Anatomy of the Superior Mesenteric Vein With Special Reference to the Surgical Management of First-order Branch Involvement at Pancreaticoduodenectomy

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Objective: To describe our approach to resection of pancreatic head cancers, which involve 1 or both of the first-order branches of the superior mesenteric vein (SMV).

Summary Background Data: In contrast to tumors which involve the proximal SMV, cancers in the inferior aspect of the pancreatic head or root of mesentery (mid gut carcinoid) may involve one of the 2 primary branches of the SMV (the ileal and jejunal branches), with or without involvement of the main trunk of the SMV. Such cases are associated with significant technical challenges.

Methods: Our surgical approach is described and illustrated.

Results: Isolated involvement of the jejunal branch of the SMV may be managed by division of this branch without reconstruction as long as the ileal branch is intact and of good caliber. Tumors which involve the ileal branch of the SMV, in the rare setting in which the jejunal branch is preserved, may also be managed by ligation and resection without reconstruction. Involvement of one of these first-order branches in association with more proximal involvement of the main trunk of the SMV may be successfully managed by ligation of one first-order branch and concurrent segmental resection and reconstruction of the other branch, and the main SMV trunk, with or without an interposition graft.

Conclusion: Segmental resection of one of the 2 first-order branches of the SMV may be performed without venous reconstruction if mesenteric venous flow is preserved through the remaining first-order branch. Detailed knowledge of the vascular anatomy of the root of the mesentery is necessary for the performance of complex surgical procedures involving the pancreatic head and root of mesentery.

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Involvement of the superior mesenteric vein (SMV) or portal vein (PV) by pancreatic cancer has historically represented a relative contraindication to pancreaticoduodenectomy (PD).[1] Over the past decade, several centers have gained experience with short-segment resection and reconstruction of the SMV and/or PV at the time of PD to facilitate a complete (R0/R1) resection of the pancreatic tumor. We have demonstrated that resection and reconstruction of these veins at the time of PD is associated with a low rate of perioperative morbidity, and similar rates of R0 resection and overall survival when compared with patients treated with standard PD performed in the absence of venous resection.[2,3]

In contrast to tumors which involve the PV or the proximal SMV, cancers located in the inferior aspect of the pancreatic head or in the uncinate process may occasionally involve one of the 2 primary (first-order) branches of the SMV with or without involvement of its main trunk or the PV (Fig. 1A). In such cases, the technical challenges associated with venous resection and primary repair or interposition grafting may be amplified by the smaller caliber and fragility of these first-order veins. Although one cannot ligate the SMV (when performing PD) and maintain normal venous return from the mid gut, we have found that either of the 2 first-order branches of the SMV, the ileal and jejunal branches, can be safely ligated or resected with the pancreatic tumor over a short distance, provided that the remaining branch is preserved and of sufficient caliber to allow for collateral mesenteric venous flow. In this report, we describe the anatomy of the SMV as it pertains to the performance of PD and describe our surgical approach to tumors that involve either of the 2 first-order branches of the SMV.

SURGICAL ANATOMY OF THE SMV

The anatomy of the SMV and PV is complex, and a comprehensive description of these structures relevant to the practice of surgery is not commonly found in standard textbooks of anatomy or surgery. Recently, autopsy studies and analyses of high-quality CT and MRI images have described the anatomy of this region.[4–7] Usually, the PV arises posterior to the superior aspect of the pancreatic neck from the confluence of the SMV and the splenic vein. The SMV lies slightly anterior and to the right (lateral) of the superior mesenteric artery (SMA) and has 2 anterior branches at the

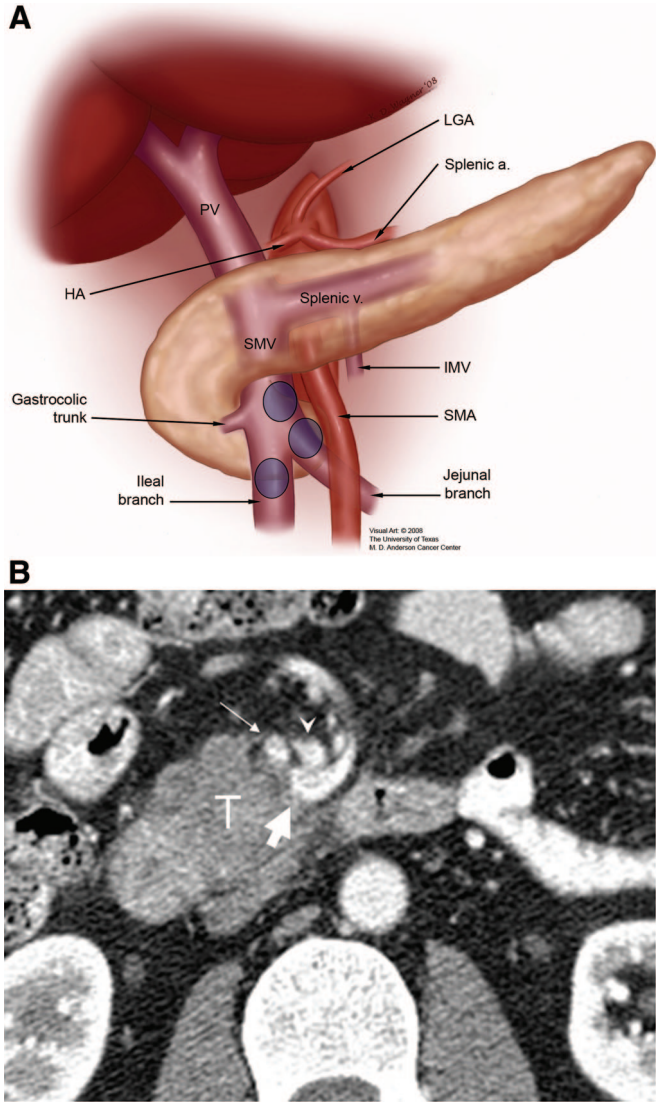

FIGURE 1. Anatomy of the infrapancreatic superior mesenteric vein (SMV). A, Tumors adjacent to the infrapancreatic SMV may involve either the main SMV trunk or either of its 2 first-order branches (blue circles). The jejunal branch of the SMV is depicted in its typical location running posterior to the superior mesenteric artery (SMA) to drain into the SMV (PV indicates portal vein; HA, hepatic artery; LGA, left gastric artery; IMV, inferior mesenteric vein). B, CT scan of a 48-year-old man with a mixed adeno/neuroendocrine carcinoma of the pancreatic head. The 4.5-cm tumor involved both the distal common trunk of the SMV and the jejunal branch. Pancreaticoduodenectomy required ligation of the jejunal branch (proximal to the tumor in the mesenteric root) and segmental resection of the ileal branch-common trunk of the SMV with interposition grafting as depicted in Figure 3C (T indicates tumor; thin arrow, ileal branch of SMV; thick arrow, jejunal branch of SMV; arrowhead, SMA).

level of the transverse mesocolon: the middle colic vein and the gastrocolic trunk of Henle. The gastrocolic trunk drains several smaller tributaries including the right gastroepiploic, right superior colic, and anterosuperior pancreaticoduodenal veins; the anatomy of these tributaries can be variable. The main trunk of the SMV arises from the confluence of 2 first-order branches, the jejunal and ileal branches. The jejunal branch usually enters the right posterolateral aspect of the main trunk of the SMV after coursing transversely, posterior to the SMA, to provide venous drainage from the proximal small bowel. In contrast, the ileal branch travels in a caudal to cranial direction in the root of the small bowel mesentery to drain the distal small bowel. The IMV typically drains into the splenic vein but may also enter the SMV directly inferior to the splenic-SMV confluence.[8]

The anatomy of the infrapancreatic SMV is somewhat variable. The main trunk of the SMV is observed in over 90% of patients; occasionally the ileal and jejunal branches merge at the level of the splenic vein without forming a common trunk of the SMV. In such cases, the jejunal branch usually courses anterior (ventral) to the SMA.[5,7] Normally, the jejunal branch of the SMV travels posterior (dorsal) to the SMA (Figs. 1A, B) but may course anterior (ventral) to the SMA in up to 20% of patients (Figs. 2A, B).[5] This variant anatomy is very important for the performance of PD, specifically with regard to the mobilization of the SMV to allow for identification of the SMA. When the jejunal branch lies posterior to the SMA, the small venous branches from the uncinate process (to the jejunal branch) must be divided to separate the jejunal branch from the uncinate process and allow medial retraction of the SMV, which is necessary for exposure of the SMA. An anterior jejunal branch makes it much easier to separate the uncinate process from the SMV as the small venous branches from the uncinate usually enter the ileal branch, rather than the jejunal branch. When an anterior jejunal branch exists, a high rate of associated anatomic variations may also be present, including the lack of a main SMV trunk and drainage of the IMV directly into the jejunal branch of the SMV.[5]

SURGICAL APPROACH TO INVOLVEMENT OF THE JEJUNAL OR ILEAL BRANCH OF THE SMV

Our approach to the dissection of the SMV during PD is well described.[9] Before surgery, high-quality CT is performed to identify aberrant vascular anatomy, to delineate the extent of vascular involvement when present, and to classify the tumor as resectable, borderline resectable, or locally advanced.[10,11] Identification of tumor involvement of the SMV, or its first-order branches, on careful review of preoperative CT images should prompt a thorough radiographic evaluation of the venous anatomy both to determine the extent of vascular involvement and to develop an optimal strategy for vascular resection and reconstruction; the need for venous resection should rarely be an unexpected finding at the time of laparotomy. Isolated tumor involvement of the first-order branches of the SMV does not represent a contraindication to resection, although it should alert the surgeon to the possibility of a more difficult technical operation as the tumor extends out into the root of mesentery. During PD, we prefer to identify the infrapancreatic SMV early in the operation when possible, but complete mobilization of this vessel does not occur until the retroperitoneal dissection is per-

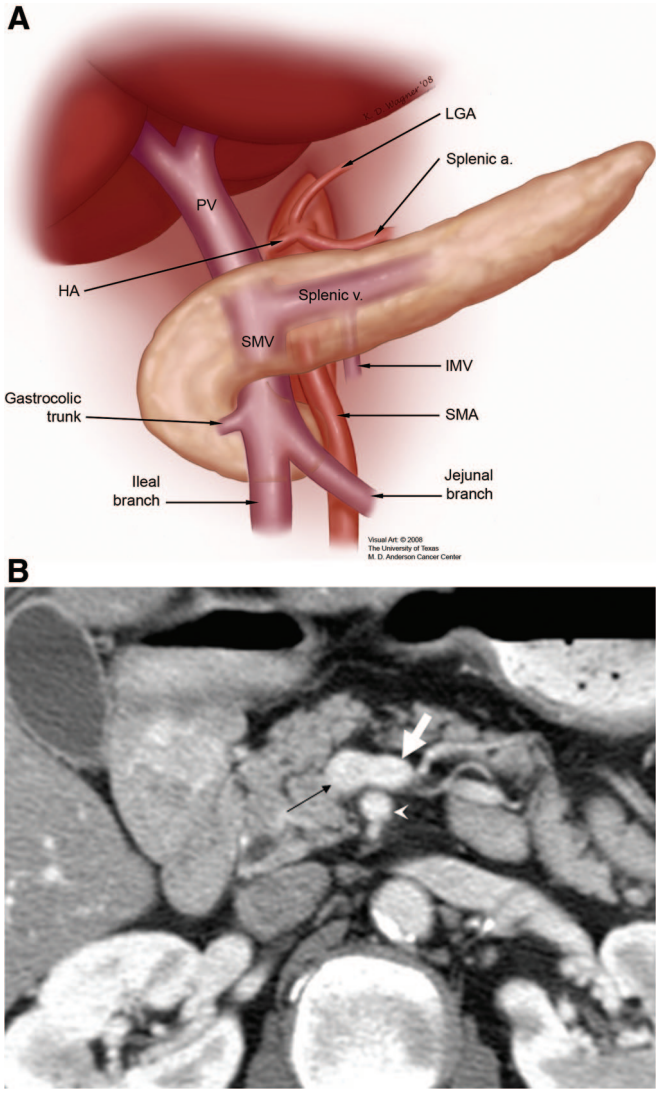

FIGURE 2. Variant anatomy of the jejunal branch of the superior mesenteric vein (SMV). A, The jejunal branch travels ventral to the superior mesenteric artery (SMA) to drain the proximal small intestine in up to 20% of patients (PV indicates portal vein; HA, hepatic artery; LGA, left gastric artery; IMV, inferior mesenteric vein). B, CT scan depicting the confluence of the jejunal branch and ileal branch of the SMV. The jejunal branch is positioned anterior to the SMA (thin arrow indicates ileal branch of SMV; thick white arrow, jejunal branch of SMV; arrowhead, SMA).

formed during the final step of the resection. It is important to avoid extensive dissection of the SMV early in the operation when the surgeon is not in an optimal position to deal with a venous injury. After transection of the neck of the pancreas, the head and uncinate process are separated from the SMV and PV by ligation and division of the small venous tributaries to the pancreas, including 2 or 3 small branches from the jejunal branch to the uncinate process.

Isolated involvement of the jejunal branch of the SMV may be managed by division and segmental resection of this branch without reconstruction as long as the ileal branch remains intact and is of good caliber (Fig. 3A). Normally the diameter of the ileal branch of the SMV is visibly larger than the SMA (at least 1.5 times the diameter of the SMA) as seen on axial CT images. Exposure of the jejunal branch of the SMV is accomplished by developing the plane of dissection to the right of the SMA, and medial to, or to the left of, the SMV. The soft tissue of the mesenteric root between these vessels is divided until the jejunal branch is identified as it courses posterior to the SMA. This dissection must be done with exquisite care as laceration of the jejunal branch as it travels beneath the SMA (to drain the proximal small bowel) is difficult to control and could lead to iatrogenic injury to the SMA, especially if the SMA is not properly exposed and mobilized. Access to the jejunal branch of the SMV is much easier in cases where the jejunal branch courses anterior to the SMA. Similarly, tumors which involve the ileal branch of the SMV, in the rare setting where the jejunal branch is uninvolved and preserved, may be managed by ligation and short-segment resection of the ileal branch without reconstruction (Fig. 3B).

Involvement of the confluence of the ileal and jejunal branches in association with more proximal involvement of the common trunk of the SMV may be successfully managed by ligation of the jejunal branch of the SMV along with concurrent segmental resection and reconstruction of the main SMV trunk and proximal ileal branch with (Fig. 3C) or without an interposition vein graft. If the splenic vein is left intact, the portal vein remains immobile and an interposition graft is usually necessary to connect the ileal branch to the main SMV. We initially reported the use of an internal jugular vein interposition graft for this purpose in 1994 and our surgical technique has been further refined since that time.[12] Reconstruction of the ileal branch is always preferred over the jejunal branch as the jejunal branch is usually posterior in location extending into the proximal left jejunal mesentery and is therefore technically difficult to access for an anastomosis. Moreover, the jejunal branch is rather delicate in nature with a thin wall. Division of the jejunal branch and resection of the confluence of the jejunal and ileal branches with reconstruction of the ileal branch (caudal to the tumor) and the main SMV (cephalad to the tumor) should only be performed if the ileal branch is of adequate caliber (Fig. 3C). Specifically, as a general rule and as mentioned above, we have not attempted resection and reconstruction of the ileal branch (in the setting of ligation of the jejunal branch) when the diameter of the ileal branch was not visibly larger than the diameter of the SMA as seen on the axial CT images. This recommendation is based on our clinical experience including the perception that long-term graft patency becomes a concern the further one goes out in the small bowel mesentery and the smaller the diameter of the ileal branch. The assessment of the adequacy of the ileal branch (for grafting and subsequent mesenteric venous return) by comparison to the diameter of the SMA (as seen on CT) is subjective and somewhat arbitrary, but we have found this comparison clinically useful when considering a very complex cancer operation.

Acute thrombosis of the PV or SMV can lead to a syndrome of vascular congestion, bowel edema, and subse-

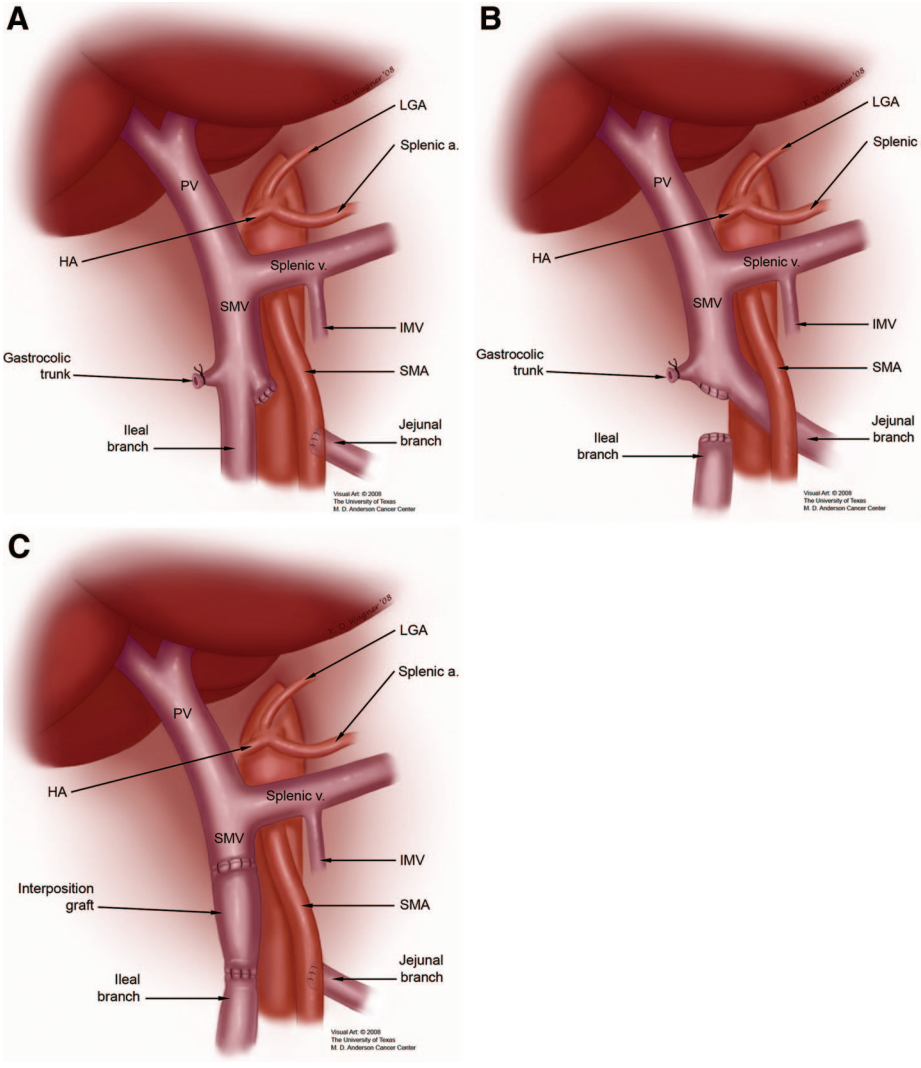

FIGURE 3. Management of tumor involvement of the first-order branches of the superior mesenteric vein (SMV) at pancreaticoduodenectomy. Segmental resection of either the jejunal branch (A) or ileal branch (B) may be performed as long as the other branch is of good caliber. C, Tumor involvement of both the ileal and jejunal branches, often in association with more proximal involvement of the common trunk of the SMV, may be successfully managed by ligation of the jejunal branch along with concurrent segmental resection and reconstruction of the ileal branch-common SMV trunk with interposition grafting. We have used both internal jugular vein and superficial femoral vein as interposition grafts; others have used the left renal vein (PV indicates portal vein; HA, hepatic artery; LGA, left gastric artery; IMV, inferior mesenteric vein).

quent systemic hypotension, bowel ischemia, and necrosis.[13] For this reason, little enthusiasm has historically existed for ligation of the mesenteric veins at the time of PD, as might be required during operations for abdominal trauma. Recent data from the trauma literature, however, suggests that SMV ligation, even in the acute setting, can occasionally be performed without catastrophic results.[14] Similarly, if the SMV or its ileal or jejunal branches are ligated at the time of elective surgery for a pancreatic tumor (due to inadvertent SMV injury), bowel ischemia may be prevented by venous collateralization as long as the pancreatic head is left in situ and not resected. Such collateralization may already be present if some degree of chronic venous obstruction was evident on preoperative imaging, and collateralization is further enhanced when the IMV enters the splenic vein or the SMV proximal (cephalad) to the site of SMV injury/obstruction.[4] However, if the main trunk of the SMV is ligated or injured beyond repair, and the pancreatic head is also removed, there will likely be inadequate collateral flow to provide for mesenteric venous return from the mid gut.

In this report, we describe the important surgical anatomy of the SMV and our operative approach to tumor involvement of the first order branches of the SMV. Such involvement can be predicted preoperatively using high-quality CT imaging and does not represent a contraindication to tumor resection when performed by experienced surgeons. As long as either the ileal or jejunal branch of the SMV is preserved (with or without interposition grafting), the other branch can be removed with the surgical specimen and adequate venous return from the mid gut will remain. Detailed knowledge of the vascular anatomy of the root of mesentery is necessary for the performance of complex surgical procedures involving the pancreas and lymph node metastases from midgut carcinoid tumors.

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REFERENCES

1. Roder JD, Stein HJ, Siewert JR. Carcinoma of the periampullary region: who benefits from portal vein resection? *Am J Surg.* 1996;171:170–174; discussion 174–175.
2. Tseng JF, Raut CP, Lee JE, et al. Pancreaticoduodenectomy with vascular resection: margin status and survival duration. *J Gastrointest Surg*. 2004;8:935–949; discussion 949–950.
3. Raut CP, Tseng JF, Sun CC, et al. Impact of resection status on pattern of failure and survival after pancreaticoduodenectomy for pancreatic adenocarcinoma. *Ann Surg*. 2007;246:52–60.
4. Yamada Y, Mori H, Kiyosue H, et al. CT assessment of the inferior peripancreatic veins: clinical significance. *AJR Am J Roentgenol*. 2000; 174:677–684.
5. Kim HJ, Ko YT, Lim JW, et al. Radiologic anatomy of the superior mesenteric vein and branching patterns of the first jejunal trunk: evaluation using multi-detector row CT venography. *Surg Radiol Anat*. 2007;29:67–75.
6. Ito K, Blasbalg R, Hussain SM, et al. Portal vein and its tributaries: evaluation with thin-section three-dimensional contrast-enhanced dynamic fat-suppressed MR imaging. *Radiology*. 2000;215:381–386.
7. Graf O, Boland GW, Kaufman JA, et al. Anatomic variants of mesenteric veins: depiction with helical CT venography. *AJR Am J Roentgenol*. 1997;168:1209–1213.
8. Misuta K, Shimada H, Miura Y, et al. The role of splenomesenteric vein anastomosis after division of the splenic vein in pancreatoduodenectomy. *J Gastrointest Surg*. 2005;9:245–253.
9. Evans DB, Lee JE, Tamm EP. Pancreaticoduodenectomy (Whipple Operation) and total pancreatectomy for cancer. In: Fischer JE, ed. *Mastery of Surgery*. 5th ed. Philadelphia, PA: Lipincott Williams and Wilkins; 2007.
10. Katz MH, Pisters PW, Evans DB, et al. Borderline resectable pancreatic cancer: the importance of this emerging stage of disease. *J Am Coll Surg*. 2008;206:833–846; discussion 846–848.
11. Varadhachary GR, Tamm EP, Abbruzzese JL, et al. Borderline resectable pancreatic cancer: definitions, management, and role of preoperative therapy. *Ann Surg Oncol*. 2006;13:1035–1046.
12. Cusack JC, Fuhrman GM, Lee JE, et al. Management of unsuspected tumor invasion of the superior mesenteric-portal venous confluence at the time of pancreaticoduodenectomy. *Am J Surg*. 1994;168:352–354.
13. Amitrano L, Guardascione MA, Scaglione M, et al. Prognostic factors in noncirrhotic patients with splanchnic vein thromboses. *Am J Gastroenterol*. 2007;102:2464–2470.
14. Asensio JA, Petrone P, Garcia-Nunez L, et al. Superior mesenteric venous injuries: to ligate or to repair remains the question. *J Trauma*. 2007;62:668–675; discussion 675.