Texas, MD Anderson Cancer Center, 2011.)

Figure 3.

Three-dimensional reconstruction of computed tomography (CT) images of a 64-year-old woman with pancreatic cancer obtained following treatment with gemcitabine-based chemoradiation. The primary tumor (green) involved the superior mesenteric vein (SMV)-portal vein confluence. The first jejunal branch of the SMV (thin blue arrow) and the inferior mesenteric vein (medium blue arrow) both entered the SMV directly after coursing anterior to the superior mesenteric artery (SMA); both of these vessels and the splenic vein (thick blue arrow) were ligated to gain access to the artery.

Figure 4.

Intraoperative photograph following tumor resection and primary end-to-end reconstruction of the superior mesenteric vein (SMV)-portal vein (PV) confluence. The right lateral aspect of the superior mesenteric artery (SMA, red arrow) has been dissected along the periadventitial plane all the way up to the origin of the SMA at the aorta. Note that the soft tissue to the left of the SMA is left *in situ* to prevent rapid gastrointestinal transit that may occur following 360° skeletonization of the SMA. CBD, common bile duct.

Figure 5.

We construct a direct anastomosis of the splenic vein (thick arrow) to the left renal vein (thin arrow) to allow blood return from the stomach and spleen if the inferior mesenteric vein (IMV), splenic vein, coronary vein, and right gastroepiploic vein are all divided and clinical parameters suggest high pressures in the sinistral portal system. (Reprinted with permission from Visual Art, The University of Texas, MD Anderson Cancer Center, 2011.)

Figure 6.

When the primary cancer abuts the superior mesenteric artery (SMA, thick arrow), the ability to control the inferior pancreaticoduodenal arteries (thin arrow) may be compromised. Following exposure of the SMA, skeletonization of the right lateral aspect of the artery can be performed safely following systemic heparinization and acquisition of vascular control above and below the segment of artery involved by tumor. (Reprinted with permission from Visual Art, The University of Texas, MD Anderson Cancer Center, 2011.)

Figure 7.

Coronal CT images of a 62-year-old man with borderline-resectable pancreatic cancer. (A) Prior to treatment, the tumor encased the superior mesenteric vein (SMV) and the SMV-portal vein (PV) confluence, abutted the first jejunal branch of the SMV (JV), and abutted the superior mesenteric artery (SMA). (B) Following treatment with gemcitabine/cisplatin and 50.4 Gy of external beam radiation with concurrent capecitabine, there was a minimal radiographic response. CV, coronary vein; SV, splenic vein.

Figure 8.

Resection and reconstruction of a segment of the common hepatic artery is performed early in the resection, prior to division of the pancreas. Following acquisition of vascular control, the artery is divided sharply. We typically reconstruct the artery using an interposition graft of saphenous vein. (Reprinted with permission from Visual Art, The University of Texas, MD Anderson Cancer Center, 2011.)

Figure 9.

(A) CT images of a 71-year-old woman following systemic chemotherapy and chemoradiation for a cancer that abutted the superior mesenteric vein (SMV)- portal vein (PV) confluence and encased a segment of the common hepatic artery (CHA). (B) Intraoperative view following CHA reconstruction. An end-to-end anastomosis was constructed between the takeoff of the CHA and the saphenous vein (black arrow). A total of five distal anastomoses were performed; the first two were end-to-end anastomoses of the distal arteries to side branches of the saphenous vein (blue arrows). The remaining three distal anastomoses were end-to-side branches constructed to the side of the saphenous vein (hidden from view by the graft). CBD, common bile duct.

Figure 10.

Three-dimensional reconstruction of CT images obtained from a 71-year-old man with borderline-resectable pancreatic cancer. The common hepatic artery (thin red arrow) aberrantly arose from the proximal superior mesenteric artery (thick red arrow) and coursed through the primary tumor (green) in the pancreatic head. The tumor also abutted the superior mesenteric vein-portal vein confluence (thick blue arrow). Thin blue arrow, inferior mesenteric vein.

Figure 11.

Reconstruction of the replaced common hepatic artery with saphenous vein (thick arrow) and reconstruction of the superior mesenteric-portal vein with internal jugular vein (medium arrow). A splenorenal shunt was not performed in this case, despite division of the splenic vein, due to the anatomy of the inferior mesenteric vein. (Reprinted with permission from Visual Art, The University of Texas, MD Anderson Cancer Center, 2011.)